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Constantine Stephanidis (Ed.)

Universal Access in Human-Computer Interaction

Users Diversity

6th International Conference, UAHCI 2011
Held as Part of HCI International 2011
Orlando, FL, USA, July 2011, Proceedings, Part II

2 Part II

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Foreword

The 14th International Conference on Human–Computer Interaction, HCI International 2011, was held in Orlando, Florida, USA, July 9–14, 2011, jointly with the Symposium on Human Interface (Japan) 2011, the 9th International Conference on Engineering Psychology and Cognitive Ergonomics, the 6th International Conference on Universal Access in Human–Computer Interaction, the 4th International Conference on Virtual and Mixed Reality, the 4th International Conference on Internationalization, Design and Global Development, the 4th International Conference on Online Communities and Social Computing, the 6th International Conference on Augmented Cognition, the Third International Conference on Digital Human Modeling, the Second International Conference on Human-Centered Design, and the First International Conference on Design, User Experience, and Usability.

A total of 4,039 individuals from academia, research institutes, industry and governmental agencies from 67 countries submitted contributions, and 1,318 papers that were judged to be of high scientific quality were included in the program. These papers address the latest research and development efforts and highlight the human aspects of design and use of computing systems. The papers accepted for presentation thoroughly cover the entire field of human–computer interaction, addressing major advances in knowledge and effective use of computers in a variety of application areas.

This volume, edited by Constantine Stephanidis, contains papers in the thematic area of universal access in human-computer interaction (UAHCI), addressing the following major topics:

- User models, personas and virtual humans
- Older people in the information society
- Designing for users diversity
- Cultural and emotional aspects
- Eye tracking, gestures and brain interfaces

The remaining volumes of the HCI International 2011 Proceedings are:

- Volume 1, LNCS 6761, Human–Computer Interaction—Design and Development Approaches (Part I), edited by Julie A. Jacko
- Volume 2, LNCS 6762, Human–Computer Interaction—Interaction Techniques and Environments (Part II), edited by Julie A. Jacko
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- Volume 4, LNCS 6764, Human–Computer Interaction—Users and Applications (Part IV), edited by Julie A. Jacko
- Volume 5, LNCS 6765, Universal Access in Human–Computer Interaction—Design for All and eInclusion (Part I), edited by Constantine Stephanidis

- Volume 7, LNCS 6767, Universal Access in Human–Computer Interaction—Context Diversity (Part III), edited by Constantine Stephanidis
- Volume 8, LNCS 6768, Universal Access in Human–Computer Interaction—Applications and Services (Part IV), edited by Constantine Stephanidis
- Volume 9, LNCS 6769, Design, User Experience, and Usability—Theory, Methods, Tools and Practice (Part I), edited by Aaron Marcus
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- Volume 21, LNAI 6781, Engineering Psychology and Cognitive Ergonomics, edited by Don Harris
- Volume 22, CCIS 173, HCI International 2011 Posters Proceedings (Part I), edited by Constantine Stephanidis
- Volume 23, CCIS 174, HCI International 2011 Posters Proceedings (Part II), edited by Constantine Stephanidis

I would like to thank the Program Chairs and the members of the Program Boards of all Thematic Areas, listed herein, for their contribution to the highest scientific quality and the overall success of the HCI International 2011 Conference.

In addition to the members of the Program Boards, I also wish to thank the following volunteer external reviewers: Roman Vilimek from Germany, Ramalingam Ponnusamy from India, Si Jung "Jun" Kim from the USA, and Ilia Adami, Iosif Klironomos, Vassilis Kouroumalis, George Margetis, and Stavroula Ntoa from Greece.

This conference would not have been possible without the continuous support and advice of the Conference Scientific Advisor, Gavriel Salvendy, as well as the dedicated work and outstanding efforts of the Communications and Exhibition Chair and Editor of HCI International News, Abbas Moallem.

I would also like to thank for their contribution toward the organization of the HCI International 2011 Conference the members of the Human–Computer Interaction Laboratory of ICS-FORTH, and in particular Margherita Antona, George Paparoulis, Maria Pitsoulaki, Stavroula Ntoa, Maria Bouhli and George Kapnas.

July 2011 Constantine Stephanidis

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HCI International 2013

The 15th International Conference on Human–Computer Interaction, HCI International 2013, will be held jointly with the affiliated conferences in the summer of 2013. It will cover a broad spectrum of themes related to human–computer interaction (HCI), including theoretical issues, methods, tools, processes and case studies in HCI design, as well as novel interaction techniques, interfaces and applications. The proceedings will be published by Springer. More information about the topics, as well as the venue and dates of the conference, will be announced through the HCI International Conference series website: http://www.hci-international.org/

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Part I

User Models, Personas and Virtual Humans

Standardizing User Models

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Abstract. In this paper we took an attempt to create a set of features to describe different types of user models. We classify the features into different sets like development process, data store, user study and so on and also describe it with the help of a case study. Finally we pointed out the benefits of standardization in user modeling.

1 Introduction

A model can be defined as "a simplified representation of a system or phenomenon with any hypotheses required to describe the system or explain the phenomenon, often mathematically". The concept of modelling is widely used in different disciplines of science and engineering ranging from models of neurons or different brain regions in neurology to construction model in architecture or model of universe in theoretical physics. Modelling human or human systems is widely used in different branches of physiology, psychology and ergonomics. A few of these models are termed as user models when their purpose is to design better consumer products. By definition a user model is a representation of the knowledge and preferences of users that the system believes the user posses [2].

There was a plethora of systems developed during the last three decades that are claimed to be user models. Many of them modelled users for certain applications - most notably for online recommendation and e-learning systems. These models in general have two parts – a user profile and an inference machine (Figure 1). The user profile section stores detail about user relevant for a particular application and inference machine use this information to personalize the system. A plethora of examples of such models can be found at the User Modelling and User-Adapted Interaction journal and proceedings of User Modelling, Adaptation and Personalization conference.

On a different dimension, ergonomics and computer animation follow a different view of user model [3]. Instead of modelling human behaviour in detail, they aim to

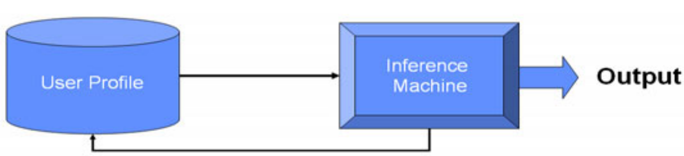

Fig. 1. Simplistic view of a user model

C. Stephanidis (Ed.): Universal Access in HCI, Part II, HCII 2011, LNCS 6766, pp. 3–11, 2011.

simulate human anatomy or face which can be used to predict posture, facial expression and so on.

Finally, there is a bunch of models which merges psychology and artificial intelligence to model human behaviour in detail. In theory they are capable of modelling any behaviour of users while interacting with environment or a system. This type of models is termed as cognitive architecture (e.g. SOAR [6], ACT-R/PM [1], EPIC [5] and so on) and has also been used to simulate human machine interaction to both explain and predict interaction behaviour. A simplified view of these cognitive architectures is known as the GOMS model [4] and still now is most widely used in human computer interaction.

Considering all these approaches together, it becomes challenging to define what a user model actually is. This lack of definition also makes the interoperability of user models difficult. On the other hand, there was a plethora of standards about human factors, user interface design, interface description language, workplace ergonomics and so on [7] that can be used to develop user models.

In this paper we have taken an approach to standardize the different user modelling approaches. One novelty of our approach is that we have also considered user models for people with disabilities which is not studied in as detail as their able bodied counterparts. In the rest part of the paper, we will try to consolidate different user modeling approaches and standards into a single set of standardization features and also describe a case study to explain our concept.

2 Areas of Standardization

We have identified the following features of the user model and corresponding development process and applications for standardization. Through these features, we aim to develop a common set of vocabulary that can be used to disseminate information and data across different user modeling systems. They are as follows:

- **Conceptualization:** This feature defines the user model and sets up the context of its development and application for discussing the other features.
- **Development process:** This feature summarizes different stages of the user model development process and aims to bring synergy among user models at different stages of development and developed for different purposes and applications.
- **User study:** User model development process always involves plenty of user studies to test the accuracy of the model. This feature ensures that data and results gathered in one user study can be shared with others.
- **Data storage:** This feature further elaborates dissemination of data collected in different user studies.
- **Evaluation:** This feature highlights how accurate a user model is and how it should be used in other projects besides the one it is developed for.

  In the following sections we have further elaborated these concepts.

2.1 Conceptualization

Definition. Since there is a lot of ambiguity about what does it mean by a user model, the definition of the model should be cleared at first.

Purpose. After the definition, the purpose of the model should be specified. A few examples of developing user models are as follows:

- Visualization
- Explanation
- Measurement
- Prediction of interaction patterns

2.2 Development Process

We have developed standards for each phase of a user model development process. We can identify the following four phases of model development.

1. Specification
2. Design
3. Calibration
4. Validation

Ideally, all of these phases should maintain a standard. The standard will help to reuse the model by other partners irrespective of its stage of development. In the following paragraphs, we propose a standard for each of these phases.

Specification. This phase should primarily identify the scope, requirement and goal of the model. According to our classification this stage should identify whether it is an

- Ergonomic model
- Application specific models
- Cognitive models
  and so on.

This phase also roughly specify the data requirement for the user profile.

Design. A simplistic view of the user model is shown in Figure 1. Following that figure, the standards in design phase should identify:

1. The structure of the user profile
2. The format of the user profile
3. The type or the specific system used as the inference machine
4. Parameters used in the inference machine

Calibration. The calibration phase will populate the model with real life data. The data can come from an existing store like published results on anthropomorphic data or can be collected through new studies. In the first case the source of the data should be specified, in the later case the data collection process should follow an existing standard like ISO 9241.

Validation. The validation process proves the accuracy of the model. Like the calibration process, it can be validated with existing data or a new study. In either case, the same standard should be followed as in the calibration stage.

2.3 User Study

The user studies should be described in such a way so that they can be replicated by other researchers. The following points can be followed to describe the study.

- Design
- Procedure / Method
- Material
- Participants
- Result

In particular, the task, environmental context of the study and detail about participants should be described in detail which also corresponds to the final application of the user model.

2.4 Data Storage

One main aim of the whole standardization process as a whole is to share data collected during the development process. The following list gives a comprehensive list of features, however it should be extended based on the context of the model.

- User Profile
  - Demographic detail
  - Structural features
  - Cognitive features
  - Impairments and corresponding disability
- Interfaces used in the study and its properties like (refer figure 2)
  - Dimension
  - Forecolour
  - Backcolour
  - Controls
    - Location
    - Size
    - Forecolour
    - Backcolour
    - Highlighting colour
    - Font size
- Task
  - Description
- Instrument
  - Technical specification
- Movement trace
  - Co-ordinates
  - Timestamp

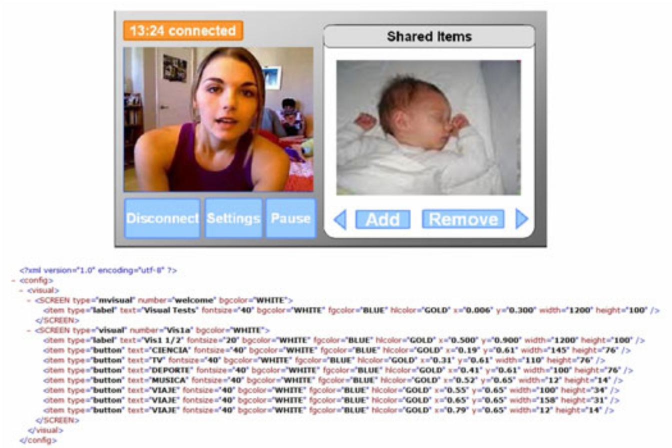

Fig. 2. An interface with its detail stored in xml

2.5 Evaluation Specification

Any interactive system can be evaluated according to the following features.

- Performance evaluation
  - Task completion time
  - Number of errors / Error rate
  - Idle time
- Subjective experiences
- Quality of life

A user model should specify which criteria it may help to evaluate. For example, a cognitive model can be used to evaluate cognitive performance while a physical simulation may predict ease of use and thus subjective experience of users while using a tool.

The following case study demonstrates a user model and shows how it can be specified in terms of the standardization features.

3 A Case Study

We have developed a simulator that explains the effect of physical impairment on interaction with electronic interfaces. It embodies both the internal state of a device and also the perceptual, cognitive and motor processes of its user. Figure 3 shows the architecture of the simulator.

The Application model represents the task (like opening an application in a laptop or changing the channel in a TV) currently undertaken by the user by breaking it up into a set of simple atomic tasks.

The Interface model decides the type of input and output devices (like mouse, trackball, keyboard, remote control and so on) to be used by a particular user and sets parameters for an interface.

The User model simulates the interaction patterns of users for undertaking a task analysed by the task model under the configuration set by the interface model. It consists of a perception model, a cognitive model and a motor behaviour model.

- The perception model simulates the visual perception of interface objects. It is based on the theories of visual attention.
- The cognitive model determines an action to accomplish the current task. It is more detailed than the GOMS model [John and Kieras, 1996] but not as complex as other cognitive architectures.
- The motor behaviour model predicts the completion time and possible interaction patterns for performing that action. It is based on statistical analysis of screen navigation paths of disabled users.

The details about users are store in xml format in the user profile following the ontology shown in figure 4 below. The ontology stores demographic detail of users like age and sex and divide the functional abilities in perception, cognition and motor action. The perception, cognitive and motor behaviour models takes input from the respective functional abilities of users. Table 1 summarizes the model in terms of the standardization features.

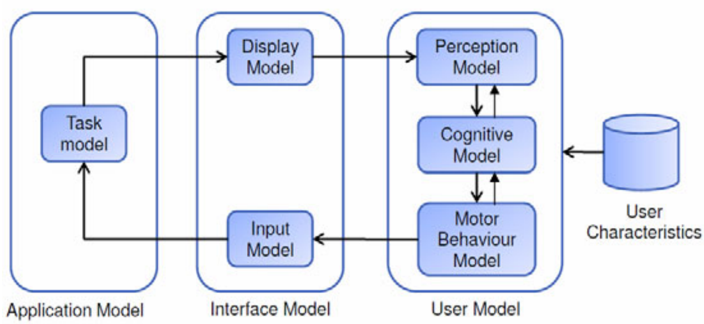

Fig. 3. Architecture of the simulator

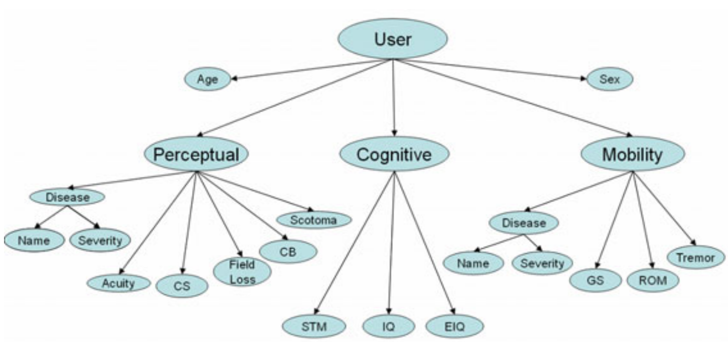

Fig. 4. User Ontology

Table 1. Our user model in terms of the standardization features

Conceptualization	
Definition	The simulator embodies both the internal state of a device and also the perceptual, cognitive and motor processes of its user.
Purpose	It has user interfaces to simulate interaction patterns of disabled and elderly users and will also later be part of a simulation and adaptation platform where interface designers can develop and test adaptation systems.
Development Stage	
Specification	Works for interaction with electronic interface.
Design	The user model works by modelling basic perceptual, cognitive and motor capability of users and simulate tasks involving any electronic interface.
Calibration	It is and will be calibrated through standard tasks by ISO and cognitive psychology.
Validation	The models are initially validated through ISO 9241 and visual search tasks involving different participants. Later output from the simulation will be compared to the existing guidelines to validate the results and later the simulation output will augment the existing guidelines in the form of the GUIDE handbook.
User study	We followed ISO 9241 pointing task and standard visual search task to collect data. Data was collected from people with and without visual and mobility impairment.
Data Storage	
User profile	We tried to follow WHO ICF in storing data about functional capabilities and limitations. A sample user profile is as follows. - <xml> - <User> <Age>**51**</Age> <Sex>**F**</Sex> <Height>**167**</Height> - <Perception> - <Disease> <Name>**Wet Maccular Degeneration**</Name> <Severity>**2**</Severity> </Disease> - <Acuity> <Value>**-3.5**</Value> <Acuity1>**6**</Acuity1> <Acuity2>**8**</Acuity2> </Acuity> <CS>**80**</CS> <FieldLossP>**0**</FieldLossP> <FieldLossC>**0**</FieldLossC> <CB>**0**</CB> <Scotoma>**0**</Scotoma> </Perception> - <Cognitive> <Disease>**Dyslexia**</Disease> <STM>**12**</STM> <IQ>**131**</IQ> <EIQ>**98**</EIQ> </Cognitive> - <Mobility> - <Disease> <Name>**Parkinson's Disease**</Name> <Severity>**2**</Severity> </Disease> <GS>**9**</GS> <ROM>**63**</ROM> <Tremor>**625**</Tremor> </Mobility> </User> </xml>

Table 1. (*continued*)

Interface definition	<?xml version="1.0" encoding="utf-8" ?> - <config> - <visual> - <SCREEN type="mvisual" number="welcome" bgcolor="WHITE"> <item type="label" text="Visual Tests" fontsize="40" bgcolor="WHITE" fgcolor="BLUE" hlcolor="GOLD" x="0.006" y="0.300" width="1200" height="100" /> </SCREEN> - <SCREEN type="visual" number="Vis1a" bgcolor="WHITE"> <item type="label" text="Vis1 1/2" fontsize="20" bgcolor="WHITE" fgcolor="BLUE" hlcolor="GOLD" x="0.500" y="0.900" width="1200" height="100" /> <item type="button" text="CIENCIA" fontsize="40" bgcolor="WHITE" fgcolor="BLUE" hlcolor="GOLD" x="0.19" y="0.61" width="145" height="76" /> <item type="button" text="TV" fontsize="40" bgcolor="WHITE" fgcolor="BLUE" hlcolor="GOLD" x="0.31" y="0.61" width="110" height="76" /> <item type="button" text="DEPORTE" fontsize="40" bgcolor="WHITE" fgcolor="BLUE" hlcolor="GOLD" x="0.41" y="0.61" width="100" height="76" /> <item type="button" text="MUSICA" fontsize="40" bgcolor="WHITE" fgcolor="BLUE" hlcolor="GOLD" x="0.52" y="0.65" width="12" height="14" /> <item type="button" text="VIAJE" fontsize="40" bgcolor="WHITE" fgcolor="BLUE" hlcolor="GOLD" x="0.55" y="0.65" width="100" height="34" /> <item type="button" text="VIAJE" fontsize="40" bgcolor="WHITE" fgcolor="BLUE" hlcolor="GOLD" x="0.65" y="0.65" width="158" height="31" /> <item type="button" text="VIAJE" fontsize="40" bgcolor="WHITE" fgcolor="BLUE" hlcolor="GOLD" x="0.79" y="0.65" width="12" height="14" /> </SCREEN> </visual> </config>
Movement trace	<?xml version="1.0" encoding="utf-8" ?> - <message type="input_pointer" timestamp="2387462374"> - <params> <coordinates x="0.005" y="0.73" /> </params> </message>
Evaluation	
Performance evaluation	Till now, the models are evaluated by measuring • correlation among actual and predicted task completion time • relative error in prediction • effect size of different design alternatives in predicted task completion times.
Subjective evaluation	We are also working on interface designers in the GUIDE project and observing how the modeling tool helps them in long term.

4 Benefits of Standardization

User trials are always expensive in terms of both time and cost. A design evolves through an iteration of prototypes and if each prototype is to be evaluated by a user trial, the whole design process will be slowed down. Buxton has also noted that "*While we believe strongly in user testing and iterative design. However, each iteration of a design is expensive. The effective use of such models means that we get the most out of each iteration that we do implement*". Additionally, user trials are not representative in certain cases, especially for designing inclusive interfaces for people with special needs. A good simulation with a principled theoretical foundation can be more useful than a user trial in such cases. Exploratory use of modelling can also help designers to understand the problems and requirements of users, which may not always easily be found through user trials or controlled experiments.

However as we pointed out at the beginning, the concept of user modeling is still pretty diverse among researchers. Each user model is useful for their own application, however there should be ways to use it in other applications as well. It will reduce the cost of reengineering new models and also help to incorporate user models in more applications. The recent EU initiative of setting up the VUMS (Virtual User modeling and simulation [8]) project cluster also supports this claim. The VUMS project cluster aims to standardize user modeling efforts to increase interoperatibility among user models developed for a wide variety of applications like designing automobile, washing machine, digital television interface and so on.

5 Conclusions

In this paper we took an attempt to standardize different user models developed for different purposes and applications. We consolidate a set of features to describe a user model. We hope it will help to develop a common set of vocabulary by which user modeling experts can exchange data and information among them. Finally we illustrated our concept with a case study and pointed out the benefits of standardization.

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Integral Model of the Area of Reaches and Forces of a Disabled Person with Dysfunction of Lower Limbs as a Tool in Virtual Assessment of Manipulation Possibilities in Selected Work Environments

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Abstract. The objective of the research project was to present new possibilities of accessibility and usefulness analysis in virtual designing of the work environment for a disabled person. This new computer tool of graphic record of anthropometric and biometric data of the set of layers was employed for a number of spectacular analyses essential for the designing practice. Results of the following investigations were presented: transfer from the wheelchair into the car of a disabled person and the accessibility of the car interior for a disabled driver, accessibility of a supermarket space for a person on a wheelchair, accessibility of furniture and equipment within the space of a typical kitchen meeting the requirements of universal design. The objects of investigations and analyses were transferred to the virtual environment of the ergonomic module of CATIA v5 computer system.

1 Introduction

The objective of the research project was to present new possibilities of accessibility and usefulness analysis in virtual designing of the work environment for a disabled person.

The demand for empirically verified and systematised design database taking into consideration specific requirements and possibilities of disabled persons has not been fulfilled so far.

Heterogeneity of expectations and specificity of needs cause that it is difficult to define and arrange hierarchically requirements for design objects utilised by handicapped subjects [4, 8, 9, 14, 15].

A special graphic database of ergonomic data was employed. Such database of anthropometric and biometric data for a disabled person sitting on a wheelchair or in a car seat was collected in the course of earlier investigations conducted to develop advanced tools of virtual engineering [4, 5, 6]. It comprises an integrated 3D model of arms' reaches and limiting forces of arms of a person. Ranges of acceptable forces in

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the graphic 3D space of manipulations can be processed dynamically from empirically obtained ranges of limiting forces following adoption of one of known models of the impact of such factors as: age, training and type of loading on human safety [11, 25]. The method of model development has an innovative character [26] and was awarded a number of international distinctions.

2 Structure of Graphic 3D Database Regarding Arm Reach and Forces of a Male Person Sitting on a Wheelchair

Empirical data about reaches and forces of arms were obtained on the basis of investigations of a paraplegic sitting on an active wheelchair or on a seat of a car from segment B. The subject of investigations was a male 32 years of age, 182 cm height and 72 kg of weight with spastic paralysis of Th5 acuteness of the trauma and unequal length of upper limbs (right 72 cm, left 68 cm). Anthropometric measurements of the subject of investigations were close to the 50 percentile male of American population [18,23]. The damage of the spinal column and differences in limb lengths and mobility of joints resulted from a traffic accident at the age of 18. In the course of experiments, the disabled person was sitting on the cushion of the SET active wheelchair manufactured by Kaleb Company (Poland) with non-foldable frame inclined 3^o down in the seat plane and 87^o angle of the backrest.

The experimental station for static and dynamic reaches of arms (Fig.1a) consists of a circular plate of a measuring protractor I in the axis of which in the reference point SRP of a person 3, a wheelchair 2 was placed (height $y_0 = 55$ cm). The protractor with the wheelchair (or a car seat) and a sitting man can turn in relation to the stationary vertical table 5. The table plane passes through the reference point SRP. Biomechanical studies of the man's forces were conducted on the assumption of the vertical direction downwards of the force action.

The method of the investigations of forces is presented in Fig. 1b. The seat arrangement and position of the table in relation to the seat are identical as in the zone measurements of the arm reaches. The table positioning mechanism at a specific height guarantees possibilities of taking force measurements at three preset levels y: the head (eyes y = 67 cm), shoulders (y = 42 cm) and waist (waist y = 13 cm) of the disabled person against the SRP point. Forces were measured at the following distances: x from 40 to 80 cm; $\Delta x = 10$ cm in relation to the reference point SRP. Results of measurements of arms' reaches in the (x, y, φ) system and of arms' forces in the f(x, y, φ) system were converted both numerically and graphically. Numerical data x,y,φ obtained from our own measurements was archived electronically and was used to plot curves of arm reaches in measurement planes at set heights of axis Z.

Individual diagrams of arm reaches were then represented by a spline type curve and a Non-Uniform Rational B-Spline (NURBS) surface was spread on the set of curves. In the analysis of forces, the numerical data $F_N = f(x,y,\varphi)$ obtained from transformations were archived in an electronic form. In this way, a biomechanical-anthropometric model was developed of a contour type structure describing free surfaces of a layer with F_N = const. taking advantage of heterogenous B-spline rational functions.

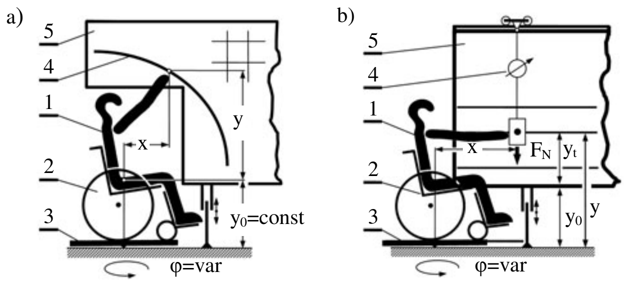

Fig. 1. Block diagram of a measurement stand and method of arm reaches (a) and arm forces (b) of a disabled person sitting on a wheelchair in a 3D space of geometrical dimensions x, y, φ: (1) – handicapped person; (2) – active wheelchair; (3) – measuring protractor, (4) – reach curve (a) or measuring dynamometer (b); (5) – table.

The outcome of the performed investigations is also a certain model of biomechanical limiting external loads of the right arm of a handicapped person sitting on a wheelchair. Values of numerical data $F_N= f(x,y,\varphi)$ obtained from transformations were archived in electronic form.

Data sets of 'crude' values of F_N force in the distance function x at constant height values y and angle of rotation φ obtained from four-parametrical measurements require "reverse" calculation processing in order to obtain three-parametrical record of the x, y, φ surface of the F_N=const. layer. It is a certain biomechanical-anthropometric model of contour line structure describing free layer surfaces of F_N=const.

Figure 2 present 3D images of sets of layers of constant force F_N sought in this study for the right upper limb of a sitting disabled male person.

On the Figure, the external layer representing the reach of the right arm of the examined disabled man was determined in an earlier study [4]. In this way, a common 3D geometrical representation of anthropometric characteristics of the reach of arms and of biomechanical characteristics of the force of the arm was obtained.

For further analysis the transformation of measured data are needed. There are several different methods of transformation of limiting forces resulting from F_g measurements to allowable F_d forces safe in definite conditions of work [1,7,10,11,25].

They are brought to the reduction of the limiting force value F_g by the introduction of the product of impact coefficients:

$$F_d = F_g \cdot \prod_{i=1}^{i=n} k_i = F_g \cdot k \tag{1}$$

where: the product of impact coefficients is described following

$$k = \prod_{i=1}^{i=n} k_i = k_1 \cdot k_2 \cdot k_3 \leq 1 \tag{2}$$

Impact coefficients take into account most commonly: age and gender (k_1), training (k_2) and kind of loading (k_3) and, in this way, it is possible to re-scale values of forces determining force zones. The above presented method of elaboration of graphic 3D of anthropometric and biomechanical database [6] will be used in future studies.

Values given on the scale in Figure 2 have been converted from values of limiting forces F_g obtained in the course of investigations to values of allowable forces F_d using the above-described coefficient methods [2,11]. Using method [6], the following values were obtained for the performed task of reaching by a person sitting on a wheelchair $F_d=k_1 \cdot k_2 \cdot k_3 \cdot F_g=0.85 \cdot 0.75 \cdot 0.4 \cdot F_g=0.255 \cdot F_g$. Figure 2 presents rescaled zones assuming the dependence $F_d=0.25 \cdot F_g$.

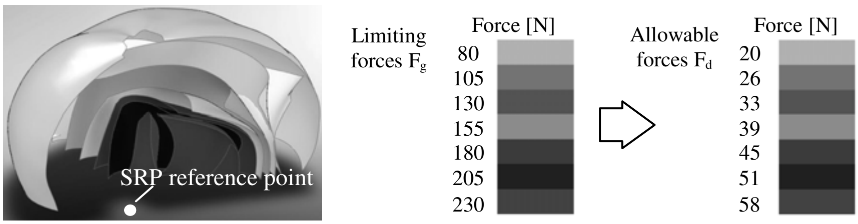

Fig. 2. Set of surfaces determining zones of occurrence of constant forces of the right arm against the external surface of the arms' reach

3 Virtual Analysis of the Accessibility to Workplaces of a Handicapped Person on a Wheelchair

The presented graphic model of integrated anthropotechnical and biomechanical data was used in: (1) the analysis of accessibility of a disabled person to technical means of sale space in a supermarket (shelves, refrigerators), (2) the analysis of transfer from a wheelchair into the personal car of a handicapped driver and analysis of accessibility to the so called comfort zones inside the car and (4) the analysis of kitchen accessibility. All analyses were performed in the ergonomic module of the CATIA software system. The anthropometric model (phantom) was characterised by dimensions corresponding to the real dimensions of the object of experiments.

3.1 Sales Space in a Market

The availability of the sales space in a market for disabled persons with advanced mobility dysfunction (e.g. those who move with the assistance of active wheelchairs) is very limited. These constraints occur due to definite range of reach and strength possibilities of human upper limbs in a specific for a supermarket element arrangement of the "man – wheelchair – element" system of sales hall equipment. The arrangement of the sales space in supermarkets is based on principles of merchandising sales intensification which remain in stark antinomy with principles of ergonomics. Groups of the most expensive products and products of the greatest rotation are placed on market shelves on the basis of the optimisation of product perception on the shelf at the height of sight of a standing, able-bodied customer (1.2 to 1.6 m). Unfortunately, it is different from the perception perspective of a disabled person sitting on a wheelchair. The imposed traffic direction (market areas on the right-hand side of the route) for first necessity goods, furthermost from the entrance is also not very favourable for all customers. The zone analysis of the force reach for the right hand revealed that the object manipulation in the course of picking an article from the centre shop shelf takes place within a restricted interval of force zones (in Figure 3, zones of 51 and 58N force values have been eliminated) due to limited possibilities of the approach of the wheelchair to the stand.

Manipulations on the top shelf are situated at the boundary of zone ranges with force values of 20 and 28N which makes handling heavier products difficult, uncomfortable and unadvisable. Since no data regarding the distribution of force zones of the bottom shelf were available, this shelf was not analysed.

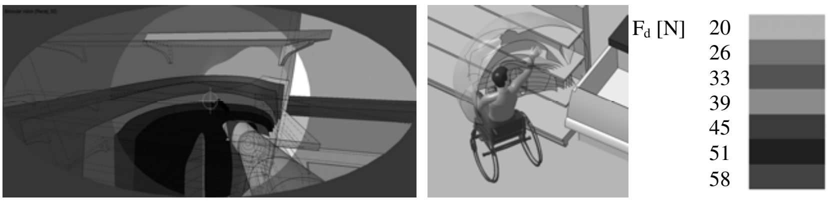

Fig. 3. Visualization of the vision field and force zones of a male with a disability in supermarket surroundings

3.2 Analysis of Car Utilisation by a Disabled Person

It is evident, from the analysis of processes of transfer from the wheelchair onto the car seat as well as actual driving of the car by a handicapped person, that critical ergonomic activities for the appropriate system configuration: disabled Person – active Wheelchair – personal Car (P-W-C) are as follows:

- dynamic transfer of a person from the wheelchair onto the car seat;
- loading of unfoldable wheelchair frame into the car as the assembly of biggest dimensions and weight (after dismantling drive wheels);
- driving and operating car devices in the so called ‘comfort zones’.

Assessment criteria of adjustment of the support devices of the P-W-C system comprise, primarily, man’s somatic features (position of a person during handling of devices, spatial restrictions, reaches of limbs, forces exerted by limbs) [20].

A phantom from the CATIA v.5 system of dimensions complying with those of a handicapped person was applied. Earlier prepared 3D models of a real car from segment B (Renault Thalia/Clio) as well as of an active wheelchair (in CAD, SolidWorks, RhinoCeros and CATIA v. 5 systems) were employed in our investigations. The form and arrangement of dimensions of two graphic representations of anthropometric features as well as reaches of upper limbs and biomechanical forces were obtained on the basis of empirical studies of a disabled person sitting on the wheelchair and on the car seat. Each of these representations of features reminds by way of their mutual overlapping “an onion” with its centre in the SRP anthropometric measuring point. Figure 4 compares system cross-sections of force layers of a handicapped person sitting in a wheelchair and on a seat of a car.

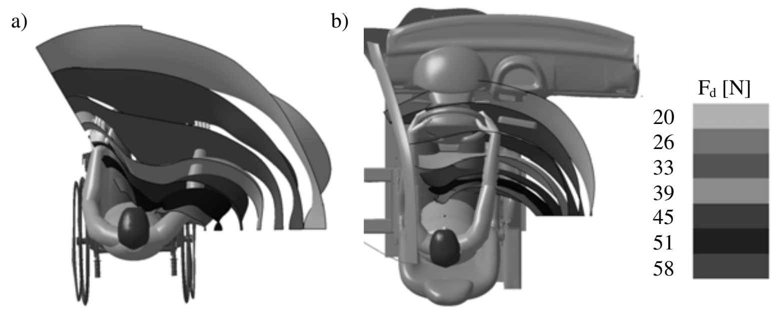

Fig. 4. Comparison of representations of force features of a disabled person sitting in a wheelchair (a) and on a seat of a car (b)

Authors analysed the process of loading objects into the car. The frame of the wheelchair is transferred by the right hand from the outside into the interior (on the passenger's seat or on the back seat) of the car (Fig. 5).

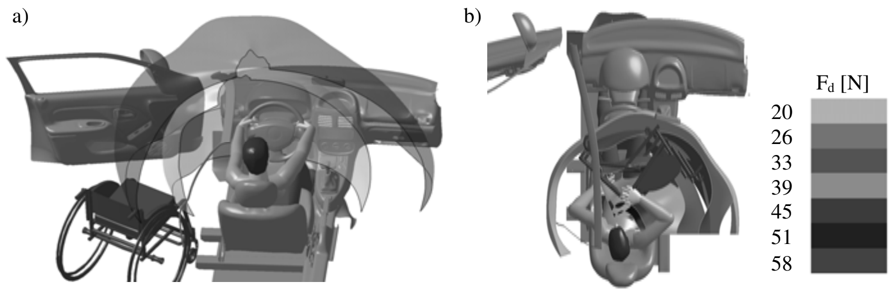

Fig. 5. Position of the static and dynamic reach of the right upper limb (a), loading of the wheelchair frame (b)

When loading the wheelchair, arms' dynamic reach must be employed. A driver sitting on the seat is not able to reach the wheelchair without breaking his back away from the seat backrest (Fig. 5a).

Other activity of disabled person is the process of transfer from a wheelchair into a car, significant loads occur. A force analysis of putting the frame of an active wheelchair into a car by a driver with disability is presented in Figure 5b. The comparison of the wheelchair frame gravity forces (weighting about 8 kg) with acceptable strength possibilities of the driver shows that the value of the permissible force was exceeded two times.

The analysis of servicing operations during driving is performed in the so called comfort zones [3. 12, 16, 17, 19, 21]. Figure 6 shows the results of analysis of force possibilities of loading of the steering-wheel and the gear lever by the driver in static position. The condition of the accessibility of arms' reaches is fulfilled.

a) b)

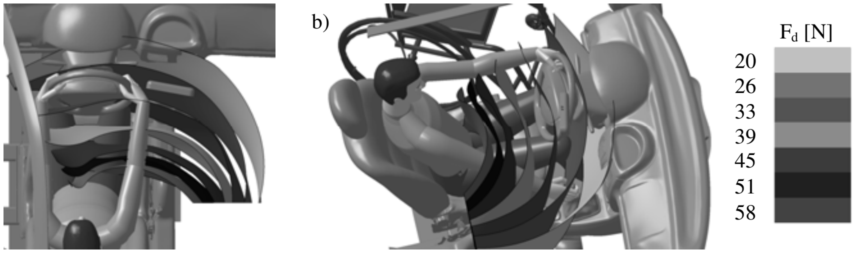

Fig. 6. Force zones during manipulation of the steering-wheel (a) and gear lever (b)

3.3 Investigations on the Accessibility and Field of Vision of a Disabled Person Sitting on a Wheelchair in Kitchen Virtual Environment

A standard kitchen usually does not fulfill the expectation and requirements of a disabled user. Interactions between the spatial structure of the work station and the user of the kitchen sitting on the wheelchair prevent him/her to adapt typical ergonomic positions. The sitting position on the wheelchair and lack of recesses in furniture as free space for feet makes close approach of the wheelchair to the front of furniture and equipment impossible and prevents the user from adopting a position identical with the standing position of other kitchen users. The sideways approach to furniture and equipment enforces an unnatural position of single-handed work, usually at the limit of arm reach with respect to dynamic leaning. In this dynamic position, work is less comfortable and the body position less stable due to the lack of the back support at the height of loins. It is true that at the wheelchair sideways approach to furniture (Fig. 7-Ia), manipulation possibilities increase but, practically speaking, all manipulations must be performed with one hand – right or left – depending on the direction of the vehicle in relation to furniture (Fig. 7-Ib, Ic). Another significant limitation is connected with the arms' reach since only the front part of the heating plate remains within the working range of arms. In addition, considerable distance from furniture causes that work is carried out with arms almost straight, limiting the applied force of the user and easily leading to rapid static fatigue. It should also be remembered that all work is performed sideways and, inevitably, when carried out long, is extremely exhausting.

In an adapted kitchen, the most important technical facilities of the kitchen equipment (e.g. gas cooker, sink) are characterised by appropriately changed dimensions. The height of the heating plate is lowered to suit the figure of the user sitting on the wheelchair. In addition, the removal of the lower part of the cupboard allows sufficient space for legs making it possible for the disabled person to access the device comfortably (Fig. 7-IIa). This position allows manipulation of kitchen utensils with both hands in the frontal half-sphere of the arms' reach. This affords significantly better manipulation possibilities at considerably reduced required muscle forces.

The field of vision of the workplace in an adapted kitchen is better. The lowered heating plate creates better manoeuvring possibilities with kitchenware and, additionally, affords significantly better observation of the working area as well as the content of individual utensils. The field of vision of the disabled in a standard kitchen is nearly parallel to worktops and, consequently, the entire work field is seen from the side (Fig. 8a). In the case of the kitchen with adapted furniture, the field of vision is moved higher and therefore the user looks at the objects from above (Fig. 8b).

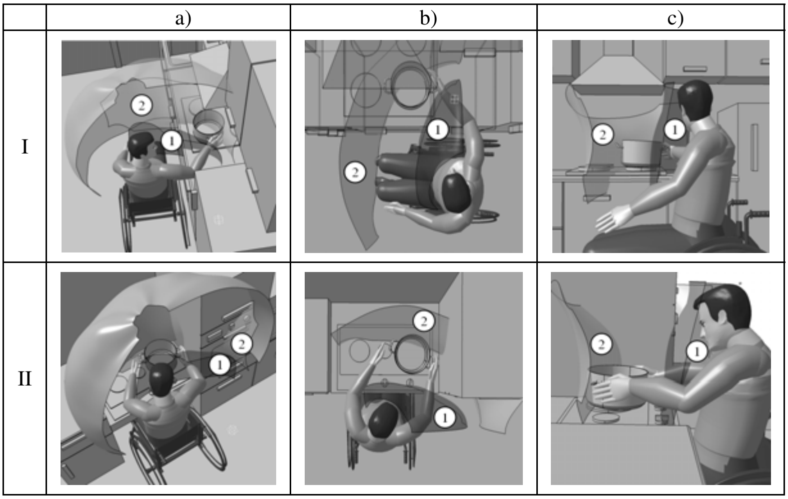

Fig. 7. Visualisation of the reach zone of the right arm and force range during manipulation at the gas cooker in a standard (I) and adapted (II) kitchen; (1) – 180 N zone, (2) – 80 N zone, grey colour – maximum range of arm reach

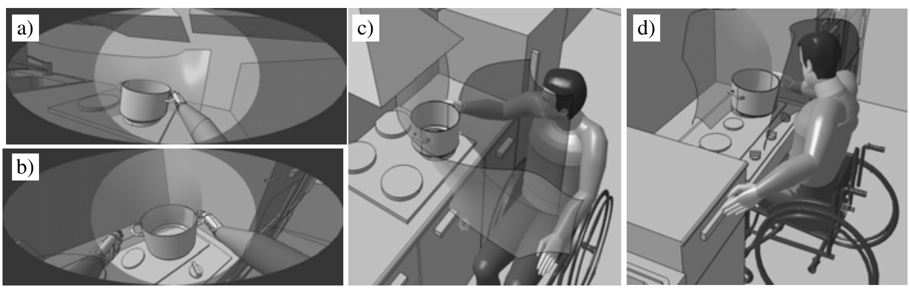

Fig. 8. Visualisation: a,b) of the field of vision of a disabled person during manipulations at the gas cooker and c,d) manipulations possibilities of the right arm for a standard (a,c) and adapted (b,d) kitchen

When analysing arms' reaches, it is also important to pay attention to possibilities of manipulation with the other (in this case, right) hand. In the case of sideways work in relation to kitchen furniture (Fig. 8c), it is possible to use only one hand when operating equipment for thermal treatment as manoeuvres with the wheelchair are very difficult. In the case of the adapted kitchen, with the possibility of access to furniture from the front, the user can employ the free hand, at any moment, to move around or reach for required elements.

4 Conclusions

The presented original method of graphic modeling of anthropometric and biomechanical data for the requirements of CAD systems can be applied universally in ergonomic designing of the workspace not only for handicapped persons. When designing workplaces, designers often overlook requirements and possibilities of persons with locomotive disabilities (especially with respect to accessibility within effective reaches of arms and allowable forces of arms) as well as limitations of the field of vision with regard to objects of manipulation. Drawing conclusions on the basis of the 3D graphic analysis of different situations in the workspace is relatively simple. Preparation of the model of computer simulation is quite labour-consuming.

The method presented in this work has been patented [26] and received numerous awards: Gold Medal on Seoul International Invention Fairs SIIF 2010, Gold medal on IV International Warsaw Invention Show IWIS 2010, Silver medal on Brussels Innova: International Exhibition of Invention Research and New Tech. Eureka 2010.

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Modeling the Role of Empathic Design Engaged Personas: An Emotional Design Approach

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Abstract. Norman suggested three dimensions of emotion to approach user-centred design to raise awareness of the importance of designing for users to achieve a higher level of satisfaction. In other words, the design should satisfy the user's emotional desires beyond usability. This opinion explains user-centred design more broadly. Companies, such as Apple and Microsoft, have already employed anthropologist to observe users' daily behaviour. Unfortunately, gathering information on users' needs is costly, time consuming and complex and has, therefore, become a barrier for designers. Additionally, most emotional design only covers shape design instead of all emotional aspects. There is little previous work devoted to tackling these problems. This research, therefore, proposed using empathic design with the assistance of personas as the main approach to emotional design. We first investigated the designers' current design pattern to explore the difficulties and problems. Next, personas were used to ascertain how they could help designers to engage in emotional design. Comparisons were then given to show the effectiveness of the proposed method. This study invited 16 designers to partake in this assessment. We explored how personas help designers in idea generations by using emotional design and some guidelines were suggested for future research.

Keywords: User –Centred Design (UCD), personas, empathic design.

1 Introduction

Today, user-centred design (UCD) is widely regarded as the design philosophy that defines how a design should be made by understanding the user's needs. In addition, the whole design process is examined iteratively to be user-centric by the guideline ISO 13407 to enhance the practice of UCD [1].

In the early years, the promotion of UCD was meant to solve the problems that had been encountered by some designs, those that were difficult to use and that frustrated users. Norman pointed out the guidelines for designers in his book, "The Design of Everyday Things", helping them to correctly design functions by considering the users [2]. However, he argued in his next book, "Emotional Design", that design should cover not only the cognitive parts but also human emotion. Therefore, he proposed three dimensions of emotion, visceral, behavioural and reflective, and suggested that designers should not neglect the role of the user's emotions when designing [3]. In

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other words, design should be customised by taking both users' cognition and emotion into account. Jordan also has similar viewpoints. He suggested the "four pleasures", which are physio-pleasure, socio-pleasure, psycho-pleasure and ideo-pleasure [4]. In addition, the satisfaction in function and usability is not enough to make users feel pleasure at a higher level of satisfaction. Jordan's points also indicated that user-centred design could be more complete by the explanation of satisfaction in advance. Therefore, the design is not the argument of design by following "aesthetics" or "functionality"; the proportions of the design elements are subjective to users.

Nevertheless, UCD is now used more in large enterprises even though there are several approaches to achieving UCD, such as contextual design, participatory design and empathic design. The reason is because the involvement of users makes the design costly. Most designers have a problem in understanding users when faced with them since it needs a high level of skill to arbitrate the decisions among users in a meeting and a professional background to resolve the users' behaviour during observations. Consequently, empathic design focuses on more aspects for the designers in the early stages of design. In addition, although empathic design offers "observation" as the method, the key point is to understand the users. Therefore, we only adapt the meaning "understanding of users" as the basis. To ask designers to think and behave like users could be a comparatively cheap solution as there is no "real user" involvement. Hence, the researchers suggested a method based on empathic thinking in order to help designers in the early stages of design to promote the benefits of cost effectiveness that are easy to manipulate.

This paper aims to explore the use of empathic design mixed with personas in order to help designers in the early stages of design to undertake emotional design more easily, enabling it to be more cost and time efficient. By doing this, we can persuade more usage of emotional design. 16 designers were invited to evaluate the proposed model by two-phase experiments and the experiment methods were interviews, think-aloud protocols and video recording. More findings are discussed in the results and discussion section. Through this research, we found this proposed method helped designers in emotional design and future suggestions were given.

User-Centered Design: User-centered design (UCD) is a design concept first mentioned by Donald Norman (1990). The definition of UCD is as its name implies, design according to users' needs. Norman criticised many inadequate designs that surround us and highlighted how they discouraged users from using the products. The significant difference of UCD is that it aims to persuade designers that design should consider the users' needs during the whole design process rather than adjusting users to accommodate the products. Even though more and more companies are aware of the advantages of UCD and believe UCD to be an important philosophy, the different properties of products mean that following UCD becomes a difficult task. The International Organisation for Standardisation (ISO) provides a framework in ISO13407. It suggests the human-centred design mechanism of the application and the evaluation. Although ISO 13407 offers a basic guideline for the interactive design process, it is not intended to specify the particular methods required to approach UCD. In addition, one of the major points in ISO13407 is the iterative structure of the design process, as shown in Figure 1. It clarifies how the design should consider the user during the whole process.

Emotional Design: In "Design for Everyday Things", Norman admitted that user-centred design defines design by considering the user's wants. However, at that time he only considered that products"make sense". In other words, he only suggested the guidelines for cognitive thinking. Later, Norman proposed a supplement to this in his book "Emotional Design", which pointed out the important role played by human emotions when designing interactive products. The main points of emotional design are based on three levels of emotional processing: Visceral, Behavioural and Reflective. As we can see from Figure 2, using this model we can easily reflect design elements according to emotional behaviour. In other words, different users may reflect their different desires on different aspects of design elements, such as aesthetics, functionality and usability. This can explain the reasons why some products that are difficult to use are still loved by some customers, whereas those that look good are more attractive to certain users.

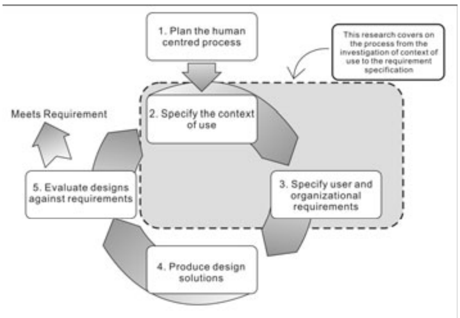

Fig. 1. The process of UCD and the area of this research [5]

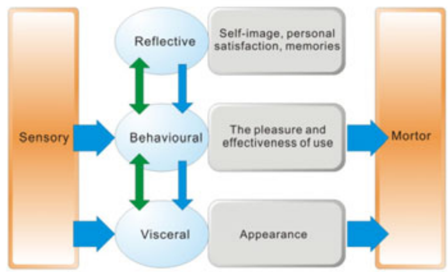

Fig. 2. The three-levels of human emotion reactions connected to the product characteristics.[3]

Empathic Design: This is an approach to UCD where the designer attempts to get closer to the lives and experiences of users and to apply the knowledge from end-users during the design process [5]. The goal of empathic design is to ensure that the product or service is designed to meet the needs of the end-users and is usable. Nevertheless, the users are only indirectly involved in the design project. It therefore tends to become 'designer-centred' instead of UCD. Additionally, professionals in empathic design promote the use of observation, although sometimes it is difficult to have the chance to freely observe the users in a particular situation. In addition to this, the involvement of users requires the design to need more skills and costs. Consequently, in this research, "personas" are used to overcome these issues and enhance the use of empathic design.

Personas: After Alan Cooper first promoted personas in his book, "The Inmates are Running the Asylum" [6], personas have been widely used in the computer science domain. Personas provide user profiles that can represent a group of people. The two main benefits of the use of personas are for communication between teams and to help designers to focus more on their users [7]. More findings, in terms of the use of personas, have been researched by Microsoft. In their work, they used personas to develop their popular software, such as "Office" and "Messenger", finding that the use of personas was a great benefit to design tasks. In addition, famous Japanese businesses are using them for organisation communication. The authors will use personas as the key technique and, inheriting many of the advantages from work previous to this research, we intend to investigate how personas can help a designer to develop their product concept in their individual work. This research will analyse the aspects that the individual designer can use to connect with emotional design, especially few scholars contributed in the area that the process of the use of personas with emotional design.

2 Methods

By reviewing the literature we will propose methods for this assessment. There will be a two-phase assessment. First is to investigate the current design pattern of the participants. The second will be to apply the proposed model to observe how designers conduct the idea generation. We will then compare the differences before and after the use of the persona-method to reach the conclusions.

2.1 The Proposed Method: Empathic Design with Personas

We have arranged a two-phase experiment. In the first phase, we aim to survey designers' current design patterns. During the second phase, we will conduct the proposed method and then make comparisons in order to further evaluate the effectiveness. The plan of the experiment is showed in Figure 3.

Fig. 3. The Illustration of the assessment plan

16 designers participated in the assessments. Even though this research can apply to various product categories, some control factors were defined in order to examine the comparable information in this assessment. Firstly, we assigned the same product in all the design tasks in which designers were asked to develop their product concepts. Additionally, the interviewees were required to have a similar background and to be able to manage the development of a design concept for a single product. Moreover, the designated task was confined to designing a product for use by an individual instead of a multi-user product. Also, the specified design task needed to cover all the elements of "appearance, function and usability". Each participant spent about 30 minutes undergoing interviews and the design tasks. A personal use product was specified to simplify the use of the personas. The design task needed to contain the appearance, function and usability in order to project the three emotional layers. Due to the criteria mentioned above a portable MP3 player for the group "pages 25-34, office ladies" were selected as the experimental task.

2.2 Phase I: The Investigation of the Current Design Pattern

During this phase, semi-structured interviews and think-aloud were undertaken in order to acquire details of the interviewee's background.

2.3 Phase II: The Investigation of the Use of the Persona

The second phase is to introduce the personas in order to investigate how they can help with the design task. Before the task is examined, some assumptions are proposed: The designers are trained to have the design common sense to design and they are assumed to have the imagination for the operation of fictional characters. Otherwise, the participants and the target task remained the same as for the first phase. The persona should be developed from the anthropology survey, except for the name and the photo, according to the previous literature. This is to avoid stereotyping a persona from familiar names and photos. Additionally, for reasons of ethics, it is essential to protect any private and personal data. Therefore, this study licensed photos from the FERET database (Figure 4. left side). The names were chosen from the most popular UK names on the website. The profile of the persona was taken from a lady who was located in our target market segment. Due to the limited task time available, the authors only assigned one persona, as the illustration on the right side of Figure 4. shows. Task 2 took 10-15 minutes and the participants were asked to design, applying the same conditions as the first phase. The only difference was they needed to develop their concept using the specified persona provided. The persona is located within the same market segment, "25 to 34 year-old office ladies". The point of this research is the investigation of the interaction between designers and the personas and the creation of personas is another big process.

3 Results and Discussion

3.1 The General Background and the Context of Design from the Interview

Thirteen of the designers were from Asia, two of them were from the UK and one was from the US. As we can see from Table 1, industrial designers were interviewed in the first and second phases. Within the group there were eleven senior designers with more than five years of work experience. Five of the group were junior designers with between six months and up to five years experience. The final group member was a senior design student who had only run independent design projects and group projects.

However, six designers felt that they needed to study the market on their own before they designed. Consequently, to avoid unfairness in the experiment, the researchers confined the task. We provided the same product information and only asked them to develop their product concepts.

Furthermore, the designers were asked to describe their present methods of practising idea generation and their general design cycle for a project. Interestingly, when the question was asked, "Does the user matter in your design projects?", only six of them answered "Yes", whereas nine responded that they did specify users but tried to

Fig. 4. The left side is example photos from the FERET database. The right side is the persona in this task.

Table 1. The background of the participants

Samples	Work Experi-ences	Project Lifecycle[2]	Idea generation methods	Emotional design
1	Senior	1-3m	Similar work gathering	C
2	Junior	1-3m	Brainstorming/Similar work gathering/ Scenarios/sketch	C
3	Junior	<5m	Similar work gathering/Sketch	A
4	Senior	1-3m	Brainstorming /Similar work gathering	C
5	Senior	1-3m	Sketch/Discussion/Similar work gathering	C
6	Senior	1m	Sketch	C
7	Junior	1m	Sketch	C
8	Student	1-2w	Sketch /User data gathering	C
9	Senior	3-5d	Sketch/ Brainstorming /User data gathering/ Similar work gathering/Sports	A
10	Junior	1-3m	Sketch/ Brainstorming /User data gathering/ Similar work gathering	C
11	Senior	>6m	Sketch/ Brainstorming /User data gathering	C
12	Senior	1-2m	Sketch/ Brainstorming /User data gathering	C
13	Senior	2-3m	Sketch/ Brainstorming /User data gathering/ Similar work gathering	C
14	Senior	1-3m	Sketch/Brainstorming/User data gathering	C
15	Senior	1-4w	Sketch/Brainstorming/User data gathering	C
16	Senior	1-3m	Sketch	C

[1]

ensure the design covered all user groups in order to gain maximum benefits. This demonstrated the current design problems that designers were usually asked to do design greedy cover the market. The final participant believed that users were not important in their design. We also asked them how much they understood emotional design. Surprisingly, only one of them showed an understanding. Most of them either said they had never heard of it or they had heard of it but they did not exactly understand the definition of emotional design. These patterns will be compared in the design task to see if the interview answers were identical to their design behaviour.

With regards to the design behaviour, several methods were used to inspire design ideas. Most of the designers tended to get the design concept by sketch, brainstorming and information gathering. Later, we gave them a design task that followed their

[1]*Work experience:
1. >5 years: Senior
2. <5 years: Junior
3. School project student[1]

2 Project Lifecycle:
m:Month
w: Week
d: Day

3 Emotional design?
A: I cam do it
B: I knew it *but I don't know* how to do it
C: I've never heard of it/ I've heard it but I don't know what it is.[1]

current methods. Before doing this task, a question was asked in order to record whether they had designed a similar product before. Four of them had designed once for the same market segment and two of them had designed the same product. This information was taken in order to record whether their memory of the previous design affected and contributed towards any bias in the design process that we asked participants to do. We asked them to do the same task twice to compare how useful the personas were.

3.2 Results from Phase I: The Investigation of the Use of the Persona

Table 2 shows how the designers developed their product concept using their current methods. As can be seen, six of them were product-centred, which means the designer only considered the product elements to make it pretty, regardless of the user. Three of the designers tended to be designer-centred with five tending to be both designer-centred and user-centred. Finally, two of the designers were user-centric but were easily distracted.

When analysing the interview results, we found that one of the weaknesses of the designers' present work is that, regardless of their experience, there was less user-centred design. When we examined the status of the user-centred designers, when interviewed, the participants expressed that they were designing for the users. However, during the design tasks, the UCD designers were, unconsciously, designer-centred rather than user-centred. Another finding was that even though two of the designers said they had undertaken emotional design before, they actually regarded that "appearance design" meant emotional design. Another drawback was that most of the designers were concerned with the design shape rather than functional design. Hence, we may summarise that the designers, without the support from a user research team, tended to ignore the users in their design.

3.3 Results from Phase II: The Investigation of the Use of the Persona

The design task followed the same conditions as the previous task. The results are shown in Table 3. As we can see in Table 3, when a persona is used, the design concepts from designers became similar in all aspects. However, they still had different ideas for their designs.

As shown by the information in the table and from interviews and observations, the designers were able to explore more design ideas. Additionally, the designers were found to use shorter timescales to make decisions. There might, however, be some errors attributed to the training effect due to the same product for the same users assigned to the same users twice. However, the supportive point from the interviews is that three of them had done the "MP3" project for the same group and one of them had designed the same product for a different group. However, there was no significant difference to the other designers.

One more important finding came to light when they were asked whether they felt the later concepts they made contradicted the previous task. All of the designers who were designer-centred and product-centred felt that the later designs were more likely to be suitable for the target users. However, the designers with more UCD in Task 1 said they did not feel there was a contradiction. They felt that Task 2 helped them to specify a design concept, such as a warm colour domain or a specific colour.

Table 2. The context of idea generations

Samples	Colour Scheme	Form	Special Functions?	Style/Tactile
1	Blue	Simple like an iPod	Wifi/ Convenient	Fashion
2	White with some pattern	Not specified	Not specified	Organic
3	Red or Pink	Sweet/ Stylish	Not Specified	Feminine and Elegant
4	Cannot decide now	Not specified	Simple MP3	Feminine
5	Black, to cover wider variety of users	Smooth/ Technology	Sound quality/Easy to play	Shiny surface for acceptance by the market
6	Pink series or multi-coloured mix	Round/ Delicate/ Match the dress	Simple keys	Elegant
7	Soft colour such as pink or white	Accessory	Friendly interface.	Plastic but metallic look
8	Red/Pink	Lipstick look	Simple buttons to operate	Shiny Plastic
9	Feel happy/pink series	Simple/Ne at/Accessory	Easy interface and to charge up	Delicate/ Fashion
10	Many colour selections such as red/pink series	Simple/ Clear	Can be used on the bus	Metallic
11	White series/ Shiny bright series/Pink series	Round/ Friendly/ Slim/Neat/ Easy to carry	Easy interface/ Shortcut to save files/ Rapid wireless to download albums	Rubber / Leather (soft feeling)
12	Silver +Black	Simple	Internet /Plug and Play and auto sorting	Metallic +Plastic
13	Cannot decide now (Multiple selection)	Simple like an iPod/ Square	Easy key/Touch panel	Plastic but metallic feeling
14	Pink/Feminine colour	Accessory to match the handbag	Bluetooth/Can have a mirror	Shiny/Plastic
15	Light pink	Curved	Not important	Comfortable
16	Silver and Green	Rectangular	DAB, Re-corder/Subwoofer/Camera/Digital frame/ Lighter	Metallic and plastic

Regarding the emotional design, here we listed an example from participant 4. As we can see from Figure 5, we can see the context of the design. Unlike most of the present emotional products in the market, this design can further touch the behaviour level of emotion rather than only “appearance design”. This result is significant as it shows the mixed used of personas with empathic design can guide designers to reach empathic design without much training. Even if we only reviewed the interview data from participant 4, other participants showed similar results and we found that inspired ideas can connect to both the reflective and behavioural levels.

The designers would get a general image of this user by the photo, name and essential profiles, such as age and gender. Then they gave a rough appearance and sensory design. When the designer looked through the detail, they usually narrowed down the ideas in relation to the reflective part. Furthermore, they started to get inspiration from combinations of the details in order to provide a functional design, which is mapped to the behavioural level. However, we have no clues from the interview that they can do the visceral design by the provided personas.

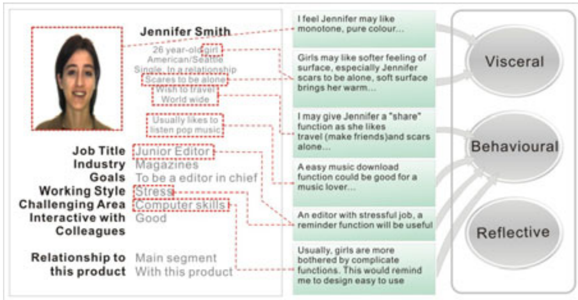

Fig. 5. The context of design in related to the persona

Table 3. The context of idea generations by using the personas

Samples	Colour Scheme	Form	Special Functions?	Style/Tactile
1	White	Like a T-shirt	Wifi/ Convenient	Clothes feel of material
2	Red	Rectangular/ Small	Agenda/Reminder/Schedule/Inspired quote to cheer up her mood	Plastic
3	White	Organic	The ability to share functions with friends	Some pattern on the plastic
4	Monotone/Simple	Rectangular/ Bigger screen but lightweight	Touch panel/ Reminder/Easy operation/ Music download /Share	Soft Surface
5	White	Smooth/Portable	Easy/Good sound/Enough music storage	Shiny Surface
6	White	Round	Play/Radio	Plastic
7	Pink	Cosmetic box	Easy keys	Shiny Plastic
8	Pink	Lipstick	Simple play Earphone design resembles earrings	Plastic/Looks elegant
9	Cute Pink	Small/Portable /Rectangular	Update files easily	Fashionable/ Leather
10	Red/Black	Simple	As simple as it can be	Simple/Elegant and professional looking/ Metallic hair silky
11	Light bright colour	Round smooth/ Square	MP3/Recorder/ Calorie measurement	Shiny plastic/Metallic look
12	High contrast colour with grey	Round smooth/ Square	MP3/Photo viewer Internet friendly/Upload and download friendly	Soft material
13	Pinky white with a flower pattern	Round smooth/ Square	Easy buttons with big touch screen/Photo Viewer/Sharing function	Shiny plastic
14	White with pink	Round smooth/ Square with curve for easier handhold	News/Music downloading from the internet	Soft on the back side for easy grasp/Shiny mirror screen
15	White with pink blue/red/orange /purple	Sportive	Calorie calculation Changeable cases for different moods	Soft material
16	Pink brown	Simple neat square	Small games to kill time	Soft material

In general, the participants were satisfied with the use of personas and felt surprised at the effect of them. They commented that the personas did help them to think about users' emotion all the time without distraction. Also, they felt that this tool can help them towards self-communication and enable them to examine the ideas they made.

From the comparison of the task before and after the use of the persona, as we can see in Tables 2 and 3, we can see the design tendency converged to a similar colour domain in aesthetic design; functions are fruitful but still stick on the users. In addition, when designers undertook the task using the persona, they tended to design quicker and concentrate more.

4 Conclusions

We found the original design made it more difficult to approach user-centred design and, as a result, it was a less emotional design. In addition, most current emotional design only guides users to undertake appearance design. Instead, this method is able to lead designers to undertake emotional design without needing to be taught further design knowledge. This assessment provided the demonstration of the process of the idea generation engaged personas to launch emotional design.

In addition, this paper suggested that continuing on from this research, more characters of personas can be chosen to explore more evidences of how the personas engage with emotional design. Especially the visual personas and the profiles personas seem to provide different inspirations to designers. In addition, a complete product process can be undertaken to further assess the product with consumers.

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Accessible UI Design and Multimodal Interaction through Hybrid TV Platforms: Towards a Virtual-User Centered Design Framework

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Abstract. We report on work towards an architecture that incorporates accessible design methods, guidelines and support tools for building and testing adaptive and accessible user interfaces (UI) for users with mild impairments. We especially address interaction constraints for elderly people, both during application design time and at run time, targeting on hybrid TV platforms. The functional principle of our architecture is twofold: At runtime, it lets users interact with hybrid TV applications through an ensemble of accessible UIs that cover different input and output modalities and are jointly adapted via user profiles and real-time feedback. At design time, it allows developers to re-use UIs and representative user personas in simulating the effect of the UI modalities on different impairments.

Keywords: Inclusive Design, Accessibility Guidelines, Development Methods, Access to the Web, Hybrid TV, Connected TV, Interaction Techniques, Usability, and User Experience, Virtual User, User Simulation, Context–awareness, Architectures and Tools for Universal Access, Adaptive and augmented Interaction.

1 Introduction

In this paper we address key research questions on accessible user interface and application design as well as multimodal interaction for elderly people through a hybrid TV platform in the living room. Aging and accessibility are highly correlated topics. It is hardly possible to refer to one without thinking of the other. According to [1], aging is a demographic trend in the age distribution of a population towards older ages, whereby, it is also a known fact that approximately 50% of elderly (persons age 65 years or older) suffer from some kind of (typically mild) disability such as visual, cognitive or motor impairment. This poses several problems and challenges to their social interaction [cf. [2], [3]] and interaction with information technology cf. [4].

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While extensive research on web accessibility [5], [6] has yielded significant results (such as the developments of accessibility APIs, tools, recommendations and guidelines in delivering broadband service on the web), there is little research work done thus far, to address accessibility problems in other environments such as digital broadcast and hybrid TV platforms. This means, considerable research effort is still required to bridge the accessibility gap between broadband and broadcast service platforms. In real life, this accessibility gap has far reaching consequences for the aging population (elderly people), who spend more time in their homes and are used to the TV in the living room as an interaction device rather than the desktop computer. According to recent reports [7], this segment of the world's population is increasing steadily at an estimated rate of 870,000 per month.

However it is also worth noting, that currently, information and telecommunications (ICT) services experience a paradigm shift. Novel standards and platforms, such as recently released hybrid TV standard-HbbTV [8], or the MeeGo or GoogleTV platforms, will be commonplace in the homes of the audience. Hybrid TV platforms, unify broadcast services and broadband (managed IP delivery solutions or via access to the web) applications.

This innovation has two main advantages: (1) developers of ICT applications (such as video-conferencing, e-learning or home automation), will soon be able to deploy their applications as important services on the Hybrid TV infrastructure; (2) knowledge gained through research on web accessibility can become the basis for understanding and addressing accessibility challenges on digital TV and hybrid TV platforms.

We view these current developments as motivation to craft engineering tools and frameworks that can on the one hand assist ICT application and user interface (UI) developers to adopt inclusive design principles in their implementations, and on the other hand, foster support for accessible features in mainstream products within the industry. Currently a significant percentage of potential beneficiaries of new ICT applications are left out, due to the fact that accessible design patterns are not yet an integral part of the development cycle of mainstream products and services.

2 Overview of Challenge: Develop for the Elderly

Inclusive design in practice is often, an expensive process that requires specific knowledge of the target user group and, related to this, may require specific UI designs to be implemented and tested with these users. In the case of UIs for elderly people, a spectrum of common impairments needs to be considered.

Design of inclusive ICT applications thus poses some obstacles to application developers: (1) There often is a significant knowledge gap with regard to the special needs of this particular group of users, (2) the development cost of specific UI components needed for personalized interaction and adapted to the user's impairments may be too high (given that, athough there are a number of accessibility APIs [10], [11], [12], [13], available for various platforms that allow developers to provide accessibility features within their applications, today none of them provides features for the automatic adaptation of multimodal interfaces, being capable to automatically fit the individual requirements of users with different kinds of impairments) and (3) performing user trials for validation of designs require substantial efforts and is often expensive and time consuming. Furthermore, it is hard to get a large number of respondents in the trials that are representative of the population of this target group of users.

Another challenge developing for the elderly, is the design of runtime frameworks that support multiple user interfaces for accessible applications like i2home [14], TSeniority [15] and PERSONA [16] and also provide design time support tools that allow developers perceive at design time the effects of a visual, cognitive or motor impairment on a user's experience of application content at runtime and to perform necessary adaptation on the user interface at design time.

3 Our Approach

Our goal is to reduce these obstacles for developers of ICT applications, especially targeting hybrid TV platforms such as the emerging connected TV standard HbbTV [8], where according to [9]; hybrid or connected TV is to create a huge market in Europe by 2015. For this purpose, we are developing an architecture that is tailored to meet the requirements of accessible UI design and support developers even without major expertise in inclusive design. From previous research work, especially in the area of ambient assisted living [cf. [14], [15] and [16]], we know that runtime platforms have succeeded in supporting a multitude of user interfaces in a multimodal interaction setting with accessible applications. Thus, adding development support to such runtime platforms (architectures and tools for universal access) seems a worthwhile approach. Collecting detailed requirements from the different application stakeholders, including end-users, developers, platform providers, resulted in a set of features of our architecture and proposed development method.

3.1 Requirements

At user level, the major design criterion is inclusive access to the ICT application. To cope with the scope of impairments in the target group, we have identified a need for multiple UI modalities and adaptation parameters to be provided as standard UI components, including adaptable speech IO, gesture and haptic interfaces as well adaptive visual rendering [17]. In addition, we identify significant accessibility challenges posed by rich internet application and advance multimedia applications developed using Ajax, and some related web technologies for broadband services. According to [6], while applications using these technologies provide rich multimedia and dynamic content, they however, cannot be perceived by people with some visual or cognitive impairment or used by people with some motor impairment. In addition, considering the huge research efforts and achievements in addressing problems of web accessibility by [5], the idea would be to explore the extent to which concepts of web accessibility can be applied to hybrid TV platforms in a digital TV environment as well as identify accessibility gaps in deploying broadband services in an internet-based infrastructure and broadcast services in digital TV environment. Further, we identify the requirement that, inclusive design for the broad spectrum of user capabilities in the target group is best supported by actually adapting parameters *across* modalities, making use of relevant recent research results in inclusive multimodal interaction[18], [19].

At developer level, the foremost requirement is to streamline the inclusive development process using the envisioned runtime framework with design time support tools. Taking into account a user-centered cyclical development process as depicted in Fig. 1, the idea is to bypass the major obstacles noted above: (1) Lack of knowledge on elderly users and their specific requirements is addressed by a knowledge repository (accessibility design guidelines or a developer handbook) that supports developers throughout the UCD cycle, incorporating guidelines such as [20] with target-group specific knowledge in the context Hybrid TV, which we elicit during user studies, (2) the benefit of providing re-usable adaptable UI components is clear, but to (3) simplify testing of these UIs within application contexts has been identified as an equally important issue. We therefore have based our design on virtual users [21] and simulation components [22] as central facilitators, leading to a "virtual user centered design" (VUCD) cycle as shown in Fig.1. This way a great portion of test with real end users may be substituted with virtual user simulations at design time.

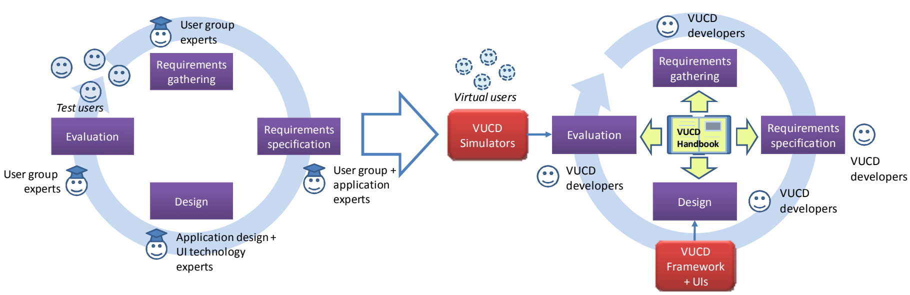

Fig. 1. Traditional user-centered design cycle vs. virtual-user centered design cycle

At the level of set top box manufacturers, connected TV (hybrid TV) platform providers, a major criterion is to incorporate the envisioned runtime UI framework supporting accessibility design patterns into underlying software framework of their middleware software stack. In this way, accessible design can become integral part of mainstream products and thus ultimately break down the product market boundaries and accessibility barriers. A further criterion is the open software framework requirement for digital TV and other connected TV platforms as identified in [23]. Such a framework should at least provide support for seamless connectivity of accessible input and assistive technologies that are required in managing user interaction and also allow for service interoperability.

4 Development Strategy

Based on the conditions as well as requirements presented in our approach, we designed a high-level architecture showing all components and their roles in Fig. 2: A runtime-framework supports ICT applications by providing interfaces for seamless communication between these and adaptable UI components through an abstract UI representation standard [24],[25]. The UI components and modal transformations themselves may be reused by developers, and for each UI modality, a simulator component that is part of a design time toolbox will be provided to evaluate user—application interaction given impairment profiles [22]. The user model underlying these profiles is derived from results of quantitative user trials. During the trials the interaction behavior of group elderly users was monitored to identify requirements and variables [26] for multimodal adaptation under impairment conditions and to provide important inputs to the design knowledge base as well as training data for deployment at runtime.

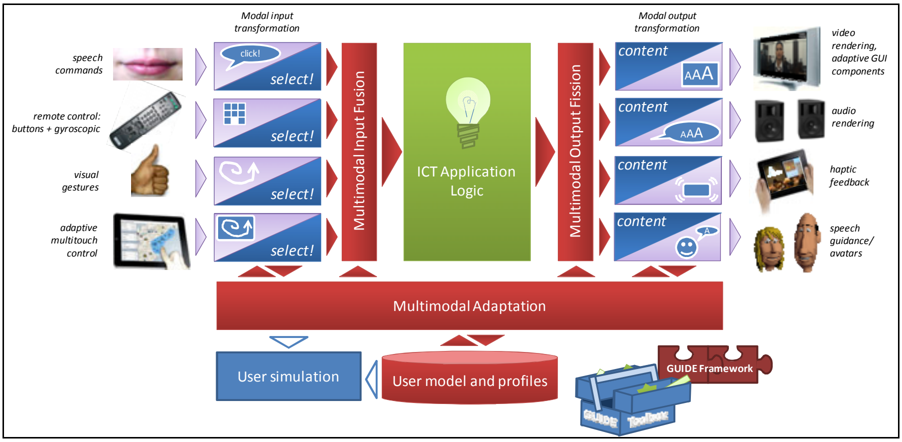

Fig. 2. An architecture for multimodal adaptive design and run-time support

It is worth noting that, in this paper, the research challenge is not in the creation of a multimodal software framework that enables an ensemble of UI components (*speech input and output, remote controls, visual gestures, multi-touch control, avatars, haptic feedback, video and audio rendering as well as graphical user interfaces*) to seamlessly interact with application content in a multimodal setting, as this has been widely explored and addressed in previous work [cf. runtime frameworks like [14], [15] and [16]], but rather to develop methods and tools that enable existing multimodal UI runtime frameworks to address fundamental questions of accessible and inclusive design. Specifically, this paper builds on a promising UI runtime framework [16] which provides the underlying software framework for seamless connectivity of accessible user interface technologies and service interoperability between ICT applications. We focus on adding engineering tools for runtime multimodal UI adaptation and user simulation [22] at design time, which allows developers to perceive the effects of a visual, cognitive or motor impairment on a user's experience of application content at runtime. Having this information at design time is crucial in ensuring an inclusive design practice during the development phase of mainstream products. In addition we claim that our approach will greatly simplify the UCD process for developers with little expertise in this area.

In the remaining sections of this chapter, we present concepts on our development methodology in realizing design time support for developers through a user simulation tool as well as multimodal adaptation at runtime. In chapter 5 we present some related work which also reintroduces the baseline runtime UI framework on which this paper is based and explores criteria for its choice for developments on target hybrid TV platforms. In chapter 6, we take a look at initial evaluation results from developer focus group sessions organized assess concepts on our proposed accessible UI design development framework and support tools. Chapter 7 presents a summary conclusion and an outlook into future work.

Our approach consists of three main steps in ensuring accessible design practice in ICT applications development at design time (DT) and multimodal adaptation at run-time (RT). Fig. 3 shows a schematic representation of these three steps, through which we aim at overcoming challenges discussed in chapter 2, that developer of accessible ICT applications face: a knowledge gap, cost of user trials and development effort of accessible UIs. In this process the driving "facilitators" are a user model and a simulation engine. In section 4.1 we explain in detail how our development process achieves a simplified UCD approach for an accessible ICT application developer while in section 4.2 we present methods for realizing runtime multimodal adaptation.

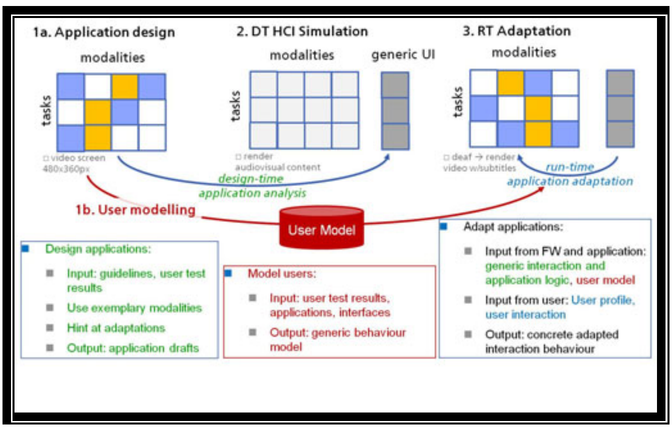

Fig. 3. A development process for design time support and runtime adaption

4.1 UCD, with the Expensive Steps Simplified

Our strategy to ensure a simplified UCD approach for ICT applications developer is based on the idea of adopting a "virtual" user centered design methodology. This is achieved by adding extensions to an existing runtime UI framework such as [16], that allow for the integration of design time support tools such as a virtual user simulation tool (comprising of a simulation engine and user personas). The simulation is a realization of different algorithms predicting [22] the performance of accessible UI components. These UIs render a graphical representation of the visual, motor and cognitive abilities of virtual users (personas) derived in a pre-design phase of user modeling, where data acquired in comprehension user trials is quantitatively analyzed to elicit parameters for classifying and categorizing user body structural and functional impairments. As shown in Fig.3, the result of this pre-design phase is a user model, which characterizes the generic behavior of a set of user personas and drives both application design process as well as its runtime adaption.

At design time, the ICT developer defines the application logic through the specification of a set of interaction tasks that the application can accomplish in some known modalities. This initially does not take into consideration special accessibility needs of users with impairments due to the knowledge gap. However based on our development approach, the application developer can in a second step, load profiles of user personas from our generic user model, that represent real world users with some visual, cognitive or motor impairment conditions. In addition, our runtime UI framework with extensions for design time support tools comes with a set of generic UI components, with which the application developer can run simulations to test their performance against visual, cognitive and motor capabilities of different personas. This process occurs as follows:

1. based on an initial step at application design time in preparing content to be viewed by an end user performing an interaction task, the developer, can query the user model for the profile of a user persona with for example, a given level of visual impairment.
2. Using this profile information, runtime UI framework will select the set of UI components that can render application content in the modalities of that user persona.
3. In a next step, the runtime UI framework will use its simulation tool extension to predict the performance of the set of selected UI components on application content for that user persona's profile.
4. Finally in the last step, the application developer is able to decide if some form of adaptation is needed at the level of content preparation in order to accommodate special accessibility need of user with such impairments

In is worth noting that, this simulation process occurs in a close loop where the developer can set break points in analogy to operating in the debug mode.

By using the proposed "virtual user centered design" approach, we ensure that developers of ICT applications are able to overcome the challenges discussed in chapter 2. Specifically, this approach enables developers bypass time consuming and costly end user tests as well as bridges the knowledge gap on accessibility needs of elderly people or users with impairments.

4.2 Realizing Runtime Multimodal Adaptation

In the previous section we showed that a virtual user centered design approach can create awareness among ICT application developers, of special accessibility needs of elderly people. To address these needs in a real life setting where the elderly user is interacting with a application running on a set-top box or hybrid TV platform in the live room, our proposed development method and framework, must provide mechanisms for runtime multimodal adaption.

We make one underlying assumption: our baseline runtime UI framework provides generic interfaces for seamless connectivity and integration of multiple UI components and ICT applications on a set-top box or hybrid TV platform.

The transition from design time performance tests of UIs rending application content to runtime multimodal adaptation occurs through (1) a replacement model of virtual user profiles (personas) with real world elderly user profiles (2) additional adaptation measures taken by the developer on application content as a result of knowledge gained through user simulations at design time and (3) the runtime framework supports generic interactions and application logic, both of which are driven by the same user model employed at design time. Following these three points, a user profile of the elderly user is instantiated from the generic user model at runtime with initial parameters for adaptation. In addition, the application provides semantic annotations using accessibility standard guidelines such as [6] in describing needed adaptation measures identified during user simulations at design time. Finally the runtime UI framework must provide mechanisms for integrating the different levels of adaptation in a coherent way during user interaction with an ICT application.

5 Related Work

Our development method and concepts towards a virtual-user centered design framework as presented in this paper, takes into consideration an important research principle of re-use and extend rather than re-invent with new features of the state of the art. In particular, this work takes into consideration, promising state of the art runtime multimodal interaction UI frameworks such as the one presented in [16] that was developed in the context of reference architecture for Ambient Assisted Living (AAL) environments. The PERSONA UI framework as present in [16], is an open distributed runtime framework, designed for adaptive user interaction in AAL environments. It provides groundwork for adding engineering tools that extend the capabilities of such a runtime framework to accommodate design time development support and promote concepts of accessible UI design. Other UI frameworks like in [14], [15] provide the basic functions of a runtime multimodal UI framework, but are still based on device-based interoperability where requests are tightly-coupled with syntactic bindings such as with service interfaces in web services, thus making it difficult to realize runtime multimodal adaptation.

6 Initial Evaluation Results of Proposed Development Method

To verify the concepts presented in this paper on accessible UI design and a "virtual user centered" development approach, we carried out two empirical research investigations based on qualitative studies: (1) in an online survey and (2) in developer focus groups sessions.

The goal of the online survey was to gain feedback on current development practice in the industry, especially for the set-top box or hybrid TV platform providers and as well as accessibility demands for future accessible TV platforms. The online survey had 79 responses were received on line from 16 countries and 30 companies or institutions.

Results from the survey clearly show that the concept of virtual user centered design is new. Only 10 out of 79 respondents declared having used simulation tools realizing such a virtual user centered approach and thought, the simulation process must accompany the various design and validation cycles, whereby graphical user interfaces and input devices are considered as most important for simulation. They also observed that user testing is very time consuming and that using those tools would save much time during the application development. Nevertheless, attention must be paid to reliability of such simulation tools.

However regarding questions on runtime multimodal adaptation and the integration of accessibility features into ICT applications, the following results were obtained:

- There is a significant difference between the user interface technology developers (preferring automatic runtime multimodal adaptation (61.1%)) and the STB / TV connected manufacturers (preferring manual adaptation (83.3%)).
- An accessibility API managed by a user interface mark-up language is more preferred (rating 41%). This ratio is still higher among the STB / TV connected manufacturers (66.7%) and the software frameworks, middleware or tool developers (58.8%).

The focus group sessions offered the opportunity to better in-depth discuss some points needing clarifications or complete the analysis of the results.

Acknowledgments. This work was carried out within the framework of an EU-funded project under grant agreement # 248893.

7 Conclusions and Future Work

In this paper we propose a development method for accessible UI design and multimodal interaction through set-top box or hybrid TV platform. We identify common challenges facing ICT application developers in designing accessible UIs and applications. We propose a solution to this problem based on a virtual user centered design methodology, which allows developers to bypass time consuming and costly end user tests as well as bridges the knowledge gap on accessibility needs of elderly people or users with impairments. Our approach is based on adding extensions to an existing runtime UI framework such as [16] that allows for the integration of design time support tools such as a virtual user simulation tool. Finally we present a detailed development strategy that simplifies the UCD process and ensures runtime multimodal adaptation. Initial evaluation results of this development method and architecture show that the concept of virtual user centered design is new and not know in the industry, but respondents in a survey observed that user testing is very time consuming and that using our approach would save much time during the accessible UI and application development. Nevertheless, attention must be paid to the reliability of such a simulation tool. With regards to future work, we expect to realize a first reference implementation of this approach and report on the results in a subsequent publication.

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Modelling Cognitive Impairment to Improve Universal Access

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Abstract. The purpose of this study is to develop a model of cognitive impairment to help designers consider the range of issues which affect the lives of people living with such impairment. A series of interviews with experts of cognitive impairment was conducted to describe and assess the links between specific medical conditions, including learning disability, specific learning difficulties, autistic spectrum disorders, traumatic brain injury and schizophrenia, and the types of cognitive impairment associated with them. The results reveal some of the most prevalent and serious types of impairment, which – when transformed into design guidance – will help designers make mainstream products more inclusive also for people with cognitive impairment.

Keywords: Cognitive impairment, medical classification, functional capability, design guidance.

1 Introduction

Cognitive functions, the mental capacity which allows a person to process information, are the foundation for all human activities [1]. Consequently, any impairment involving these functions, including perception, attention, memory, language and thinking, has a profoundly detrimental effect on the overall functional capability of an individual [2]. Cognitive impairment is associated with many medical conditions; however, the same condition can cause diverse patterns of impairment in different individuals. Some medical conditions are static, others progressive, which adds to the difficulty of assessing their impact. In addition, the co-morbidity of certain medical conditions causes unexpected patterns of cognitive impairment. [3] With certain conditions, such as brain injury, the impact of the impairment depends entirely on the location and extent of brain damage [4]. Furthermore, the number of people living with cognitive disability is growing due to population ageing and the improved survival rates for trauma patients [4; 5]. Neuropsychiatric illnesses and traumatic brain injury are among the leading causes of disability [5]. All this leads to cognitive impairment being an intrinsically complex phenomenon, for which no simple solutions exist.

Considering the impact it has on an individual's capability to interact with his or her environment, cognitive impairment has not been adequately addressed in current research. Related research conducted in the field of assistive technology has given

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valuable insight into the design of devices for specific medical conditions and impairment types [e.g. 6; 7; 8]. There are also design guidelines which outline some general aspects of product usability, partly aimed at minimising the cognitive load to users [e.g. 9; 10; 11].

However, there is no systematic and comprehensive review of design issues relating to cognitive impairment. Assistive technology products tend to be developed for a very specific purpose and tailored to each individual, whereas design guidelines are often too general and fail to provide justification or deeper understanding of the needs of the people with cognitive impairment. In addition, it is not easy to estimate the number of people excluded from using a product, as there are no comprehensive statistical data available about the prevalence and incidence of cognitive impairment. In view of the complexity of issues involved and the growing number of people affected, more detailed information about cognitive impairment should be incorporated into the design process. Quantitative information about the prevalence and patterns of cognitive impairment as well as qualitative information about the practical implications of living with cognitive impairment are needed.

Inclusive design has become one of the key approaches of reducing the impact of disability following from impaired functional capability: it aims at minimising the number of people excluded from using a product by making products more accessible and easier to use [12]. Understanding users and knowing their needs and requirements is vitally important to the success of inclusive design [13]. As important as user involvement is in the design process, there are particular challenges when involving users with cognitive impairment. Designers need support if they are to make design inclusive of people with cognitive impairment. One way of supporting designers is to provide them with information that is accurate, relevant, offers them insight and inspiration and is presented in a way that makes it easy to apply. This paper reports the first steps of a study that seeks to develop a model of cognitive impairment providing such design guidance.

This paper is organised as follows: Firstly, a general framework for studying cognitive impairment is presented, followed by a brief description of the research method. Then the results of the study are presented. The paper concludes with a discussion of the work so far and the next steps of the research.

2 Framework for Studying Cognitive Impairment

This study aims to discover the particular needs and requirements of a person who has cognitive impairment limiting his or her ability to use a product. To this end, it is important to recognise the wide variety of cognitive impairment affecting the functional capability of an individual. Cognitive impairment can be diagnosed through the medical condition causing it. Therefore, building the link between medical conditions and cognitive functions they impair is essential.

In order to get a comprehensive view of the medical conditions with potential impact on cognitive capability, existing and established medical and disability classifications were used. Two widely used classifications, the International Classification of Diseases (ICD-10) [14] and the Diagnostic and Statistical Manual of Mental

Disorders (DSM-IV) [15], were used as the basis for developing the categorisation of medical conditions appropriate for this study. To systematically cover the wide variety of cognitive functions, the International Classification of Functioning, Disability and Health (ICF) [16] was used.

This framework consisting of categories of medical conditions and cognitive functions (see Table 1) was intended to work as a communication tool, translating the medical terminology and the neuropsychological approach to a format that is easier to understand outside medical context.

Table 1. Framework for studying cognitive impairment by linking medical conditions with the cognitive functions they typically impair

Medical condition	Perception	Attention	Memory	Thinking	Language	Learning	Psychomotor
Disorders of development							
Learning disability							
Autistic spectrum disorders							
Specific learning difficulties							
Cerebral palsy							
Degenerative diseases and ageing							
Ageing							
Alzheimer's disease							
Parkinson's disease							
Multiple sclerosis							
Acquired conditions							
Traumatic brain injury							
Stroke							
Mental illnesses							
Schizophrenia							
Depression							

The cognitive functions included in the framework are defined according to the International Classification of Functioning, Disability and Health (ICF) [16] (Table 2). ICF is a classification of human functioning and disability, and it covers body functions and structures and their impairments as well as the potential activity limitations and participation restrictions following from them [16].

Five of the medical conditions in the framework (Table 1) were covered in this first stage of the study.

Table 2. Definitions of cognitive functions included in the framework

Cognitive function	**Definition**
Perception, including visual auditory, visuospatial and tactile perception	Specific mental functions of recognizing and interpreting sensory stimuli
Attention, including sustaining, shifting and dividing attention	Specific mental functions of focusing on an external stimulus or internal experience for the required period of time
Memory, including short-term and long-term memory	Specific mental functions of registering and storing information and retrieving it as needed
Thinking, including abstraction, organisation and planning, time management and problem-solving	Specific mental functions required for complex goal-directed behaviours such as decision-making, abstract thinking, planning and deciding which behaviours are appropriate under what circumstances
Language, including reading, writing and calculation	Specific mental functions of recognizing and using signs, symbols and other components of a language
Learning, including learning to read, write and calculate and acquiring skills	Developing the competence to read written material, to produce symbols that represent words, to perform mathematical operations and learning purposeful actions
Psychomotor functions, including sequencing complex movements	Specific mental functions of control over both motor and psychological events at the body level

Learning disability (also called intellectual disability or mental retardation) affects 1 – 2.5 % of the population in the Western world. Certain medical conditions, such as Down's syndrome are common causes of learning disability. [17] Learning disability is not a medical condition as such but can be diagnosed based on three factors: 1) intelligence quotient (IQ) below 70; 2) impairment in adaptive behaviour and 3) onset during childhood [18].

Specific learning difficulties (SpLD) differ from learning disability in that they are not indicative of IQ. These learning difficulties include problems of reading (dyslexia), writing (dysgraphia), mathematics (dyscalculia) and motor skills (dyspraxia), which are not a result of poor education. [19; 20] There are no consistent estimates of the prevalence of SpLD but dyslexia in particular is considered fairly widespread, affecting 5 – 17.5 % of the population [21].

Autistic spectrum disorders, including autism and Asperger's syndrome, are developmental conditions characterised by deficits in social interaction and communication and repetitive patterns of behaviour [22]. Prevalence estimates vary depending on the definition but when considering the whole spectrum, approximately 60 per 10 000 children are affected [23].

Traumatic brain injury (TBI) is the leading cause of death and disability in younger age groups, particularly due to motor vehicle accidents, combat wounds and sports injuries; in older age groups, TBI is most often caused by falls [24; 25]. Although TBI can cause deficits in almost any brain function, impairment in cognitive control functions appear to be common [25]. In the UK, 135 000 people live with long-term problems caused by brain injury [26].

Schizophrenia is an illness of mental health which affects about 1 % of the population [27]. It is among the leading causes of long-term disability worldwide [28]. It is characterised by psychotic symptoms, such as delusions and hallucinations, negative symptoms such as apathy, and impairment in attention, memory, learning and other cognitive functions [27].

3 Method

A series of expert interviews was conducted in order to learn more about the medical conditions and the types of cognitive impairment associated with them. Using the framework described above, each of the interviews focused on one medical condition and the interviewee was a medical professional working with people who have been diagnosed with the condition. Each interview lasted between 45 minutes and 2 hours and was recorded and transcribed. Each interview consisted of three parts:

1. A semi-structured part where the interviewee was asked about the general aspects of the medical condition they specialised in, the nature of their work in the area and their definition and characterisation of the medical condition in question.
2. A semi-structured part where the interviewee was asked to describe a typical case. They were prompted to think of a person they work with or imagine a person who is in some way characteristic of the medical condition. The interviewee was asked to describe a typical day in the life of the person, their background and any particular problems they might encounter due to their impairment.
3. A structured part where the interviewee was asked to fill in an assessment form in which they evaluated how significant each cognitive function is in causing functional impairment. The assessment was made on a 5-point scale, ranging from '1 = Not significant' to '5 = Very significant'.

4 Results

The types and severity of cognitive impairment associated with each medical condition vary widely (Fig. 1).

In learning disability, the most significant impairment is to thinking and learning functions. Specific mental functions most often affected are organisation, planning and problem solving. Impairment in these functions can cause difficulties in tasks that require an individual to identify relevant information, integrate separate pieces of information and to use the information to determine an appropriate course of action. Difficulties are exacerbated when there are conflicting pieces of information, as the process of developing a solution is impaired. Handling numerical information and understanding mathematical concepts is particularly difficult.

With specific learning difficulties, dyslexia in particular, mental functions most often impaired are associated with language and learning. Both receptive and expressive skills can be impaired, causing problems of both understanding and creating spoken or written messages. The processes of learning to read, write and calculate are consequently often slow and difficult. Problems occur when an individual is required to copy information or rehearse a sequence of information.

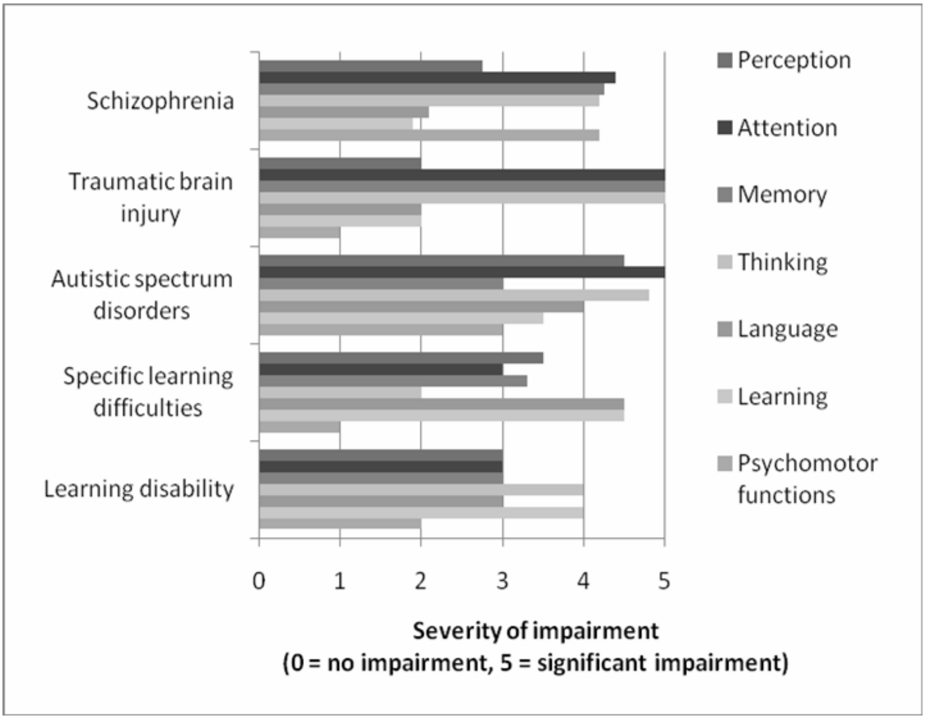

Fig. 1. The severity of cognitive impairment in certain medical conditions

Autistic spectrum disorders can cause impairment of any of the cognitive functions. Attention and thinking functions are often among the most significantly impaired areas. Particularly tasks that require cognitive flexibility, abstraction and judgement can cause difficulties. An individual might have problems in understanding the abstract general ideas and qualities that characterise concrete, specific objects. They might find it difficult to solve problems that require changing strategies and evaluating different options. They might also have additional problems with language and their sensitivity to certain perceptual stimuli, particularly auditory and tactile, can be either heightened or diminished.

The types of impairment caused by traumatic brain injury depend on the location and extent of the injury. Generally, the mental functions affected include attention, memory and thinking. An individual might have difficulties in concentration and short-term memory. Thinking impairment might present itself through difficulties of problem solving, decision making and time management. They might find it difficult to discriminate between options to form an opinion and assess the circumstances to make an appropriate judgement.

Schizophrenia is often associated with impairment in thinking functions, particularly organisation and planning. Thinking impairment can also manifest as a problem of insight, resulting in a poor awareness and understanding of oneself and one's behaviour. Particularly tasks that require sustaining attention for longer periods of time or dividing attention between several stimuli can cause difficulties. Long-term memory might be impaired and the process of retrieving items stored in memory can be problematic. For a significant number of people with schizophrenia, psychomotor problems are significant. This type of impairment generally causes difficulties when an individual is required to control the speed of behaviour or to sequence complex movements.

A summary of the results is presented in Table 3.

5 Discussion

A preliminary analysis of the results reveals that although the patterns of cognitive impairment associated with the medical conditions vary widely, certain types of impairment are more significant than others. Thinking impairment is particularly important, as it is common in many of the medical conditions and causes severe problems in planning, judgement, problem-solving and decision-making. This leads to difficulties in tasks that require an individual to identify relevant information, integrate separate pieces of information and to use the information to determine an appropriate course of action. The individual might find it difficult to solve problems that require evaluating different options and to assess circumstances to make a decision.

Issues such as these can be addressed in the design of products. The goal of this research is to develop a model describing cognitive impairment and its implications for product design. Ultimately, the model would help designers understand users with cognitive impairment. Based on this understanding, they would be able to make informed design decisions, such as identifying potential problems and estimating the number of users excluded because of too demanding design solutions.

The results reported here are based on a preliminary study, and the limited number of interviews might restrict the applicability of the results. Future research will address these issues and a prototype of the model will be tested with designers to ensure its relevance and applicability. When complete, the model of cognitive impairment could provide designers with an understanding of the needs and requirements related to cognitive impairment. The model cannot replace direct contact with actual users but it will help designers understand them, overcome some of the problems related to special populations as design partners, and enhance the eventual interaction with the end-users by providing designers with background information about their needs and requirements. Knowing more about people with cognitive impairment might also help designers to make necessary adaptations to traditional methods and techniques of user research so that they are able to involve cognitively impaired participants in the design process.

Regardless of the complexity of the issues or the limitations of the current study, this is a topic that should be addressed: people with cognitive impairment have needs that designers should be aware of. When provided with the required knowledge and tools, designers will have the ability to help people with cognitive impairment participate as equals in a society which depends on the information processing capability of its members.

Table 3. Summary of the results: typical impairment associated with each medical condition

Medical condition	Characteristic impairment
Learning disability	— Organisation and planning, identifying relevant information to determine appropriate actions — Solving problems, analysing conflicting information — Learning to read and write — Understanding numerical information
Specific learning difficulties	— Understanding and creating spoken or written messages — Expressing ideas in a coherent manner — Learning to read, write and calculate — Copying or rehearsing information — Additional problems of visual and auditory perception, attention and short-term memory
Autistic spectrum disorders	— Understanding abstract concepts — Difficulties in evaluating options and changing strategies to solve problems — Impaired language skills — Heightened or diminished sensitivity to certain stimuli
Traumatic brain injury	— Difficulties in focusing and sustaining attention — Impaired short-term memory — Problems of decision-making, problem-solving and time management — Impaired judgement of options and circumstances
Schizophrenia	— Problems of organisation and planning — Poor awareness and understanding of oneself and one's behaviour — Difficulties in sustaining and dividing attention — Retrieving items from long-term memory — Controlling the speed of behaviour and the sequence of movements

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Integrating Human Modeling and Simulation with the Persona Method

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Abstract. This paper proposes a method to integrate human modeling and simulation with the persona method to efficiently predict human behavior with different personalities in a variety of situations. We have applied the method to predict residents' behavior in an emergency situation to design emergency announcement strategies and have confirmed that this method can semi-automatically construct several different personas and their behavior scenarios successfully. The method provides a systematic procedure for creating personas and is expected to reduce time and cost in the design process.

Keywords: Human modeling and simulation, persona method, user scenario, emergency announcement.

1 Introduction

Human modeling and simulation is an effective method for predicting human behavior under various parameter settings and for finding potential problems from the results without costly and time-consuming user tests and experiments. To date, in HCI studies there are many good examples of simulation studies based on a human model, such as the estimation of users' reaction times through simulation with Card's information processing model (Cards 1983), prediction of users' reactions as well as human errors by ACT-R based simulations (Anderson 1998). One of the limitations of this approach, however, is that it is difficult to validate the results, owing to the difficulty of obtaining sufficient corresponding actual data for comparison. Another limitation is that parameter tuning to represent personal differences or personalities is relatively arbitrary. It is therefore, not reliable to use human modeling and simulation to predict human behavior in contexts where these limitations are critical and not insubstantial. Another approach to predicting human behavior for HCI design or product design is the persona method. Personas are fictional characters created to represent the different user types within the targeted user groups. These characters are usually described with a few demographic details and a 1-2 page user scenario that includes behavior patterns, goals, skills, attitudes, and the environment. Personas help design team members share a particular image of the target users and promote simulation of user behaviors and their needs. Many man-hours, however, are required to create a persona, particularly to produce a user scenario that gives a typical but virtual context for estimating user behavior. In this paper, we propose a method that combines the above two methods to compensate for the limitations of each. We have applied the method to the creation of

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personas to predict residents' behavior in an emergency situation to design emergency announcement strategies.

In the next section, we explain how these two approaches are integrated, while in Section 3, we present the details of the human model used in the case study. In Section 4, we introduce an example of applying the method to the design of an emergency announcement strategy. A discussion and our conclusions are presented in Section 5.

2 The Proposed Method

An overview of the proposed method is illustrated in Fig. 1. The upper process corresponds to human modeling and simulation, while the lower one corresponds to the persona method. The intermediate outputs from each process are used to integrate these two processes. The proposed method follows the steps given below.

1. Define target user groups based on the survey data and create skeletons and detailed user profiles. This is the initial step in the persona method. In this step, the human model can be used to describe the skeletons, i.e., the model provides the vocabulary for this process.
2. Develop a human model to describe and explain target human behaviors, which is a typical human modeling process.
3. Set model parameters based on the user profiles. In most human models, the parameter set is arbitrary; any combination of parameters can be tested, but there are no good guidelines for setting appropriate parameters to represent specific user characteristics. The target groups with demographic details help determine these parameters.
4. Run the simulation with the parameter sets and obtain time-series behaviors of the output parameters. In most simulation studies, we usually analyze and discuss this result to predict human behavior. However, as mentioned in the previous section, in

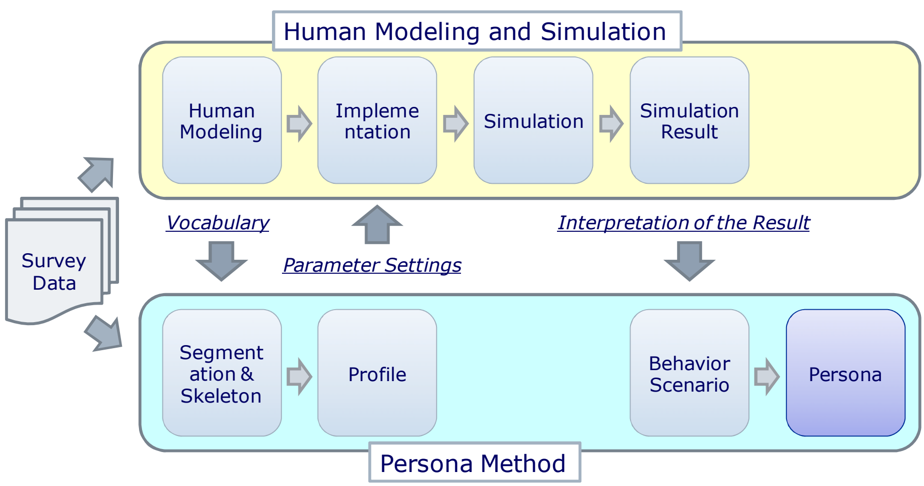


Fig. 1. Overview of the proposed method

some cases it is difficult to validate the simulation result, and thus, the reliability of such predictions may be lowered.

5. Interpret the result and give a narrative explanation of the simulation result considering both the time-series behavior of the result and the environmental assumptions of the simulation. In the persona method, we need to create a user scenario that describes typical behavior patterns, goals, skills, attitudes, and the environment to make the persona a more realistic character. This requires many man-hours and skills. The interpretations are semi-automatically generated according to a guideline, which becomes a user scenario.
6. Complete a persona. Because human modeling and simulation are only used to generate user scenarios to stimulate the imagination, and not to make critical decisions, we can use the method even if it is not totally reliable.

3 Model of Residents' Behavior in a Disaster

In this study, we applied the proposed method to the design of an emergency announcement system that considers a variety of residents' characteristics. In our previous study, we developed a model for the residents' decision making process in the event of a nuclear accident and confirmed that the model and simulation could clearly explain the residents' responses in an actual disaster (Kanno, Shimizu and Furuta 2006). We used an extended version of this resident model for the case study. This section explains the details of this model.

3.1 The Qualitative Model

Fig. 2 shows an overview of the model. This model consists of the process of establishing residents' behaviors, together with the influencing factors and their effects on the process extracted from the case analyses.

We modeled the process on a conventional stimulus–organism–response (S–O–R) model for human information processing (Woodworth 1958). The first step ("S") includes the process of obtaining relevant information from the environment, media, and other sources. Comprehending the information and judging its trustworthiness is also carried out in this step. Then, based on the information obtained, recognition of the current situation, particularly the recognition of danger, the need for action, or fear, occurs in the "O" step. Based on the results of the previous two steps, decisions as to whether or not one should take some concrete action are made in this step ("R"). Various influencing factors on these steps such as the attributes of the information, characteristics of residents, and environmental conditions have also been reported.

3.2 Implementation with Bayesian Belief Network

An extended version of the previous simulation model is used in this study. The main part of the previous model was implemented with a Bayesian belief network (BBN) shown in Fig. 3. This BBN corresponds to the information input and situation judgment process and outputs the probabilities of the nodes. The probabilities of the symptom nodes in this BBN represent the status of "with" or "without" information about the content provided by the various information media. In our design the evidence value is gradually increased with the times of acquisition to represent the qualitative influence of the amount of information. The previous model introduced an attention and an action barrier to represent, respectively, the difficulties in information acquisition and hesitations in action. Both work as the thresholds for information acquisition and action execution.

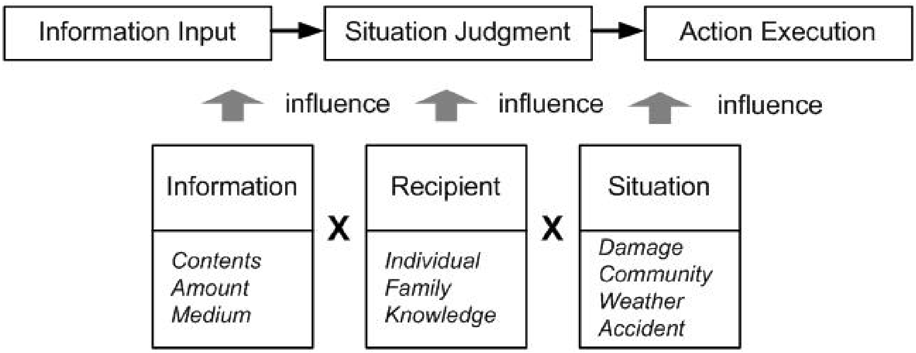


Fig. 2. Qualitative model for resident response

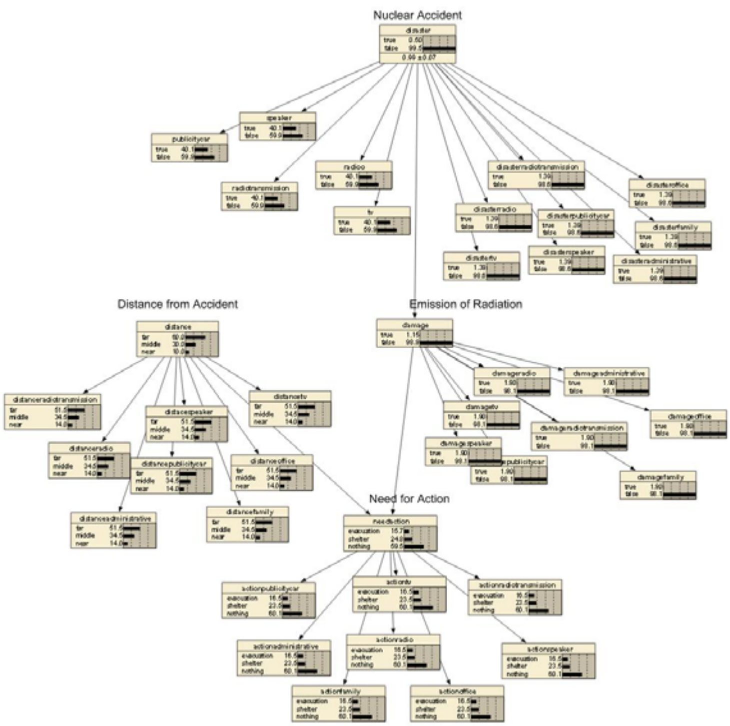


Fig. 3. Bayesian network for situation assessment

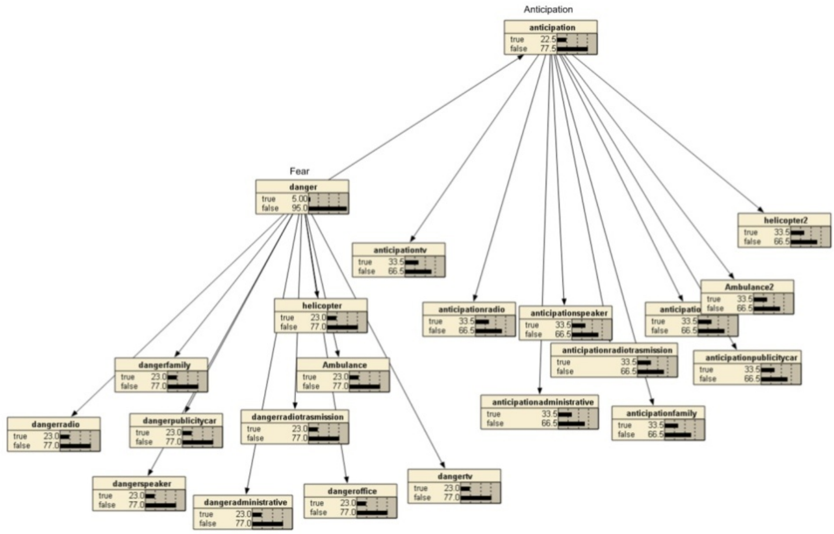


Fig. 4. Bayesian network for fear and anticipation

Based on the previous model, in this study we also considered the effects of fear and anticipation in an emergency. The causal network underlying such mental status triggered by the information obtained from the environment, mass media, and other sources, was implemented with a separate BBN as shown in Fig. 4. The probabilities of the symptom nodes in this network also represent the status of "with" or "without" information about the content provided by various information media. The belief probabilities of these symptom nodes are propagated and the network outputs the belief probability of the node for "Fear" and "Anticipation". This value affects the sensitivity to new information in the first BBN. That is, if the probability increases/decreases, then a resident is becoming more/less sensitive to new information from the environment, mass-media, or other sources. This value also affects the value of "Need for Action" as shown in Table 2. Whether a resident will take an action is determined by the corrected value (P') of the node "Need for Action". The coefficients used in this study are given in Table 2. P' is calculated by multiplying these coefficients and then normalizing for comparison with the threshold (the action barrier) for each action to determine whether he/she carries out the action.

4 Case Study

We applied the proposed method to the design of an emergency announcement system that considers various residents' characteristics in the event of a nuclear accident. First, by reviewing the reports and journal papers about the residents' behavior in the JCO criticality accident in 1999 in Japan (Furuta et al., 2000; Umemoto et al., 2000), we selected several important characteristics of residents and their behavior. Then, we set the target group as those who did not adopt a quick and appropriate response in the accident, and developed further categories for these residents as shown in Table 1.

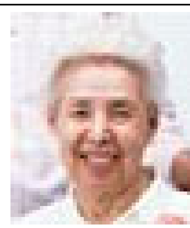
Table 1. Key characteristics of the target groups

Characteristics	Explanation
Older people	• They often have trouble in hearing public announcements. • They have some physical problems.
Male/Female	• Males in general are relatively insensitive.
Possessing fixed assets	• They are often reluctant to evacuate because of their assets.
Adverse effect of disaster experience	• Cry-wolf syndrome.

4.1 Resident Profile and Parameter Settings

We created five skeletons and their detailed profiles based on a combination of the above five characteristics. Fig. 5 presents an example of a resident profile with all five characteristics; this persona is that of an old female who owns fixed assets (a farm and crops). From past experience, she distrusts public emergency announcements. Based on this detailed profile and the parameters shown in Table 2, the BBN resident model of this persona is constructed.

Name Kaori Ayase (Female)
Address Tokai-mura village Ibaraki Pref
Age 80
Family husband(live with) two sons (not live with)
Hobby Cooking
Personality Cheerful and extrovert



Profile
Kaori Ayase is 80 years old and lives with her husband They are happily married Her personality is very cheerful and extrovert She and her husband run a farm and she usually works on the farm during the day She loves the farm and crops as her children She is in good health but she has a pain in her back and knee after her many years of farming She believes that public announcements about disasters are always nothing to be alarmed about

Fig. 5. Profile of a persona

4.2 Simulation Results and a Scenario Guideline

We used the same input messages (announcements) as in the previous study (Kanno, Shimizu and Furuta, 2006), which were made based on the actual announcements broadcast by governmental agencies or the mass media during the JCO accident. Each announcement is written in XML format and contains information about the content, medium used, and the time when it is announced. Resident agents receive the announcement if they are paying sufficient attention as well as satisfying physical and spatial conditions. After receiving the announcement, the resident agents update the probabilities of the BBN and proceed to situation judgment and action execution if

Table 2. Coefficients of Actions

category	evacuate	shelter	nothing
With Assets	0.7	0.9	1.3
Without Assets	1	1	1
Age over 80	0.6	1.2	1.4
Age under 80	1	1	1
Male	0.8	0.9	1.2
Female	1	1	1
Anticipation (*p*)	if *p* > 0.65 then 2 else 0.05	if *p* > 0.65 then 2 else 0.05	if *p* > 0.65 then 2 else 0.05

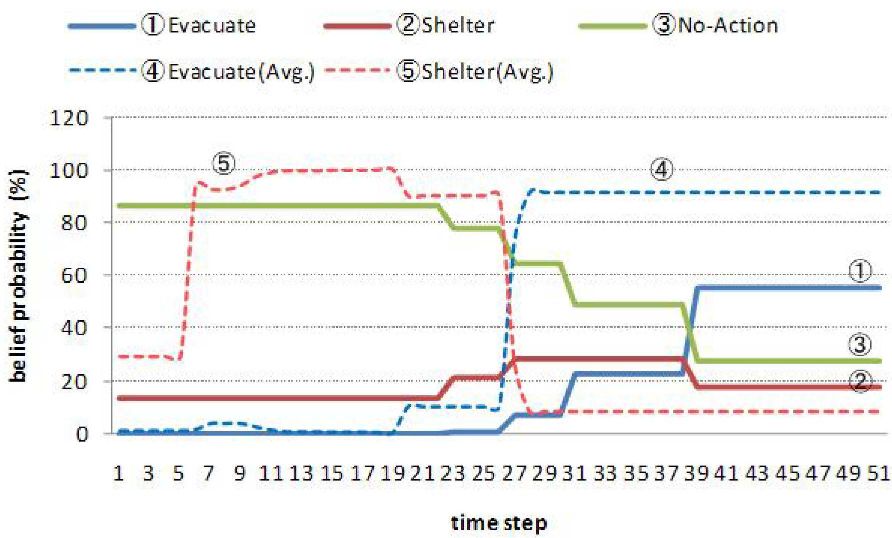


Fig. 6. Simulation Results

necessary. In this simulation, the set of announcements during an emergency is the input, and the time-series behavior of the values of each agent's BBN is the output.

Fig. 6 shows transitions in belief of "Need for Action" nodes. The dashed lines represent the action of a normal persona who decides to evacuate after the announcement around the 25th step, while the solid line represents that of the target persona. As shown in Fig. 6, the persona developed a competing but lower value for the belief probability between ''Shelter'' and ''Evacuate'' after the announcements and consequently did not take either action. The result contains rich data not only about situations and events happening in the simulation, but also about a persona's cognitive status such as attention, information acquisition, situation assessment, and action execution, and thus the analysis of these results can create a detailed story about Kaori Ayase during the accident.

Table 3. Example of the Scenario Guide

Observed Event	Reason	Interpretation
could not obtain information	lack of attention	• did not hear an announcement because he/she was at home • not paying much attention to it
	did not watch/listen	• because he/she did not watch tv or listen to the radio
	weak hearing	• because he/she has weak hearing
	working	• not aware of the information because he/she was working hard
did not evacuate	a farmer	• because he/she was worried about his/her farm and crops
	a fisherman	• because he/she was worried about his/her fishing boat
	adverse effect of disaster experience	• because he/she distrusts public announcements • because he/she remembers a similar situation that turned out to be a false announcement
	male	• because he is somewhat obtuse

Kaori Ayase was working on the farm with her husband. She saw an ambulance passing by at the bottom of the farm, but she continued working without paying much attention to it. After a while, she heard a public announcement over a speaker, but she could not understand the content because she was hard at work and she has weak hearing. Because the announcement was repeated several times, she only gradually became aware of it, and therefore paid a little attention to it. After a while, she eventually realized that the announcement was informing her of an accident at a nuclear facility not far from their farm. But because she did not know about the facility and considered the accident to be insignificant, she continued working. At 15:30, she noticed a public announcement car calling for an evacuation, but initially she did not believe it. At 15:47, she heard an announcement calling for an evacuation from the speaker, but she was still reluctant to follow it because she remembered a similar incident in the past that turned out to be a false report. About 1 hour later, her husband prompted her to evacuate, but she insisted on staying there because she was worried about their farm and crops.

Fig. 7. A Resident Scenario

To interpret the simulation results easily and create a resident scenario, we developed a list, as shown in Table 3, of partial narrative scenarios that explain excerpts of a simulation result in terms of the model and parameters. The leftmost column represents possible events we can find in a simulation result while the center column represents influencing factors on those events. Narrative scenarios for an observed event considering the influencing factor are listed in the rightmost column. By analyzing the result and consulting this list, resident scenarios can be semi-automatically created.

4.3 Results

Fig. 7 gives the resident scenario for Kaori Ayase created by the proposed method. The parts underlined with a dashed line correspond to the descriptions based on the profile. Those with a solid single underline correspond to the interpretations of the simulation result concerning situations and events, and those with a solid double underline correspond to the interpretation of the cognitive aspects of the results. For example, the first sentence comes from her profile, while the second describes the announcement in the simulation configured in the input data. The third sentence describes the behavior of the value of a symptom node after the announcement.

5 Discussion and Conclusions

We proposed a method to integrate human modeling and simulation with the persona method for efficient prediction of human behavior with different personalities in various circumstances. Through the case study, we confirmed that the resident scenarios are not inconsistent with the survey data and the insight obtained from empirical knowledge and thus the proposed method is applicable for creating personas for the design of an emergency announcement system. Moreover, creating a resident scenario from the simulations results was relatively easier and required fewer man-hours than the standard process based on the creator's imagination.

One of the disadvantages of such human modeling and simulation as used in this study is that it is virtually impossible to validate the results, owing to the lack of actual data for comparison purposes. It is, therefore, difficult to apply this method directly to predict human behavior in serious issues, such as those presented in the case study that require critical decision making. However, since the proposed method uses the simulation as a means to create a resident scenario for a persona, the disadvantage becomes less critical. In other words, because a persona aims to stimulate the designer's imagination to predict human behavior and to find potential problems, a resident scenario is not required to be highly reliable. In this sense, the proposed method is an example of using less reliable human modeling and simulation for a real-life practical problem.

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User Modeling through Unconscious Interaction with Smart Shop

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Abstract. Ubiquitous, mobile and wearable networks unified on the internet are rapidly promoted and introduced into our daily living sphere. That means people, unfamiliar to information technology and human computer interaction issue, are becoming a large part of the users of the unified information environment. Thus we need a new concept of information environment design which does not force a person to have and use any computer skills. Such an information environment would provide modest and human friendly manner for users including elderly people.

This paper introduces a concept of Kansei modeling from the aspects of users' needs in information service. To show its attractive facilities, this paper describes the state of the art of our studies on personal information assistance service in a smart space, such as ubiquitous and wearable environment with robotic information processing mechanism.

Keywords: Kansei Engineering, Kansei Modeling, Behavior Log and Analysis, Smart Shop.

1 Introduction

Ubiquitous, mobile and wearable net-works unified on the internet are rapidly promoted and introduced into our daily living sphere. That means people, unfamiliar to information technology and human computer interaction issue, are becoming a large part of the users of the unified information environment. Thus we need a new concept of information environment design which does not force a person to have and use any computer skills. Such an information environment would provide modest and human friendly manner for users including elderly people.

This paper introduces a concept of KANSEI modeling from the aspects of users' needs in information service in Chapter 2. To show its attractive facilities, this paper describes the state of the art of our studies on personal information assistance service in ubiquitous and wearable environment, in Chapter 3 and 4, respectively.

2 Kansei Modeling

Subjective feature of each user's requirement in information service can be schematically summarized as following [1];

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(1) Intuitive perception process of objects: A user may receive some impressions viewing objects. We assume such a process as physical, physiological, psychological and cognitive levels of interpretation. In this process, a portion of the graphical features of an object, such as its colors and their combination, textures and shape, is a dominant factor in his intuitive perception. We can statistically model these relationships between some graphical features of objects and their interpretations [2], [3].

(2) Subjective interpretation of situations: A user may show his intentional choice of assistance services according to his situation, such as time, place and occasion. Even if people physically sharing the same time, place, and occasion, each of them may expect to receive different assist according to his life style. We assume such a process as physical, bottom-up multiple interpretation and top-down service-based levels of interpretation. We can model these relation-ships by statistical behavior log analysis.

(3) Knowledge structure of service domain: Novice users may only have restricted knowledge on a service domain, while the others have much and well organized. Such a difference means each user is expecting his own answer according to his knowledge base in his mind. We can formalize this kind of knowledge structure as ontology. We are also relating subjective concepts on feeling with some graphical features of objects.

(4) Feature of behavior pattern: A user often shows some specific behavior unconsciously according to his interest on something; for instance, if he is interested in some goods, he often watches, touches and grasps them unconsciously to have a closer look at them. Thus, we can statistically analyze a degree of interest on objects by each person's behavior log [4], [5], [6].

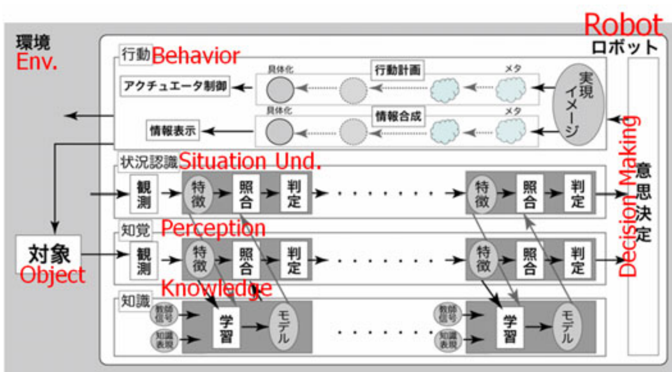

Fig. 1. Schematic model of KANSEI [1]

(5) Tendency of decision making process: A person often makes his own decision pattern according to his view of life, which is originate from his intuitive perception process of objects and subjective interpretation process of situations, which is compared with his knowledge base in his mind, and which cause the difference in his behavior pattern in taking an action.

We can schematically summarize such relationships as shown in Figure 1.

3 Personal Assistance Service Using Ubiquitous Environment

3.1 Kansei Modeling on Personal Preferences: Smart Sphere

Current personal information services highly depend on registered preferring items which are referred as a template of the user's model. Such systems force their users to answer a huge number of questionnaires to describe the individual preferences. It is a bottleneck in modeling.

Our basic ideas are (1) to find user's interested and / or preferred items through observation on his behaviors in ubiquitous information environment, (2) to automatically build his preference model, and (3) to apply the model to provide suitable information service in the real world.

Microscopic, mezzoscopic and macroscopic observation. Utilizing ubiquitous sensors, we apply three types observation methods to modeling each user's preferences, which are microscopic, mezzoscopic and macroscopic observation methods as shown in Figure 2.

(A) Microscopic view identifies a user by his RFID name tag as well as detects eye tracks by his facial image and some handling motions on some item by locally equipped cameras.

(B) Macroscopic view covers a location of each person in a room by a matrix of global view cameras equipped on the ceiling. It also covers the overall spatial allocation and density of the people as well as the items in the room.

(C) Mezzoscopic view extracts and traces each person's locations and behaviors as time series data both from microscopic and macroscopic views. It also manages personal behavior log database.

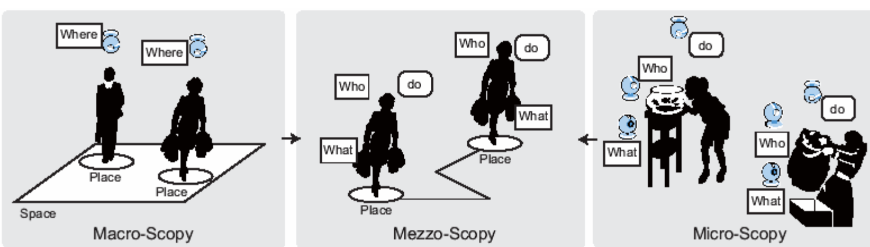

Fig. 2. Microscopic, mezzoscopic and macroscopic views

Indirect interaction in active observation. To enforce answering a huge number of questionnaires on users is a bottleneck in modeling personal preferences. One idea is just taking their behavior log via ubiquitous sensors without asking them, and mining some specific features by statistical analysis. Such a method is called passive observation. The problem of this method is to require long time and huge personal log to cover enough behavior data.

Our idea is to show several messages to each user, i.e., applying active observation, without expecting direct answers. If a message is informative and interesting to a user, he may pay attention, gaze, and follow the suggestion according to the message. In this process he is freely behaving by his intention without feeling any enforcement to answer to the system. In this case, monitoring each user's behavior, i.e., responses to the messages, via ubiquitous sensors enables to attain enough behavior data effectively. This method corresponds to indirect interaction in active observation. The system can throw suitable and controlled messages to a user to build up his precise preference model without putting any stress on him. Thus, the system can statistically analyze a degree of interest on objects by each person's behavior log effectively without a huge number of questionnaires.

3.2 Experimental Prototype: Smart Shop

In the business field, finding consumers' preferences is an important issue. Point of sales systems are popularly used to detect the current consumers' preferences as well as store management.

We have been developing an experimental prototype system, Smart Shop, as an application of personal information assistance in shopping context.

(1) Microscopic view devices: Each shelf is equipped with (a) an RFID tag reader to identify each consumer around there, (b) a facial camera to detect his face direction, (c) several item cameras to detect his behaviors related to the items, such as touching, grasping and wearing, and (d) several LCD monitors to show personal messages to him as well as to show public messages to the consumers.

(2) Macroscopic view devices: The ceiling of the shop is equipped with camera array to cover whole area without occlusion to detect a location of each consumer at each time slice.

(3) Smart shop servers: We have three types of database servers; which are (a) microscopic information servers to detect each behavior of the customer by image processing with his customer-ID by an RFID reader at each shelf, (b) a macroscopic server to integrate location data of consumers' from camera array by image processing at each time slice, (c) a mezzoscopic server to integrate personal behavior log data from microscopic servers and macroscopic server and to manage the behavior log database, (d) a preference model server to statistically analyze each customer's preferences from each of his behavior logs and to manage preference model database, and (e) a recommendation server to assist a customer in shopping.

We can expect that the consumer's prefe-rence may appear his behavior; for instance, the order "grasp > touch > watch > ignore" shows his interest. Our assumption is that we can construct his preference model on items by behavior analysis.

Nevertheless we should note that we cannot directly estimate consumer's preference form a single behavior itself. It should be evaluated all through his behavior log. It is because "shopping style" is roughly classified into two types; direct shopping type and survey type. For the former type, even a single touch shows a strong interest, while for the latter, a single touch is just one of them.

The system functions are as following;

(1) If a customer comes to a shelf, its micro-scopic server is activated and senses his RFID to identify.

(2) If he is interested in an item, he may stay there for a while to watch. If he is more interested in it, he may also touch and grasp it to have a closer look at it. Such a sequence can be detected by the ubiquitous cameras in the space. Thus, his personal behavior log is accumulated into the smart shop personal behavior log database.

(3) By statistical analysis on the frequency and total elapsed time of watch, touch and grasp of each item, we can judge the shop-ping style and finally estimate the preference of the consumer on the items in the shop.

Through this process and iteration, the sys-tem can build up and update each customer's preference model without forcing him to answer huge questionnaires.

4 Personal Assistance Service Using Wearable Environment

4.1 Kansei Modeling on Subjective Interpretation of Personal Situation

Even if we have a specific personal preference model tuned for the user's perception process, a uniform service all through the day is insufficient. Even if some people physically sharing the same time, place, and occasion, each of them may also expect to receive different types of assistance. Each person may expect various types of information assistance suited to his situation, i.e., the time, place and occasion (Figure 3) [7], [8], [9].

We should consider such a situation is also subjectively interpreted by each person according to his context of the day as well as his life style. We assume such a process as physical, bottom-up multiple interpretation and top-down ser-vice-based levels of interpretation. We can model these relationships by statistically analyzing the relationships between the personal situation and behavior log.

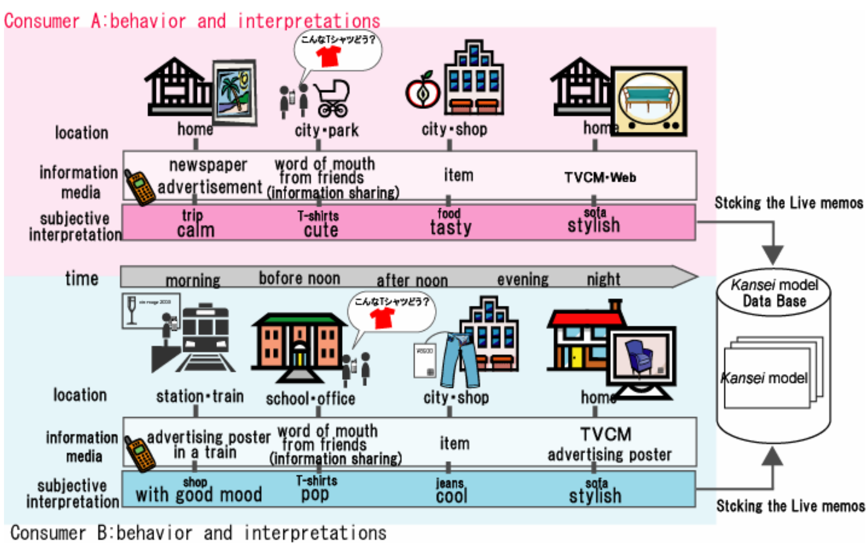

Fig. 3. Expected assistance in situation-based information service

4.2 Context of User's Situation

It is essential to understand the users themselves in order to provide in-formation services which can satisfy the requirements of users. This requires understanding the ordinary behavior of users. These are the behaviors users have performed so far (state transition) in usual locations (creating meaning of location) and what actions users may take in the future (behavior pattern).

These elements for judgment can be identified by making “multiple interpretations” in bottom-up process of the stored information which has been ac-cumulated by the ordinary actions of users as “history”. This means that one piece of location information can refer to a wider range of information. For example, the spot of “Shinjuku Station” is taken as “Shinjuku Ward” or as “Tokyo Metropolitan”. We should consider such a situation is also subjectively interpreted by each person according to his context of the day as well as his life style. We assume such a process as physical, bottom-up multiple interpretation and top-down service-based levels of interpretation. We can model these relationships by statistically analyzing the relationships between the personal situation and behavior log.

Assumption is made by selecting the interpretations suitable for users among these plural interpretations. It may be considered to be possible to assume the “action pattern” of users from the scored “location” and “time,” the “creating meaning of location” of users from scored “location” and “action,” and then the “state transition” of one day from scored “time” and “action.”

4.3 Sensing of the Behavior and Situation of Users by Wearable Sensors

It is essential to understand the users themselves in order to provide in-formation services which can satisfy the requirements of users. This requires understanding the ordinary behavior of users. These are the behaviors users have performed so far (state transition) in usual locations (creating meaning of location) and what actions users may take in the future (behavior pattern).

It is necessary to know the movement of users in order to assume the situation and the tasks of users. Then, we grasp the situation of users and their surroundings by the use of wearable sensors to provide the necessary information.

We adopted a GPS sensor as a location detector as well as out-door detector. In the former use, we attain user’s physical location, map location, and postal address to select suitable information from the database. In the latter use, we estimate inside or outside of a building to distinguish the purpose of moving.

We also adopted a three-axis acceleration sensor attached on a leg to detect the speed of the moving as well as the motion and pause of the user, e.g., running, walking, standing, sitting and standing in a lift, etc.

From the TPO sensors above, we collect “location information,” “time information” and “action information” which are taken to judge the tasks of the user at that moment. This “action information” consists of the plural pieces of sensor information, for example, which can assume a task such as “shopping” and a situation of “moving” “in doors” as summarized in Table 1.

4.4 Personal Assistance Service by Wearable HMD or Mobile Phone

As the display device of information, a constantly wearable see-through type small HMD was used for this study (Figure 4). This equipment is set on the edge of glasses and indicates the transmissible display in the low sight of vision. Recommended information can be browsed only by shifting the eye level to the low sight. Users may browse the distributed information easily.

Table 1. Example of Tasks on Holidays

	motionless	**moving**
indoors	during dinner movies on a break	shopping Visiting a museum moving to a destination
outdoors	on a break waiting	Walking moving to a destination

In our experiment, the information is selected from three categories, which are "during dinner," "shopping" and "playing" as listed in Figure 5. It can be selected per category by handling joystick-type interface. If one category is selected, three pieces of information are displayed, which are included in the category. By selecting a preferred piece of information, such detailed information can be browsed as shown in the center of Figure 5. Then, of the information, the evaluation can be made by the four steps of "will go," "may go," "not so much" and "of no interest" to get an instant survey of recommendation as shown in the right of Figure 5.

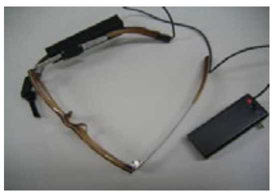

Fig. 4. Constantly wearable small see-through type HMD

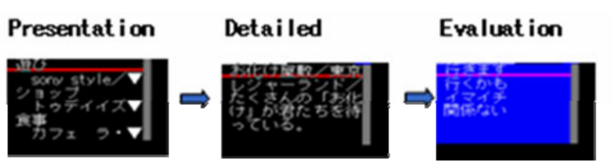

Fig. 5. Transition of HMD screen display

5 Summary

This paper proposed a concept of KANSEI modeling from the aspects of users' needs in information service. The key issue is to computationally describe human information processing process from these aspects; (1) intuitive perception process, (2) subjective interpretation of their situations, (3) knowledge structure of service domain, (4) feature of behavior pattern, and (5) decision making process. We should notice that these aspects are in the same framework of modeling in robotics field. This idea will be one of a fundamental concept for next generation information and communication environment, because the 21st century is an era for diversity as well as symbiosis among humans and artificial objects.

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Supporting Inclusive Design of User Interfaces with a Virtual User Model

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Abstract. The aim of *inclusive design* is to successfully integrate human factors in the product development process with the intention of making products accessible for the largest possible group of users. In order to meet this challenge, the involvement of human users has so far been an efficient approach. Yet, such ergonomics evaluation experiments that employ a versatility of user groups can be very time and cost-intensive. Therefore, *virtual user models* (VUM) have been proposed for supporting certain phases of the product development process. In this paper a *model-based design approach* is proposed, which supports inclusive design of physical user interfaces of consumer products at the early stages of product development. Accordingly the objective is to explore how virtual user models can be used to conceptualize user interfaces of consumer products in such a way that even the needs of users with physical impairments are fully considered.

Keywords: Inclusive Product Design, Virtual User Models, Product Development, Model-Based Design Approaches.

1 Introduction

Inclusive design is a process that results in inclusive products or environments which can be used by everyone regardless of age, gender or disability [1]. The main barriers for adopting inclusive product design include technical complexity, lack time cost-effectiveness, lack of knowledge and techniques, and lack of guidelines [2]. Although manufacturers of consumer products are meanwhile less reluctant to invest efforts in user experiments, consumer products nevertheless conditionally fulfil the accessibility requirements of users [3]. The reason is that product tests with users are usually done at a rather late stage of the product development process. Thus, the more progressed a product design has evolved - the more time-consuming and costly is an adaptation of the product design. Evaluating alternatives from an accessibility standpoint, when it is still relative inexpensive to change the design, can improve the accessibility features of the product [4]. As a consequence, there is a substantial demand for methods and

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tools which are capable of credibly replacing experiments with human users in the early product development phases.

One promising practice for realizing inclusive product design is to employ virtual user models (VUM). Virtual user models can be seen as an abstract representation of the simulated behaviour a human user. According to contemporary definitions, virtual user models are three-dimensional, model-like images of reality and usually contain the following functions: (1) Human body modelling and analysis (2) Animation of virtual users (3) Interaction of virtual users with virtual objects [5].

Nowadays virtual user models are utilized for ergonomic analysis in vehicle and workplace design within the automotive or aerospace industry. They are used to validate the design in a simulation environment, check in a loop if the design is suitable, refine it considering recommendations and best practices and finally, when found suitable produce a prototype to be checked by end users as shown in Fig. 1.

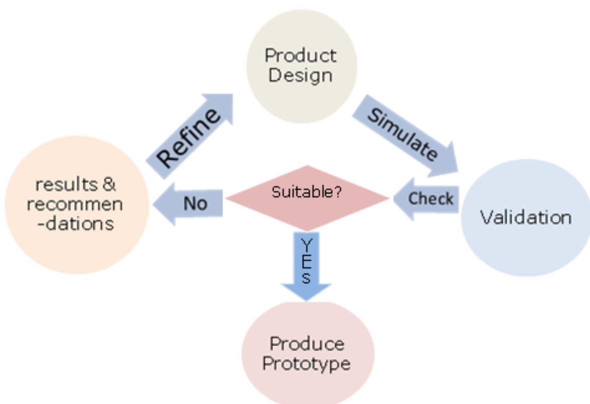

Fig. 1. General usage approach of virtual user models in inclusive product design [5]

More rarely are virtual user models applied in the evaluation of user interface designs of consumer products, and even less for usability and accessibility of consumer product's interfaces - although having similar objectives for inclusive design processes. For the specification phase static models of the user are applied, while during the design phase virtual user models of humans can have the notion of three-dimensional human models, in most cases incorporated as an enhancement of CAD applications (e.g. Human Builder for CATIA [6]). Despite the different approaches which involve virtual user models, only the approach of the so called *digital human models*, which are a sub-category of virtual user models, based on anthropometrical data are suitable for serious simulation and can meet the ambitious goals of the accessibility evaluation of user interfaces of consumer products at the early stage of the development process. However, there is neither a common framework, nor a common understanding of how elements involved in the creation, development, and interaction of virtual user features are done. As such the usage of virtual user models for a continuous support of specification, design and evaluation phases can therefore be considered as unique. Thus, contemporary approaches where virtual user models are utilized are only partially suitable for inclusive design.

2 Related Work in Virtual User Models

The first attempts to develop virtual user models began in the 1960's when the digitization of two-dimensional anthropometric models became available. In the early years and decades many research groups from industry as well from universities followed their own proprietary approaches, because the costs of the realization of such models were comparatively low. The concepts ranged from a representation of a human as simple composition polygonal main body of the modelling from many horizontal layers up to the representation of a variety of stapled balls. Further developments were mostly driven by specific requirements from the industry. The majority of these models were mainly developed for the areas of aerospace and design of airplanes, where training and experiments on real tasks were mostly expensive or impossible; therefore they had to be simulated and one element of such simulations were virtual user models. In the further course - mainly in the 1980s - the features of today's Human models became more mature. Some special solutions were used and improved others were just redesigned, but the actual human models have been more versatile and comprehensive in their functions. This led to the fact that the number of models has decreased, because the effort to create new models has become much more complicated [7].

User modelling on the other hand is an established area of HCI (Human-Computer Interaction). However, most of the conventional user models do not consider possibilities of unexpected error modes or influences of body shapes and movements of users. The scope of usability assessments also tends to ignore spatial relationships between users and objects of their environment. Furthermore, user models have been implemented by proprietary infrastructures to manage and query their respective models. These models are in the first place complex data structures revealing many similarities to VUMs in the way they are structured, managed and how they are consumed by services.

Virtual users have also been suggested for testing, such as trying the capacity of search engines or other interactive web applications in handling different cases, but also mass usage and scalability. This approach was practiced already over 20 years ago [8], and still is being used [9]. Yet these approaches do not require individual virtual entities, but can work on statistical models, for instance. Toru Nakata, et al reported of a virtual user prototype that simulates human machine interaction including errors in body actions and mistakes in cognitive decision, they used it for simulation of a car driver, the virtual user model generates human-like body movements and error escalations in cognitive process [5]. In this respect, many important software models were created such as *Anthropos BoeMan* (1969), *CyberMan* (1988), *Franky* (1988), *CombiMan* (1988), *ERGOMan* (1988), *TEMPUS* (1988), *CrewChief* (1990), *ErgoMAX* (1998), *Ergo* (1998) *or Safework* (Safework 2000). Many of these models were developed as standalone models or were partially merged or integrated into other models.

3 Towards a Model-Based Approach for Inclusive Design of User Interfaces

3.1 Conceptualization of the VUM

Since a virtual user model as an abstract representation of an envisaged user group which includes a description of the underlying context, it is legitimate to consider the

VUM as a *context model*. Context represents on a universal scale, the relevant aspects of the situations of the user groups [10]. Hence, a context model describes the characteristics, features, and behaviour of a specific user group. Complementarily it also includes the aspects related to the tasks, interactions, user interface, and the environment, where she or he interacts with consumer products as highlighted in Fig. 2.

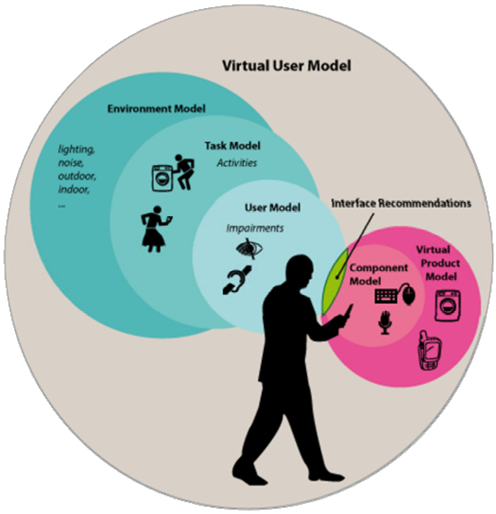

Fig. 2. Aspects of a Virtual User Model (VUM)

Accordingly, the VUM as proposed in this paper possesses different facets for supporting the development process. Fig. 3 provides an overview of the underlying concept emphasizing the interplay between the virtual and real world. The virtual user model is based upon real-time accessibility needs of the envisaged end user groups. In the virtual world the VUM interacts with the specification, design and evaluation phase of a product. It is foreseen that the support by the VUM works in the following way: In the initial specification phase, a support appears in form of text-based recommendations with respect to potential user interface elements. In the design phase the VUM will guide the designer with templates and design patterns for interaction components of consumer products. For the evaluation phase, a 3D virtual character in a virtual environment will be established in order to evaluate a conducted product design against predefined usage scenarios. After several iterative development cycles, the results are then used for realization of a physical prototype and final product in the real world.

In summary, the VUM approach should go beyond existing approaches by:

- Accompanying the design process from the scratch until the final CAD design cycle, by providing different standalone recommendation systems for the idea finding stage, the sketch phase and components for integration with CAD systems,
- Incorporating different accessibility features in the user profiles,

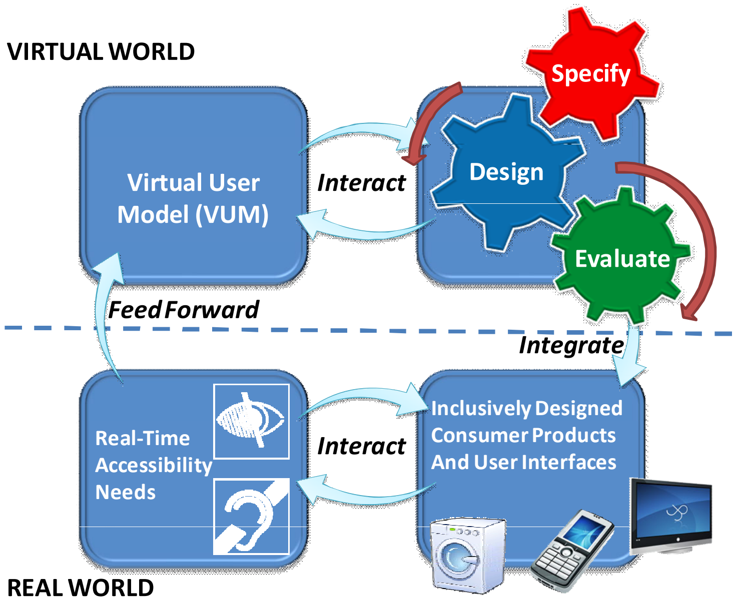

Fig. 3. Overview of the Approach

- Adding new reporting mechanisms e.g. web based reports and visual responses in the virtual user itself.

As an example, a designer is planning to design a new product such as a mobile phone would like to incorporate accessibility features into the future mobile phone. The designer invokes the recommendation system, selects from the device list "mobile phone" and configures from the "target user group" the target user group. Based on the entered information the system lookups into its repositories and displays for him a list of existing use cases and additionally links to existing guidelines. In the further course the designer makes a scratch layout of the future mobile phone, saves it and imports it to the recommendation system. The system then displays more accurate recommendations dedicated to the scratch layout and the selected target user group.

The other component required is a *3D virtual user system*, which allows either the development of CAD designs or the import of CAD designs into it and provides analysis tools. It will allow the assignment of tasks to the virtual user. An execution procedure reports the results visually to the designer.

3.2 Implementation of the VUM

It is compulsory that the VUM should possess the capability of determining guidelines and recommendations of appropriate interaction components for a consumer product. Therefore, the VUM should incorporate appropriate partial models which incorporate the context to determine proper recommendations. A suitable taxonomy for the VUM may consist of at least of the following sub-models:

- **User Model**, where all information about a Virtual User such as physical impairments or diseases are stored. User Models could be divided into several subgroups (Profiles), where for every criterion the profiles are divided into different levels of impairments. Additionally there are mixed profiles describing the group of elderly people suffering upon a mixture of hearing, sight and dexterity impairments. **Component Model,** where pre-defined hardware components are stored (e.g. coloured buttons, visual display, etc.), which will be presented as recommendations.
- **Model for Textual Recommendations**, where guidelines are stored. These may consist of the predicates "Name", "Text", "Summary" and an Attachment, where e.g. the user can get guidelines, which he or she can use for the sketch phase.
- **Environment Model,** where all environment-related data is stored. That includes the physical conditions of the environment of the real world, objects and characteristics of the environment etc.
- **Task Model,** describes how to perform activities to reach a pre-defined goal. This model may be based e.g. on Hierarchical Task Analysis (HTA)[1] providing an interface, where the designer can define actions of the user for the evaluation in the virtual environment.

In relation to functional requirements, such as gaining of component recommendations as an output, the virtual user model needs to be able to parse the sub-models using logical constraints. This is necessary in order to build an inference model with all relevant data.

For the implementation, an architecture is proposed, which includes the VUM as a knowledge base. The architecture (Fig. 4) consists of a frontend and backend part: In the frontend the client application connects itself with a server (backend) through a Java Interface for SQL (JDBC), where all information regarding the user models, recommendations, environments and tasks is stored to acquire the latest version. Through the application of a Reasoner or semantic reasoning engine, a new ontology model is sequentially created which consists of all available data. In the backend all data is stored in a SQL Database including a timestamp for versioning support. Afterwards the Knowledge Base builds the complete Virtual User Model as seen in the next section. By using a Generic Rule Reasoner and the Jena Ontology Interface the application is able to perform requests to the Ontology to present the needed instances. Additionally the sketch phase system includes also Visualization, Import from XLS / CSV files and a Recommendation Viewer to present the results to the designer.

While Fig. 4 highlights the underlying architecture in relation to the sketch phase, Fig. 5 focuses upon the support of the VUM-based system which is provided during the whole product development process (sketch phase, design phase, evaluation phase).

As in the sketch phase, the only input the system receives by the designer is the selection of a user, environment and task model, the second phase deals with a detailed design of a user interface of a product. In the third and final phase (evaluation phase) the system is in the status of possessing the most advanced quality and quantity of information to generate recommendations. In each phase the designer is currently

[1] In a hierarchical analysis (HTA), the designer breaks down a task from top to bottom, thereby, showing a hierarchical relationship amongst the tasks, and then instruction is sequenced bottom-up.

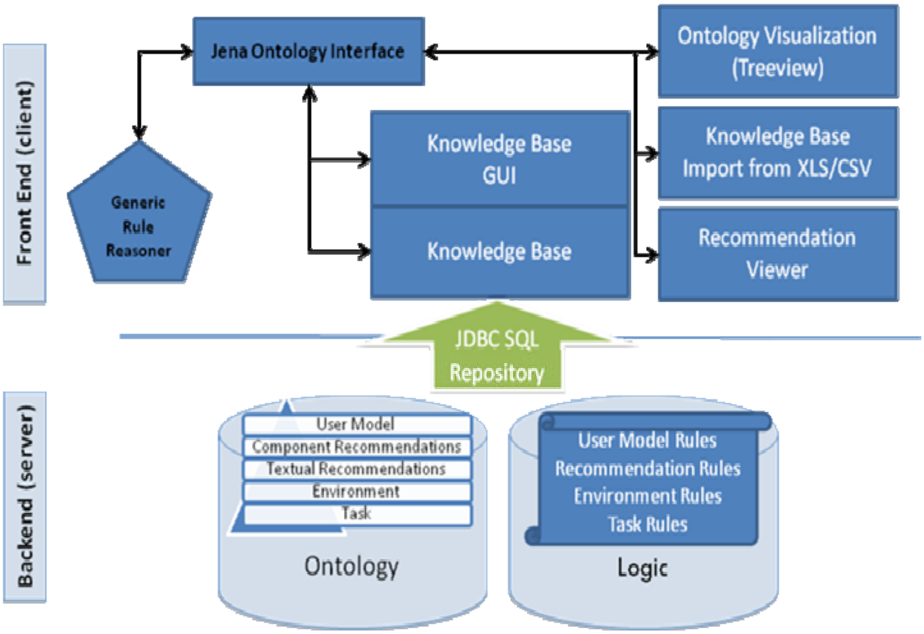

Fig. 4. Architecture for sketch phase

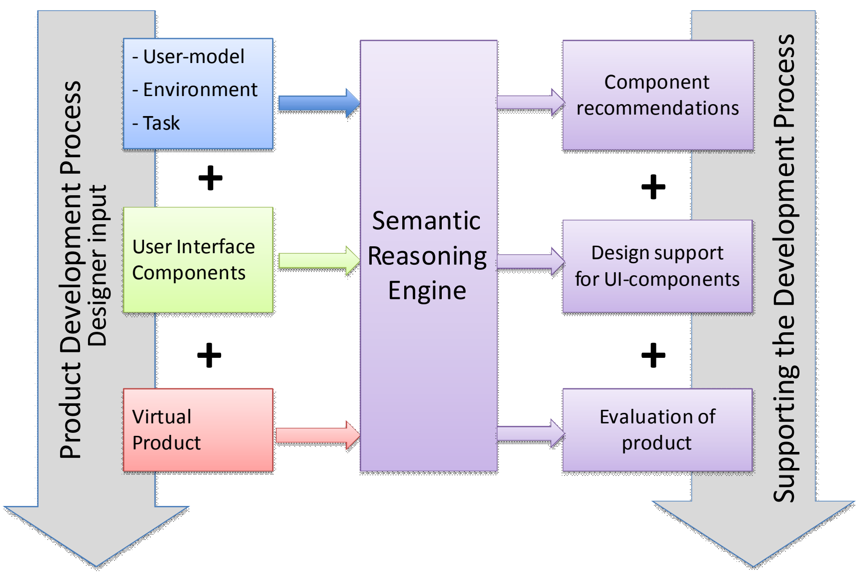

Fig. 5. Overview of the support provided during the whole product development process

involved, his/her input is incorporated. At the same time the underlying knowledge base increases, which leads to the situation that the system is signed by additional information in order to generate appropriate recommendations.

The “Semantic Reasoning Engine” in centre of Fig. 5 is based upon the already described modules (Knowledge base, Reasoner, etc). In analogy to the sketch phase, in all other phases, logical consequences are being inferred from a set of asserted rules as proposed in 4.2. In a practical sense, the Semantic Reasoning Engine can be considered as an enabler for determining results for supporting the design process.

3.3 Inference of the VUM

The sequential creation of inference models of the Virtual User Model is divided into 5 steps, which apply specified rule sets by every one step as illustrated in Fig. 6. Iterative Creation of Recommendations during the Sketch Phase:

1. **Applying of user model Rules**
   The General Rule Reasoner uses the user model rules to define all instances of the user model class as members of specified WHO ICF profiles (e.g. “HProfile2” for severe hearing impaired people).
2. **Generation of component Recommendations**
   Until this step, all component recommendations are only members of the recommendation class. The Reasoner applies rules, which defines all instances of these recommendations as members of the WHO ICF profile groups. So after this step every user is a member of a profile class, which has analogue recommendation profile classes (e.g. “HProfile2_Reco” consists of all component recommendations for the profile of severe hearing impaired people).
3. **Generation of textual Recommendations**
   This step is the same as the second step, with the difference to use the textual recommendation rules and instances.
4. **Creation of environment Recommendations**
   This step creates classes based on the names of every environment, followed by a “_Reco” and adds all textual and component recommendations, which were reasoned by the environment rules, as members of these new recommendation classes (e.g. “Kitchen_Reco” is the recommendation class for the environment with the name: “Kitchen”). These rules can also use the previous defined recommendation classes.

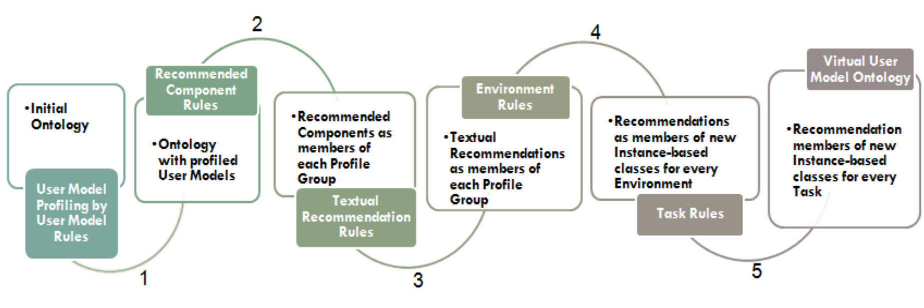

Fig. 6. Iterative Creation of Recommendations during the Sketch Phase

5. **Creation of task recommendations**
   The last step creates all task related recommendations based on task rules and all previously defined recommendations.

4 Conclusions

In this paper a model-based design approach was presented based upon the creation and implementation of a virtual user model. It was shown that the design approach is potentially capable of supporting the early product development stage (before realizing of physical prototypes) by providing component and design recommendations. So far the feasibility of the approach during the sketch phase has been demonstrated by implementing the virtual user model according to the architecture specified in Fig. 4. Through the introduced virtual user approach it was shown that insufficient knowledge of product designers regarding the needs of people with mild and moderate age-related impairments can be completed. The benefit for mainstream manufacturers of consumer products is obvious as they would be able to develop their products in an inclusive manner, making them accessible for users with mild to moderate impairments, thus at the same time remaining attractive for non-impaired users as well. On behalf of this thesis, it is particularly interesting to investigate the feasibility of the approach in the second (design) and third (evaluation) phase.

5 Future Work

In the next stage it is foreseen to determine how the VUM can support the designer in the design and evaluation phase. A main challenge will be to seamlessly integrate the VUM into existing product development processes of companies, e.g. integrated into mainstream CAD applications. In this respect, a design support through the VUM may involve presenting qualitative and quantitative recommendations based on the specified values in the CAD software. These recommendations may consist of a unified set of previous shown guidelines, partial components and additional information particular regarding the design of a product.

In order to obtain the practical value of the approach, it is therefore foreseen to test and validate the VUM, based upon two real design cases: (1) mobile phone and (2) washing machine in close cooperation with two well-known consumer goods manufacturers. The aim shall be to confirm the benefits of the proposed design approach on a practical scale, but also to identify the limits of a virtual user model-based design support to the research community and design industry.

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Virtual User Concept for Inclusive Design of Consumer Products and User Interfaces

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Abstract. Many research projects have identified three major obstacles to a broad implementation of Design for All: lack of awareness among users, designers and suppliers, technical feasibility and commercial viability. Mainstream manufactures do not have a detailed understanding of the needs of people with disabilities. This paper presents an approach to use standards-based Virtual User Models that covers mild and moderate disabilities to support designers in understanding these needs. This approach consists of a virtual laboratory with three design phases to allow designers to plan and evaluate the user interfaces of their products. We review here the state of the art and present our Virtual User Model as a mixture of human and environment context.

Keywords: virtual user model, computer design, design for all, accessibility, usability, ontology.

1 Introduction

This paper presents the output of a study of existing virtual user models and virtual user model-based approaches in combination with CAD design tools under the scope of the VICON research project.[1] Additionally, we describe the development of a methodological framework of an evaluation scheme for a virtual user laboratory.

Understanding and incorporating the requirements of persons suffering from physical impairments will only be achieved when designers are able to see more clearly the impact of specifications and design decisions, regarding the accessibility of their envisaged products. Simulation of the causes and levels of design exclusion using virtual users has the potential to provide such insight.

We will review:

- existing approaches in the area of human factors in the workplace and product design;

[1] http://www.vicon-project.eu/

C. Stephanidis (Ed.): Universal Access in HCI, Part II, HCII 2011, LNCS 6766, pp. 79–87, 2011.

- task analysis equations and tools identifying design problems to avoid the causes of less usable or inaccessible designs; and
- additional analysis types and extensions to demonstrate the VICON objectives in relation to designing mobile phones and washing machines.

The envisaged beneficiary user group in VICON is represented by users with mild to moderate physical impairments. The intention behind the project is to come up with a design support tool in order to highlight areas of particular accessibility issues during the design process of a product before the realization of any hardware prototype. This approach incorporates a user capability range that does not cover the “average user”, thus takes into account multiple combinations of disabilities.

The focus in VICON lies on the user interface of the product, and subsequently touches the issue of interaction of persons with physical impairments with consumer products. This plays a crucial role in determining how well a particular consumer product is accessible and suitable for use by elderly and disabled persons. Generally, how a human will behave and interact in relation to a product or system is particularly difficult to predict. Yet, usability or accessibility issues traditionally have been often addressed by intuition. Usually, real tests are performed after the product can be easily modified. Very often this results in the decision by the design teams of neglecting the accessibility demands on such products.

Designers therefore need support by simulating the interface between users and a consumer product from the earliest stages of the design and engineering processes. Evaluating alternatives from an accessibility standpoint, when it is still relative inexpensive to change the design, can improve the accessibility features of the product [1]. VICON strives to provide such a support from the initial stages until the beginning of the prototyping and production phases.

The approach pursued in VICON has the potential of providing an in-depth understanding of crucial problems encountered by design for all, including elderly and disabled persons. This will support designers to incorporate the requirements of users with disabilities, without putting the burden on the designers to know a lot about the different disabilities and their grades and combinations, and how to compensate them by applying specific design patterns [1, 4].

Looking at contemporary virtual user models, a lot of existing approaches were identified –ranging from figures used to create cartoons and simple games to avatars used in Second Life and alike. Only the approach of the digital human models based on anthropometrical data are suitable for serious simulations and can meet the ambitious goals of the accessibility evaluation of user interfaces of consumer products.

There is neither a common framework, nor a common understanding of how elements involved in the creation, development, and interaction of virtual user features are done [1]. Therefore, there is a need for describing (1) existing resources, (2) virtual users composition and features, and (3) the different levels/fields of knowledge comprehended.

Investigations of existing systems, approaches and models were based on literature review and upon hands-on experiments with some virtual user systems, accessible as public versions or as licensed agreements with the vendors. Another source of information was based upon currently ongoing or finished EU funded research projects in the same area, such as the VAALID[2] and the AEGIS[3] projects. The main differences of existing projects compared to VICON were (1) the direct user target group, which comprehends here designers and not the beneficiaries themselves, and (2) the focus on specific target devices, which are in VICON washing machines and mobile phones. Available experiences with the inclusion of virtual users have been analyzed in order to base the VICON approach on a foundation of past experiences, and derive an improved methodology. Starting with a thorough study of literature of virtual user approaches, this will infer requirements and best-practices. The virtual users will be modeled in a hierarchical way, one level describing a target user group in a more general way, the next level modeling instantiations as "virtual users" explicitly. This will also serve traditional methods, such as scenario-based analysis, while allowing comparing them with Virtual Reality-based methods. Benefits of such virtual user models strongly depend on two qualities: (1) the validity of the user model, i.e., the match between model and reality, and (2) its capability to predict the user behavior correctly. Further, we considered the flexibility of the virtual user models, i.e., their capability to apply the model during all phases of the design process [4].

2 State of the Art

A virtual user concept is commonly utilized for ergonomic analysis in vehicle and workplace design in the automotive industry. It is used to validate the design in a simulation environment, check in a loop if the design is suitable, refine it considering recommendations and best practices and finally, when found suitable, produce a prototype to be checked by end users (see **Fig. 1**). More rarely are the tools applied in the evaluation of consumer product designs and even less for usability and accessibility of consumer product's interfaces, although having similar objectives for user-centered design processes.

In the area of accessibility only one case-study was identified, which is the HADRIAN system based on the SAMMIE CAD [5], which tried to detect accessibility issues during the interaction between users and ATM machines. Virtual user systems for the purpose of validation of product and workplace design are based upon anthropometry, joints' range of motion, description and appearance of the virtual user customized to meet the requirements of the task at hand. Virtual user models (digital human models) are as mentioned above already established tools in many companies for specific analysis tasks in product design or in process design and development. In this survey we have gathered information about the state of the art of models used in CAD (Computer Aided Design) and PLM (Product Lifecycle Management) systems [6].

The majority of existing models are mainly developed for the areas of aerospace and design of airplanes, where training and experiments on real tasks were expensive or impossible; therefore they had to be simulated and one element of such simulations were Virtual User Models [7].

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[2] http://www.vaalid-project.org/
[3] http://www.aegis-project.eu/

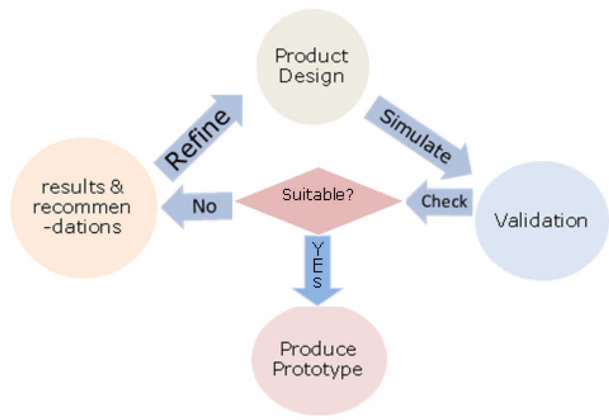

Fig. 1. General usage approach of virtual user models in inclusive design

2.1 Characteristics of Existing Digital Human Models

The main characteristics of existing virtual user models include a definition of the physical environment, a definition of virtual users segregated into segments and joints or links, and that the virtual users should perform the analysis with a reasonable posture. Furthermore, a generic process for virtual user model analysis includes the following major steps: understanding the task, understanding the work environment, understanding the user population, understanding the limits of the software used, performing the analysis, analyzing and applying judgments to the results, and finally, reporting the results of the analysis. The documentation of analysis results also needs to be structured as a natural part of the virtual user modeling process. In the following we present the main components of a virtual user system in existing systems [3]:

- **Virtual user.** It represents the humans who are interacting with the product or vehicle. The existing virtual user models represent the human body as a kinematic system, a series of links connected by rotational degrees of freedom (DoF) that collectively represent musculoskeletal joints. Standard set-ups are usually made available, so that the designer can select from a list of existing stereotypes of virtual users such as: customer type, power plant worker type and manager type. It is also possible to specify a unique type of virtual users, which is then generated in the human simulation tool by defining the virtual user characteristics, e.g.: nationality, age, gender, percent of target population considered and key anthropometrical variables.
- **Physical environment.** It refers to descriptions of the workplace, the device characteristics or vehicle parts which a human interacts with by performing tasks. The environment is described in the detail that the analysis requires. Relevant information is applied, such as size in a clearance analysis, and weight in a force/torque analysis. The numbers of the drawings used to create the simulated environment are stored. In addition, simplifications as well as limitations of the environment descriptions are explained.

- **Tasks.** The task is the action that the virtual user will perform. Initially, the task is divided into subtasks using hierarchical task analysis in order to retrieve simple tasks that can be handled and simulated. Secondly, constraints for performing the task are defined. Standard constraints for different tasks are available and visualized in the process with an illustration of a driver with marked constraints.
- **Results.** In the results, it is possible to attach generated animations, pictures and tables of the analysis to the documentation. It is also possible to write text with illustrations or to just describe results in text.

2.2 Existing Virtual User Models for Ergonomic Analysis

There are many Virtual User Model platforms and products available mainly in the area of product lifecycle management like, e.g., Tecnomatix (Siemens/UGS) which is using a model called eM-Human. The model Santos was developed in the frame of the Virtual Soldier Research Program of the University of Iowa. It uses accurate biomechanics with models of muscles, deformable skin and the simulation of vital signs. With this system analyses of fatigue, discomfort, force or strength can be done. Furthermore, modules for clothing simulation, artificial intelligence and virtual reality integration are available for real-time systems. Unfortunately, this model is not available for the research community in Europe. Some other models like the Boeing Human Modeling System (BHMS) or the System for Aiding Man-Machine Interaction Evaluation (SAMMIE) complete this listing. Many problems can be solved with nowadays Virtual User Models. Nevertheless, there are still many unsolved issues which can be developed and integrated in the future, by enhancement of existing or development of in new models.

3 The VICON Approach

The VICON evaluation methodology consists of many components (see **Fig. 2.** and **Fig. 3**) and is based on existing approaches of virtual user systems in the areas of ergonomic and usability as described in section 2.2. The VICON approach goes beyond the existing approaches by:

- accompanying the design process from the scratch until the final CAD design cycle, providing different standalone recommendation systems for the idea finding stage, the scratch phase and components for integration with CAD systems based on the VICON virtual user concept;
- incorporating accessibility features in the user profiles, especially audio analysis, which was not considered in any of the existing virtual user platforms;
- developing further analysis tools to assess accessibility requirements in the virtual user system; and
- adding new reporting mechanisms, e.g., web-based reports and visual responses in the virtual user itself.

A recommendation system is being created to assist the designer at the first stages of ideas finding and scratch design. The recommendation system will be made available as a standalone application and will provide an API to be integrated into other applications.

Following an example is given of the **VICON recommendation system** as a web based virtual user recommendation system on inclusive design for mobile phones and washing machines to assist designers from the beginning utilizing existing guidelines, standards and materials.

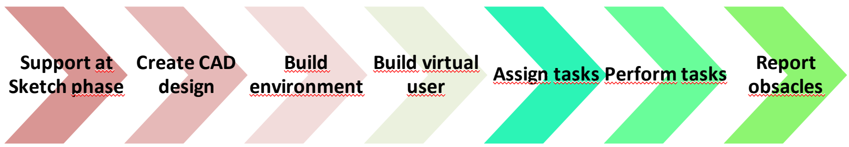

Fig. 2. Overview of the VICON process

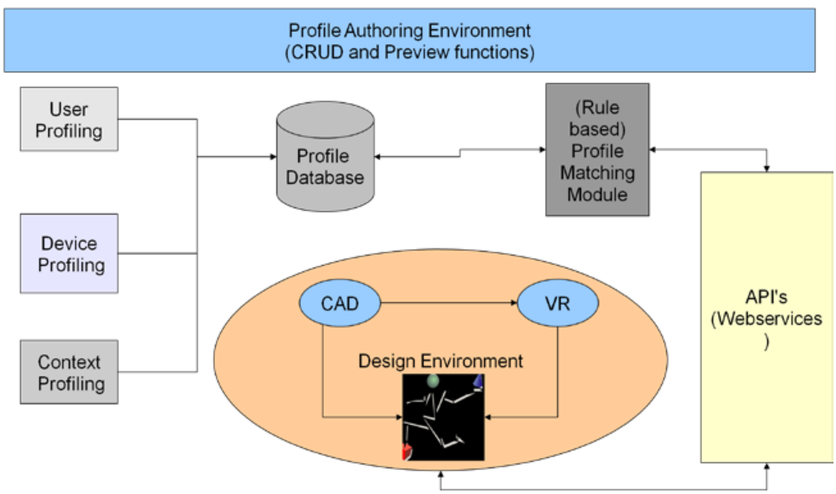

Fig. 3. Overview of the VICON approach

The designer is planning to design a new mobile phone and wants to incorporate accessibility features into the future mobile phone. The designer invokes the standalone VICON recommendation system and selects from the device list “mobile phone” and configures from the “target user group” list its target user group. Based on the entered information the system looks-up into its repositories and displays to her a list of existing use cases as defined in earlier stages of the VICON project and additionally links to existing guidelines. In the further course the designer starts a graphics application and makes a scratch layout of the future mobile phone, saves it and imports it to the VICON recommendation system. The system then displays more accurate recommendations dedicated to the scratch layout and the selected target user group.

The other component will be the 3D virtual user system, which allows either the development of CAD designs or the import of CAD designs into it, and provides analysis tools. It will allow the assignment of tasks to the virtual user. An execution procedure reports the results visually to the designer.

The user of the VICON virtual user model executes the following steps, which comprises the virtual user system:

1. Define parameters, which enable the consideration of dynamic behavior and interaction between the components of the VICON system,
2. Incorporate task analysis tools, which formalize and structure the performance of a virtual user in a sequence of goals and actions carried out during the interaction,
3. Create virtual user environments, where the designers could configure a virtual environment,
4. Design products in a CAD system, where the designer can invoke a VICON context sensitive recommendation system,
5. Build a virtual environment,
6. Import the CAD design into the VICON virtual user system,
7. Position the virtual user in the environment,
8. Assign tasks to the virtual user, and
9. Analyze how the human performs.

4 Criteria and Methods to Validate the Vicon Model

The objective of evaluation of the VICON virtual user system is to examine the validity of such models and to what extent accessibility simulations of interaction tasks with washing machines and mobile phones designs correctly predict the real outcomes of the accessibility evaluation by real users using real devices. Furthermore, it checks whether recommended guidelines originating from accessibility simulations are correctly considered. The evaluation was conducted in a virtual lab setting by the industrial partners of VICON. The results should show whether the virtual user models and related analysis tools are useful for providing designers easily and without extra burden with accessibility hints. When the virtual user conducts tasks, it will measure, if accessibility issues are recognized correctly. The evaluation studies identified areas that require additional development in order to improve the virtual user system itself and its ability to correctly predict the accessibility evaluation outcome.

The evaluation will include an investigation about the limits of the concept of the virtual model in comparison to real world field studies. This investigation is necessary, because of the novelty of the virtual user concept in the domain of accessible design for impaired users as target group.

The evaluation should determine rules on to what extent and detail level the virtual user should emulate real world users in order to achieve optimized designs for the selected user group.

Virtual user models are visually very impressive and they can be very useful as a validation tool (e.g., for performing sight field analysis). It is already obvious that this solution will not replace real user tests [4]. One of its major downfalls is that virtual user models can not 100% build-up the real environment and there will be shortcomings in the relations and dependencies between all the variables involved in the system. However, virtual user systems can play an excellent role in automated detection of many accessibility problems in designs of products. They can play a very useful role in the communication between designers and other stakeholders to explain and discuss accessibility issues.

In the following, we suggest criteria and methods on how to assess the VICON approach, in particular the validity of the virtual user concept.

1. **Audio analysis.** The analysis methods of audio issues include the configuration of an appropriate virtual environment.
   Success criteria: The virtual user should display any lack of hearing sounds and signals.
2. **Vision field analysis.** The analysis methods of vision issues include the configuration of an appropriate virtual environment.
   Success criteria: The virtual user should display any vision problem encountered.
3. **Reach analysis.** The analysis methods of reach issues include the configuration of an appropriate virtual environment.
   Success criteria: The virtual user should display any reach problem encountered.
4. **Force feedback analysis.** The analysis methods of force issues include the configuration of an appropriate virtual environment.
   Success criteria: The virtual user should display any force problem encountered, e.g., when pressing buttons.
5. **Push/Pull analysis.** The analysis methods of push/pull issues include the configuration of an appropriate virtual environment.
   Success criteria: The virtual user should display any push/pull problem encountered, e.g., when opening or closing a door.
6. **Lift/lower analysis.** The analysis methods of lift/lower issues include the configuration of an appropriate virtual environment.
   Success criteria: The virtual user should display any lift/lower problem encountered, e.g., when carrying the cloths' basket and putting it down.
7. **Grasp analysis.** The analysis methods of grasp issues include the configuration of an appropriate virtual environment.
   Success criteria: The virtual user should display any grasp problem encountered, e.g., when grasping the mobile phone.
8. **Manipulate analysis.** The analysis methods of manipulate issues include the configuration of an appropriate virtual environment.
   Success criteria: The virtual user should display any manipulation problems encountered, e.g., when manipulating the tiny keys of the mobile phone.
9. **Combined analysis.** The analysis methods of combined issues include the configuration of an appropriate virtual environment.
   Success criteria: The virtual user should display any combined problem encountered, e.g., the ability not to see clearly the buttons and not having enough strength in the fingers to press them.

5 Conclusions

We have investigated the existing virtual user models relevant for the analysis of Human Factors and Human Activities. We think only this type of virtual user systems would be suitable for an automated analysis of accessibility features in CAD design. We have defined the main analysis types. We are building the required prerequisites based on the use cases gathered in the virtual user model, which will be specified and built in the upcoming phases of this project. The results in the VICON virtual user system should be presented visually to the designer, so that they must not be experts on accessibility to interpret and utilize them.

In our study of existing virtual user systems we identified many possible candidates to be used in the forthcoming development of the VICON virtual user model. The first one is SAMMIE CAD, the extension HADERIAN was developed to study tasks for elderly and disabled persons. Here a database with nearly 100 users was built. The main disadvantage of SAMMIE CAD is that the hand model is not sophisticated enough to grasp and manipulate objects like mobile phones. The Pro/ENGINEER Manikin is a highly sophisticated virtual user model based on standards like the Digital Human Model structure. It conforms to the H-ANIM standard (ISO/IEC 19774)[4]. However, the provided features of Pro/Engineer Manikin are more or less comparable to those i.e. of Jack, RAMSIS or CATIA human builder. The main advantage appears in conjunction that it is the preferred CAD application of the VICON industrial end-users. Hence a quick and comprehensive integration of the VICON platform into respective development process appears to be much easier.

Highly sophisticated CAD systems and virtual users based on anthropometry may be misleading concerning the validity of the models. Therefore we will test in detail all features of the VICON virtual user system to ensure its validity.

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Modeling Users for Adaptive Semantics Visualizations

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Abstract. The automatic adaptation of information visualization systems to the requirements of users plays a key-role in today's research. Different approaches from both disciplines try to face this phenomenon. The modeling of user is an essential part of a user-centered adaptation of visualization. In this paper we introduce a new approach for modeling users especially for semantic visualization systems. The approach consists of a three dimensional model, where semantic data, user and visualization are set in relation in different abstraction layer.

Keywords: Adaptive Visualization, Semantic Visualization, User Model.

1 Introduction

The conflation of the research areas Information Visualization and Adaptive Systems plays more and more a key-role in today's research. Both research fields declare the adaptation of information visualization systems as a main challenge. Information Visualization recognizes the development of "novel interaction algorithms incorporating machine recognition of the actual user intent and appropriate adaptation of main display parameters such as the level of detail by which the data is presented" [17] as a main challenge. The research in Adaptive Systems already presented first attempts to adapt visualizations to the different characteristics of users. Main challenges for the adaptation of the visualization to the user are the identification of relevant users' attributes, their processing from users' interaction with graphical systems and the adaptation of the visualization based on the gathered information. This important information is designed and persisted in user models, which mostly provide a domain-specific model of certain users attributes. The information is gathered implicit from the interaction of the user with a set of data, which is currently modeled as a common text-based user interface.

With the adaptation of visualizations another research challenge appears in this area: the modeling of users attributes, based on their interaction with a pure graphical representation and the application of the gathered information to adapt a pure graphical representation and visualization respectively.

In the following paper we present a new approach for domain-independent user modeling for the adaptation of graphical information systems especially for semantic visualization.

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The approach introduces a three-dimensional matrix consisting of both user attributes that are relevant for visualization and visualization parameters that are important for the perception of information with visualizations. The identified parameters of visualizations are classified into two levels of abstraction: First the visualization-type adaptation, which represents a set of easy-to-use and established visualization methods and layouts and second the parameterization of each selected and recommended visualization, e.g. color and size of entities, level of zoom or level of details. The attributes of the visualizations evinces a static character and fill out two dimensions of our approach, on the one hand the several identified visualization types and on the other hand the parameterization of each visualization type.

In contrary to the visualization dimension the user dimension evinces a dynamic character based on the users' behavior. Here the most relevant information about users' interaction with the graphical representation of information is mapped to the two dimensions of the visualizations. In this dimension not only the interaction with the data behind the graphical representation is registered, but also the interaction with several visualizations. Therefore the user gets a new approach of multiple-visualization, a "Visualization Cockpit" and the interaction with each of the visualizations is measured for example to model a relation between user and the visualization-type dimension.

In the first section of this paper we give a general overview about main aspects of user modeling, followed by existing adaptive visualization systems. the existing visualization adaption systems and their user-modeling method. The following section will introduce the new approach of the three-dimensional user modeling. After that the most relevant attributes of both, the visualizations and their parameterizations and the user will be described.

2 User Models and Adaptive Systems

A user-centered adaptation of any system needs information and knowledge about the user. Based on these users' information a system is able to provide a user-centered adaptation effect. The mentioned information about users is commonly described as knowledge about the user in user models. The following chapter will give an overview about the way how this information is modeled and how user models can be classified.

To envision an appropriate picture of user models the classification of Slemann [28] will be used, which categorizes user models in the following layers:

- *Nature: What is being modeled?*
- *Structure: How this information is represented*
- *User modeling approaches: How different kinds of models are maintained*

Thus our approach focuses on the nature of a user models we will give an overview of approaches on the nature of user models provide state-of-the-art examples for the approaches. For the investigation of user models for information or semantic visualization it is further necessary to differentiate between those systems, which uses information retrieval techniques for filtering, ordering and organizing information and those, which uses and models users knowledge and are often used in Intelligent Tutoring System (ITS) [21] and knowledge systems.

The information retrieval systems are often used in recommendation systems, where the user interests are modeled over time using data mining approaches ([26], [27]). Besides these approaches which focus on user interest the most popular user features, which models users as individuals are: *knowledge*, *interests*, *goals*, *background* and *individual traits*. . [8] In the following we describe these often used features for modeling users:

Knowledge: User's knowledge is the most important feature, especially for e-Learning system, e.g. Adaptive Hypermedia Systems (AHS) and Adaptive Educactional Systems. [8] This feature is used in the majority of systems by both, for navigation through a knowledge domain and an adaptive presentation. [8]. The simplest and most common way to model the user's knowledge is the *scalar model*, which estimates the user's level of knowledge. A scalar model may consist of quantitative or qualitative values. Quantitative values may be a number ranging, in which the user is classified. The qualitative scalar model classifies a user into several levels of knowledge within a knowledge domain, e. g. Novice to Expert. The scalar model is very similar to stereo type systems, where different users' are compared with each other. Different examples ([21], [9], [5], [6], [7]) of scalar model-based adaptive systems shows, that despite the scalar modeling is a very simple way to model user, the systems provide promising und useful adaptation effects.

Another approach for modeling users' knowledge is the structural model, "which *assumes that the body of domain knowledge can be divided into certain independent fragments*." ([8], p. 7) The most popular form of structural model is the overlay model [8], which represents an individual user's knowledge by a subset of a given domain level. The simplest way of an overlay model assigns a Boolean value to each knowledge fragment compared to the domain knowledge. This value can be enhanced by the introduced scalar model, where each fragment gets a qualitative or quantitative value. The second model, a combination of the scalar model and the simple overlay model has been established in different systems ([15], [25]).

Other approaches for designing and modeling users' knowledge are *bug model,* which compares the non-knowledge of the user ([18], [31]) and the genetic model [11].

User Interest: User interest is the most important part for of a user profile in adaptive information retrieval and filtering systems, e.g. recommendation systems, that deals with large amount of information and adapts (filtering, highlighting) the relevant part of the large for the user.

There exists two different way, how user interest can be modeled: The weighed vector of keywords method [2], a keyword-level approach, which is still the most popular model for model user interest. And the weighed overlay model, where user interest are modeled as a weighed overlay of a concept-level. This model is very similar to the described knowledge overlay model. User interests are represented as an overlay of a concept-level model of the domain that the system covers. Because the two models, knowledge overlay model and concept-level weighed overlay model are very similar, many systems modeling users by using these both models by separating the overlay over the same network of concepts ([3], [24]).

Goals and Tasks: The user goals and tasks represent the immediate purpose of a user within a system. [8] This can be the need for certain information, solving a given problem, learning a specific learning object or fulfilling a certain task. The information about users' tasks and goals (or intentions) can be used by adaptive help systems ([12], [10]) to provide an adequate help in during several steps of solving a problem while working with a system. Further Intelligent Tutoring Systems [21], especially with the focus for conveying procedural and problem-solving knowledge; analyze goals and tasks of the users.

Background and Individual Traits: Background and Individual Traits are common and aggregate names for several user features outside the core domain and define the user as an individual. For gathering knowledge about these two features more than only user interviews are needed. The modeling needs specially-designed psychological tests. [8] The most famous system, which build a user profile from the cognitive abilities, is CUMAPH [29].

3 Adaptive Visualizations

For the community of Information Visualization, the way from data-oriented visualization to a more human-centered information presentation plays a key-role. In 2007, one of the ten main challenges for Visual Analytics and Information Visualization respectively was the inclusion of the semantics or context (data characteristics, user goals, etc.) in information visualization systems [30]. In the following year, especially the human as an implication and decision factor for information visualization was placed in the forefront of the research. Keim et al. declared the aspect of User Acceptability as one of the most important technical factors for deploying Information Visualization for the changing requirements of users. [1718] The strengthening of the ongoing trend to involve the user with her individual intentions and preferences in the forming process of Information Visualization is noticeable in the challenges and scopes of Visual Analytics in 2008, where the adaptation of information visualization systems was proclaimed. Thus, one of the most important challenges is the development of "novel interaction algorithms incorporating machine recognition of the actual user intent and appropriate adaptation of main display parameters such as the level of detail, data selection, etc. by which the data is presented" ([17], p. 162).

Already different approaches have been proposed to support an automatic or semi-automatic adaptation of UIs. Cicero, for example is a component-oriented architecture [4], where a central UI adaptation manager is used; on the contrary agent-based environments [14], where UI models are transformed and rendered into different platforms adapts user interfaces to different impact factors. The only applications that adapt the visualization to certain impact factors, e.g. user interactions or user-goals are the following applications:

Gotz and Wen are using the user interactions for analyzing and extracting a certain "behavioral-pattern", which is used to suggest a different visual representation of the data [13]. The impact factors for their visualization-recommendation are the iterative interactions of users, which is used to recognize a user-behavior. Based on the recognized behavior a certain visualization type (Line Graph, Fan Lens, Parallel Coordinates or Bar Charts) is recommended for the user. But a visualization type has always characteristics and parameters, e.g. color of entities, order, size, layout etc., which can and should be used for communicating designated information adaptively. On the contrary Ahn & Brusilovsky are adapting visual parameters of a single visualization type and visualize the user-specific relevance of a query [1]. In this case a single static visualization type (Spatial Visualization) is used to represent the searched information.

The related work could point out that the number of existing adaptive visualizations is very limited and these approaches focus either on the adaptation of the visualization type, using a single set of parameters (e.g. [13]) or on the adaptation of the parameters of a given single visualization type [1]. Despite a good research in both areas, a sophisticating system with an adequate user modeling approach especially for the visual representation of the system could not be found.

4 Adaptive Semantics Visualization and User Modeling

In the previous section we could point out that several methods for modeling users in different forms of adaptive application are already developed. We could further point out that the number of adaptive visualizations is very limited, but there is a need and a visible change to a more human-centered view in the development of information visualization systems.

We introduce in this chapter a conceptual design for modeling users especially for the adaptation of visualizations. First we discuss the nature of user information needed for adapting visualizations. Therefore the aspect of information visualization will be investigated as a general way of presenting information. After that the visualization will be considered in several layers of abstraction and a new approach for adapting visualization will be presented.

4.1 Relevant User Features for information Visualization

Information Visualization bridges the gap between complex and huge information and the user. It is one of the most powerful bridges between human and complex information structure: *A picture is worth a thousand words.*

But each picture and with it each way of visualization can be perceived by the individual user in deviate ways. While a textual presentation of information gives little room for interpretation, the visualization of the information can be interpreted in several ways.

It is obvious that visualization and perception are very near to each other. Users' history in interacting and using information visualization systems is very important for modeling her in the context of visualization. With history her experiences with different real and virtual visual artifacts are meant in this context. Users' experience can be modeled as shown in chapter two, as her knowledge. So the users' knowledge or pre-knowledge plays an essential role for choosing the right visualization. But the main question is: "how is a system able to gather information of a user about her experience and pre-knowledge in interacting with visualizations?"

A very easy and obvious way is, to present different visualizations and observe the users' behavior. For the presentation of different visualizations, different metaphors can be used:

- Presenting a single preselected visualization with a set of possible other visualization techniques. *(1)*
- Presenting a (preselected) set of visualization as a multi-view User Interface *(2)*

For the process of pre-selection methods from Visual Analytics ([16], [17]) can be used, which recommends visualizations based on the data, which are visualized.

The following figure demonstrates the described ways of visualization presentation.

Fig. 1. Choosing Visualization for the User Model

From the users' interaction in both presentation ways, the preferred visualization and thus knowledge about the user can be gathered. But of the presentation forms have advantages and disadvantages: The multi-view presentation way treats all of the visualization in the same way and does not manipulate the user. But putting several visualization in one User Interface, may overcharge the user. The single-way visualization is very simple and provides is more easy-to-use visualization way. But this way of presentation may manipulate the user to use the presented visualization. To avoid a manipulation and overcharging of the user and gathering information about the user, a mixture of both presentation forms is a solution: On the hand the user knows explicitly that there exist several visualization types for choosing and on the other hand the multi-view UI is constrained to two visualizations and thus does not overstrains the user.

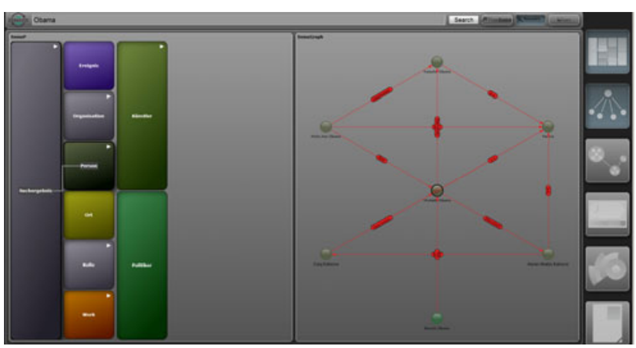

Fig. 2. Mixture of visualization presentation

Information visualization systems visualize huge amounts of data and information respectively, thus the consideration of users' interest is another factor, which brings an added value. Ahn and Brusilovsky already presented in [1] an approach for ordering the items of a search results based on a recommendation system (thus based on user interests). To enhance this method the interaction of the users with the graphical representation of the data are considered too. With the algorithm presented in ([22], [23]) we are analyzing the interactions of users to create a profile of the user interests. The results are highlighted by using different graphical primitives ([22], [23]).

The following figure shows the described mixture.

4.2 Layers of Visualizations of Semantic Data

In the previous section we could point out that there are two natures of user information used and necessary to provide a visualization adaptation. Further we pointed out that different visualization layers are investigated in the process of adaptation and user modeling. In this chapter these layers will be presented, which consists of three so called components. The here described components are developed for visualizing semantics data [20].

General visualized components (GVCs) are abstracted visualizations and form the UI. GVCs are primarily responsible for the selection, placement and initialization of visualization types in their layout layer. In our case, we used a mixture of visualization presentation and the opportunity to choose a visualization type. Choosing a visualization type implicates a kind of preference in the way of the user interaction and perception and models her knowledge.

Semantics visualization components (SVCs) visualize the structure of the semantics data and provide the possibility to interact. SVCs are the real visualization components and consist of one or more visualization algorithms, e.g. force directed or concentric radial. The visualizations are already chosen by the user. Here the user interacts with items (graphical representation of the information) within the visualization. With this information the users' interest are registered and analyzed.

Content Visualization Components (CVCs) are responsible for the presentation of the content referenced by the semantics. Examples for CVCs are pictures or HTML-viewers. They are interactively coupled to one or more SVCs and inherit the semantics, presentation and layout form theses coupled SVCs. If a user chooses the content and navigates through the content, it may implicate a "hit". This part is under investigation.

4.3 Three Dimensions of User Model

We could point out that the interactions with different layers of visualizations give us different information about the user. Interacting with a graphical object, which represents an information entity could be used to change the parameterization of the visualization and gives us information about his interests.

Choosing one or more visualization gives us information about the user's preferences and experiences respectively in interacting with visualization and thus implicates a kind of users' knowledge. We brought three dimensions together: The users with the features interests and knowledge, the data (behind the graphical representation or in a content viewer) used for computing the interests and the visualization with the separation of visualization type (graphical metaphor) and the parameterization of the visualization.

The following figure shows the mentioned three dimensions:

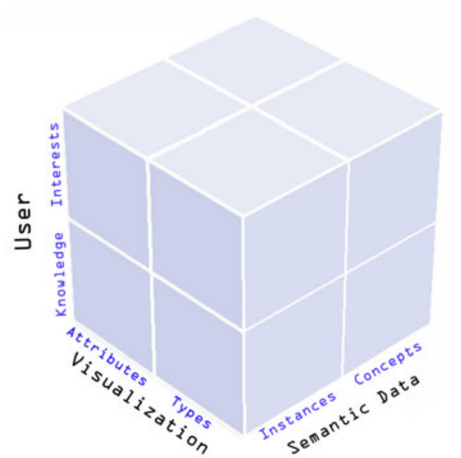

Fig. 3. Three Dimensional User Model

5 Conclusion

In this paper we presented an approach for modeling users especially for semantics visualization. With the usage of interaction analysis systems information about users are analyzed in different levels. The chose of a visualization metaphor is interpreted as information about users' knowledge; further the interaction with a graphical entity and thus the interaction with data is investigated similar to recommendation systems. The parameterization (attributes) of the visualization is adapted based on the interaction with the data, while the recommendation for a visualization type is related to the data (structure, hierarchy) and the interaction of the user within visualization or the chose of visualization.

The further progress of this work includes a comprehensive evaluation that further examines the potentials and benefits of adaptive visualizations. In particular the future work includes a comparison with common presentations with respect to the discovery and analysis more user features and the effects for the user.

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An Investigation of a Personas-Based Model Assessment for Experiencing User-Centred Design

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Abstract. User-centred design (UCD) has been widely used to solve those failure products that are not proper designed for target users. Although UCD techniques are varies, some similar drawbacks were found as it requires complex skills to manipulate and it is time consuming as well as costly. Big enterprises have no problem with carrying out UCD because of rich resources. However, most of researchers made effort on the improvement of approaching UCD. Lack of studies contributed to the area of promotion UCD to those companies which do not launch UCD correctly or barely know UCD. Neither any of studies addressed on the investigation in difficulties those companies have and therefore helped them to be solved. Hence, this research aimed to assess a cost-effective UCD model to assist designers in idea generation. 16 designers were invited into the two-phase assessment. In addition, there were 51 end users as the participants to evaluate that if the designers who followed the proposed model can generate better UCD ideas. In this project, an MP3 was chosen because it is portable, easy, and with both aesthetics and functionality factors. In addition, 25-34 office workers were selected as the target users as the participants. This research was a whole process of the assessment of a cost-effective UCD model in assist designers' idea generation, and this assessment successfully showed that the cost-effective UCD model could eliminate the complex of the UCD skills and the cost, in which the UCD results were identified by the users. Therefore it could encourage more designers to apply UCD in their work. Further recommendations were also illustrated in this paper.

Keywords: User-centred design, personas, idea generation.

1 Introduction

Today, user-centred design (UCD) is widely regarded as the design philosophy that defines how a design should be made by understanding the user's needs. In addition, the whole design process is examined iteratively to be user-centric by the guideline ISO 13407 to enhance the practice of UCD [1].

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Nevertheless, UCD is now used more in only large enterprises even though there are several approaches to achieving UCD, such as contextual design, participatory design and empathic design. The difficulties for small-companies are as follow: the involvement of users makes the design costly; to understand the users' behaviour needs professional skills [2]; the design process is longer when users are involved. Consequently, empathic design focuses on more aspects for helping the designers in the early stages of design. In addition, although empathic design offers "observation" as the method, the key point is to understand the users. Therefore, we adapt the meaning "understanding of users" as the basis of empathic design. Just to ask designers to think and behave like users could be a comparatively cheap solution as there is no "real user" involvement. Hence, the researchers suggested a model based on empathic thinking in order to help designers in the early stages of design to promote the benefits of cost effectiveness that are easy to manipulate. However, since there are no real users directly involved in the design process, we used the personas as "virtual users" to reinforce the engagement of designers and users in empathic design. Personas are usually used as a bridge for design communication [3]. And here they help designers to concentrate more when thinking about users.

Plenty of literatures addressed the creating of personas but none of them evaluate the effectiveness as this paper. Especially this paper focused on the encouraging UCD from non UCD designers, none of papers contributed in this area.

This paper aims to assess the use model to find out whether the model could help designers in design to undertake UCD more easily, enabling it to be more cost and time efficient. By doing this, we can persuade more usage of UCD.

There were 16 designers invited into the first two stage of assessment In the final stage, there were 51 end users as the participants to evaluate that if the designers who follow the proposed model can generate better UCD ideas. In this project, an MP3 was chosen because it is portable, easy, and with both aesthetics and functionality factors. In addition, 25-34 office ladies were selected as the target users. The evaluations from the target-users were also tested to evaluate if the proposed model can help designers in UCD idea generation.

The result showed the ideas generated by the proposed model were more likely chosen by target users. In another words, the model provided a user-centred guide for design practitioners. Besides, questionnaires from designers showed that designers' satisfaction of this proposed model has significantly high rate. This research therefore verified a personas-based model which can help designers work with UCD principal. Especially this model cut the research and design work into two parts and reduced the level of complexity of UCD. Hence this model can promote the use of UCD in the small companies or companies with small budget. The research constraints were given, as well as future suggestions.

Empathic Design. This is an approach to UCD where the designer attempts to get closer to the lives and experiences of users and to apply the knowledge from end-users during the design process. The goal of empathic design is to ensure that the product or service is designed to meet the needs of the end-users and is usable. Nevertheless, the users are only indirectly involved in the design project. It therefore tends to become 'designer-centred' instead of UCD. Additionally, professionals in empathic design promote the use of observation [2], although sometimes it is difficult to have the chance to freely observe the users in a particular situation. In addition to this, the involvement of users requires the design to need more skills and costs. Consequently, in the proposed model, "personas" are used to overcome these issues and enhance the use of empathic design.

Personas. Since Alan Cooper [4] first promoted personas in his book, "The Inmates are Running the Asylum", personas have been widely used in the computer science domain. Personas provide user profiles that can represent a group of people. The two main benefits of the use of personas are for communication between teams and to help designers to focus more on their users. More findings, in terms of the use of personas, have been researched by Microsoft. In their work, they used personas to develop their popular software, such as "Office" and "Messenger", finding that the use of personas was a great benefit to design tasks. In addition, famous Japanese businesses are using them for organisation communication.

During this research, the authors used personas as the key technique and, inheriting many of the advantages from work previous to this research, we intend to investigate how personas can help a designer to develop their product concept in their individual work. In other words, this research will not concentrate on communication between teams, one of the biggest beneficial functions. Instead, this research will analyse the aspects that the individual designer can use to connect UCD. In addition, although plenty of research addressed the work of creating a persona, lack of literature addressed on the evaluation of the area where designers have less UCD experiences.

2 Methods

The aim of this study is to assess a cost-effective UCD model to benefit designers' idea generation in order to promote UCD to non-UCD designers. However, this model is also suitable to compensate general UCD design method when the user is not available. Additionally, there are two main objectives of this research:

1. To launch the proposed model and compare with the results before the use of the proposed model. In addition, the satisfaction of designers in using this proposed model will be surveyed by questionnaires.
2. To evaluate the effectiveness of the proposed model with preset target users. This is to access if the effective UCD model can actually be user-preferred.

Based on the objectives, we selected methods for two-phase assessments and a final UCD evaluation with preset target users. For the first objective, we tried to conduct the proposed model and compare the data after use proposed model and before. In addition, designers' satisfactions were survey and further expertise opinions were used to refine the model. The methods we selected here are the questionnaires and the think-aloud for the small design tasks.

The second objective was implemented from users' vision. We used the results of idea generation by designers to assess with the preset target users, who are the 25-34 office female workers.

The proposed model: empathic design with personas: As introduced in the previous sections, the empathic design focuses more in the early stage of design and would be a possible cost-effective method if we set the "virtual users" in this proposal. As we called "virtual users" here, is to differentiate between other UCD approaches In other words, we only took the idea of "empathic" to understand and think like the users instead of traditional observations from users. As a result, due to the lack of real user involvement, empathic design is an economic approach compared to participatory design and contextual design. In addition, we adapted the personas to reinforce the existence of the users.

Based on the concept above, Chen et al. [5] constructed the personas-based model. The model aimed to make personas be integrated into designers' current work. Moreover, the use of personas and the creating of the personas were cut into two parts in order to make the proposed model more modularized to adjust the sequence of work-flow when it is needs. The model also suggested making the creation of personas to be as simple as possible since practitioners have less research background. Also, the amount of personas can be acquired subjected to the need of designers. The other benefit from this model is that this model only tells designers to look the generated personas when each idea is generating. It does not need very complicated skill to manipulate. The model is shown in Figure 1.

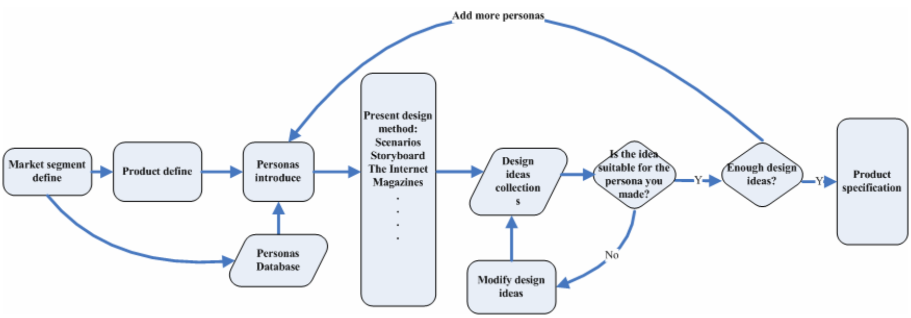

Fig. 1. The demonstration of the cost-effective UCD model

The Plan of the Assessment with Designers: Accordingly, we have arranged a two-phase assessment with designers and one assessment with end users. The purpose of the two-phase assessment is to get the generated ideas and compare them. Furthermore, the target users in the final evaluation will evaluate the idea set. The illustration of the two-phase plan is showed in Figure 2.

Fig. 2. The Illustration of the two-phase assessment with designers

We invited 16 designers to participate in the experiments. Even though this research can be relevant to various product categories, the researchers defined some control factors in order to examine the comparable information in this experiment.

Firstly, we assigned the same product in all the design tasks in which designers were asked to develop their product concepts. Additionally, the participants were required to have a similar background and to be able to manage the development of a design concept for a single product. Moreover, the designated task was confined to designing a product for use by an individual instead of a multi-user product. Each designer-participant spent about 30 minutes undergoing interviews and the design tasks. Besides, the design task needed to contain the appearance, function and usability in order to project the three emotional layers.

The authors chose a portable MP3 player for the group “ages 25-34, office workers” as the experimental task. MP3 player is mostly for individual use. Some product such as a remote controller is a multi-user device, which will bring more complicated factors to the research. Therefore, a personal use product was specified to simplify the use of the personas.

Assessment Phase I (The Investigation of the Current Design Pattern). In this task, we are going to examine whether the designers could focus on users to launch emotional design, and to find out the current design problems.

Assessment Phase II (The Investigation of the Use of the Model). The second phase is to introduce the personas-based model in order to investigate how they can help with the design task. Before the task is examined, some assumptions are proposed: The designers are trained to have the common design skills and they are assumed to have the imagination for the operation of fictional characters. Otherwise, the participants and the target task remained the same as for the first phase.

The persona should be developed from the anthropology survey, except for the name and the photo, according to the previous literature. This is to avoid stereotyping a persona from familiar names and photos. Additionally, for reasons of ethics, it is essential to protect any private and personal data. Therefore, this study licensed photos from the FERET database which is usually used in face recognition. The database captured various emotions from each person. Nevertheless, in this experiment, we only took smile face to link the emotional design as the example photos in Figure 3 left side.

The point of this research is the assessment of understanding designers’ current work of idea generation by the personas-based model for them to easily design for users. Therefore, this paper will focus the interaction between designers and the personas since there has been plenty of literature addressed the personas generation. Accordingly we simply followed the literature in order to generate a suitable persona. Olsen [6] offered the guidelines for creating personas and Pruitt and Adlin [3] provided more knowledge about personas in their book.

In terms of the photo, as the conditions of the tasks which specify the age and the gender, we randomly picked up a photo from the database above. Additionally, the names were chosen from the most popular UK names on the website. The profile of the persona was taken from a lady who was located in our target market segment. Due to the limited task time available, the authors only assigned one persona and assumed this lady is the archetype of this group s the illustration on Figure 5.right side shows.

Fig. 3. The left side is example photos from the FERET database. The right side is the persona in this task.

Task 2 took 10-15 minutes and the participants were asked to design, applying the same conditions as the first phase. The only difference was they needed to develop their concept using the specified persona provided. The persona is located within the same market segment, "25 to 34 year-old office female workers".

The Plan of the Evaluation with Target Users. This stage aims to evaluate the effectiveness of idea generation from the proposed model. This user group (25-34 office female workers) is the target when the designers do the design during the assessment. First, we grouped the ideas into two set, one set is the ideas generated before the use of the model; the other is the ideas after use of the proposed model. Next, we put the 16 sets of ideas of portable MP3 players randomly into the options. Then we invited the users to do the online questionnaires. The last part is to analyze the data to see which set of ideas were more preferred by these target users.

3 Results and Discussions

The industrial designers were interviewed in the first two stages. There were eleven senior designers with more than five years of work experience. Five of them were junior designers with between six months and up to five years experience.

However, six of the designers felt that they needed to study the market on their own before they designed. Consequently, to avoid unfairness in the experiment, the researchers further confined the task. We provided the same product information and only asked them to develop their product ideas.

Furthermore, the designers were asked to describe their current methods of practising idea generation and their general design cycle for a project. Interestingly, when the question was asked, "Does the user matter in your design projects?" only six of them answered "Yes", whereas nine responded that they did specify users but tried to ensure the design covered all user groups in order to gain maximum benefits. This demonstrated the current design problems that designers were usually asked to do design greedy cover the market as a result they seems destructive and confused the real user group as we will see this phenomenon in the following design task. The final participant believed that users were not important in their design. We also asked them how much they understood emotional design. Surprisingly, only one of them showed an understanding. Most of them either said they had never heard of it or they had heard of it but they did not exactly understand the definition of emotional design. These patterns will be examined in the design task to see if the interview answers were identical to their design behaviour.

With regards to the design behaviour, several methods were used to inspire design ideas. Most of the designers tended to get the design concept by sketch, brainstorming and information gathering. Later, we gave them a design task that followed their current methods. Before doing this task, a question was asked in order to record whether they had designed a similar product before. Four of them had designed once for the same market segment and two of them had designed the same product. This information was taken in order to compare whether trained-effect factor contributed towards any bias in the design process that we asked participants to do.

One important data of this stage is to understand the difficulties of practising UCD. None of them said that they have not heard the principle of UCD. And within all these designers, they do not have experience of gathering real users to explorer their needs and responses. They reflected that the design projects were mostly doing without real users' involvements. This problem was blamed to the short design schedule and no extra cost was given for them to do this kind of user research. Some other difficulties of practising UCD will be revealed in the task in which designers were asked to generate their design ideas on their own.

Results from Phase I of the Assessment (Before the Use of the Proposed Model). This part of result shows how the designers developed their product concept before using the proposed model. As can be seen, six of them were product-centred, which means the designer only considered the product elements to make it pretty, regardless of the user. Three of the designers tended to be designer-centred with five tending to be both designer-centred and user-centred. Finally, two of the designers were user-centred, but were easily distracted. While the assessment of this task, the designers were asked to sketch only due to the limited of time and to make the process keep consistent for every designers.

When analysing the interview results, we found that one of the weaknesses of the designers' present work is that, regardless of their experience, there was less user-centred design. When we examined the status of the user-centred designers, when interviewed, the participants expressed that they were designing for the users. However, during the design tasks, the UCD designers were, unconsciously, designer-centred rather than user-centred. Another finding was that even though two of the designers said they had undertaken emotional design before, they actually regarded that "appearance design" meant emotional design.

Another drawback was that most of the designers were concerned with the design shape rather than functional design. Hence, we may summarise that the designers, without the support from a user research team, tended to ignore the users in their design.

Results from Phase II (The Investigation of the Use of the Model). The design task followed the same conditions as the previous task.From interviews and observations, the designers were able to explore more design ideas. Additionally, the designers were found to use shorter timescales to make decisions. There might, however, be some errors attributed to the training effect due to the same product for the same users assigned to the same designers twice. However, the supportive point from the interviews is that three of them had done the “MP3” project for the same group and one of them had designed the same product for a different group. However, there was no significant difference to the other designers.

One more important finding came to light when they were asked whether they felt the later concepts they made contradicted the previous task. All of the designers who were designer-centred and product-centred felt that the later designs were more likely to be suitable for the 25-34 year-old office female workers. However, the designers with more UCD in Task 1 said they did not feel there was a contradiction. They felt that Task 2 helped them to specify a design concept, such as a warm colour domain or a specific colour.

The designers would get a general image of this user by the photo, name and essential profiles, such as age and gender. Then they gave a rough appearance and sensory design. When the designer looked through the detail, they usually narrowed down the ideas in relation to the reflective part. Furthermore, they started to get inspiration from combinations of the details in order to provide a functional design, which is mapped to the behavioural level. However, we have no clues from the interview that they can do the visceral design by the provided personas.

In general, the participants were satisfied with the use of personas and felt surprised at the effect of them. They commented that the personas did help them to think about users’ emotion all the time without distraction. Also, they felt that this tool can help them towards self-communication and enable them to examine the ideas they made.

From the comparison of the task before and after the use of the persona, we can see the design tendency converged to a similar colour domain in aesthetic design. Regarding to functional design, ideas are fruitful but still stick on the users. In addition, when designers undertook the task using the persona, they tended to design quicker and concentrate more.

Furthermore, by conducting the phase II, we got an impressive finding in this experiment. This proposed method not only reached to empathic design, but also, designers do not need to be trained for this method. Even they do not know much about the theoretical part.

Results from the evaluation with users: There were 51 effective answered from online questionnaires, and all of them are Taiwanese office ladies with the age from 25-34. We labelled answered set of ideas into two categories: Proposed Model (A) vs. Original Design (B). And there were 16 sets of ideas from 16 designers designed before and after (the use of the proposed mode). The original data of sixteen sets from were shown in Table 1.

We used the paired-T test to analyze if the data is oriented to Group A (idea generated by using the proposed model). And the result shows most of the target users preferred the ideas generated by user-centred model as shown in Table 2 and Table 3.

Table 1. The votes from target users

No. of designers' idea set	*Vote counts from 51 preset target users A (ideas generated by using the proposed model*	*Vote counts from 51 preset target users B (Original ideas)*
1	28	23
2	23	28
3	38	13
4	44	17
5	37	14
6	41	10
7	44	7
8	26	15
9	14	37
10	30	21
11	15	26
12	33	18
13	25	26
14	39	13
15	33	18
16	20	31

Table 2. Paired Sample Statistics

	Mean	***N***	***Std Deviation***	***Std Error***
Group A	30.25	16	9.191	2.298
Group B	19.19	16	8.758	2.189

Table 3. Paired Sample Test

	Paired Differences							
				95% confidence Interval of the difference				
	Mean	Std D	Std Err	Lower	Upper	*1*	*df*	*Sig(2-tailed)*
Paired A-B	**11.063**	**17.582**	**4.396**	**1.694**	**20.431**	**2.517**	**15**	**.024**

These results show that even the idea generation by the proposed model is just a short time test. The model still can bring significant effect to the design work. And therefore the evaluation of the work made this research more complete.

Research Limitations. Some constrains were existed in this studies. First, the duration of task arrangement is limited, that may lead designers to design not as well as they usually do. Additionally the short period of time made the ideas less concreted. Second, the designers were asked to use one of their current design methods: sketch. Sketch is the most common skill of designers and hence it is good for the comparison in this assessment. However, some of the designers may tend to use more method to benefit their idea generation. Hence this part may contribute the bias of this task assessment.

4 Conclusions and Recommendations

In phase I, we found that during the original design, the design is easily distracted from users. And the assessment from designers showed the high satisfaction of using the proposed model. Besides, when evaluated the idea generation, the statistical results showed that the ideas generated by interacting with users were more attractive to the preset target users. This model is able to lead non-UCD designers to undertake UCD without needing to be taught further design knowledge as well as to design both aesthetics and functions.

Continuing on from this research, the authors would suggest to develop a CAD tool to assist the use of and collection of personas, since most designers have difficulties of generating personas. Therefore, this research suggested putting the personas generation separately. And the CAD may rise the willing of use.

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Numerical Analysis of Geometrical Features of 3D Biological Objects, for Three-Dimensional Biometric and Anthropometric Database

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Abstract. This article presents application of modal analysis for the computation of data base of biological objects set and extraction of three dimensional geometrical features. Traditional anthropometric database contains information only about some characteristic points recorded as linear or angular dimensions. The current face recognition systems are also based on the two-dimensional information. Such biometric systems are used obviously during passenger control on the airport or boundary crossing. To increase level of security the methods need to operate on three-dimensional data. In the article authors present method of 3D modal analysis for decomposition, extraction features and individual coding of analyzed objects sets. Authors apply empirical modal analysis PCA (Principal Component Analysis) for two types of 3D data: human femur bones and human faces. Additionally for face recognition, as support information, the thermal (infrared) images was tested. In this paper the results of PCA analysis of each type of database were presented and discussed.

1 Introduction

Many engineering CAD technologies have an application not only in mechanical design but also in different disciplines like biomechanics, bioengineering, biometrics, etc. This interdisciplinary research takes advantage of reverse engineering, 3D modeling and simulation, modal analysis and other techniques. The 3D virtual models have a numerous applications such as visualization, medical diagnostics (e.g. virtual endoscopies), pre-surgical planning, FEM analysis, CNC machining, Rapid Prototyping, advanced digital calculations, etc. Several engineering technologies can be used for advanced analysis of biological objects. In further chapters the two applications, anthropometric (femur bones) and biometric (human faces) of three-dimensional models will be presented and discussed. For biometric database the thermal (infrared) images was tested as support information.

1.1 Biometric Technology

With the expansion of international traffic and globalization of the world, the necessity of research of new methods in security systems is increasing. The security and

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access systems are very important and rapidly advancing, not only in computer vision. Such systems are used obviously during passenger control on the airport or boundary crossing [5]. Biometrics identify people by measuring some aspects of individual anatomy or physiology – such as hand geometry or fingerprint, some deeply ingrained skill, or other behavioral characteristic – handwritten signature, or something that is a combination of the two – voice [1]. In generally the biometrics can be sorted into two types [2]: a) physical – face, fingerprint, hand/finger, iris, ear, retinal, DNA, vein, blood pulse, dental, lips, nail; b) behavioral – voice, gait, tapping, signature, keystroke dynamics, mouse dynamics. The face recognition method is the oldest and the most "natural" method of identification person's. Recognizing people by their facial features is going back at least to our early primate ancestors [6].

The disadvantage of the most commonly used recognition techniques is their insufficient reliability [3]. A 2D dimensional photo cannot be measured like a landscape and simply doesn't contain the same amount of information as the 3D photo. This problem is especially essential for twins, when the similarity of face shape is very high.

Facial identification reads the peaks and valleys of facial features. These peaks and valleys are known as nodal points (80 nodal points exist in a human face, but usually only 15-20 are used for identification – known as „Golden triangle" region between the temples and the lips [4].

1.2 Anthropometric Database

Traditional anthropometric database contains information only about some characteristic points (other parameters are not collected). The set of the bones is described only in two-dimensional space, by the collection of linear and angular dimensions (Fig. 1). Three-dimensional knowledge about mean geometry of the bones does not exist. For using CAx tools the 3D geometrical model is required. The problem is insufficient information in existing databases.

2 Methods

In presented research the modal method is used for statistical analysis and to minimize the number of parameters which describe 3D objects. One of the methods based on modal decomposition is PCA (Principal Component Analysis, known also as POD – Proper Orthogonal Decomposition). The empirical modes (PCA) are optimal from the viewpoint of information included inside each of the modes (Holmes, Lumley and Berkooz, 1998). In PCA analysis the 2D and 3D data can be used. This analysis requires the same position, orientation and topology of the data for all objects. To achieve this, each object in database must be registered.

2.1 Acquisition of Input Data – 3D Scanning

For obtain the 3D input data the 3D scanning system (the structural light scanner) was used. The two groups of biological models were measured: set of human faces and set of femur bones. Each input object was scanned and 3D surface model was computed.

To increase the accuracy of PCA analysis, each face was described (Fig.1.) by individual point cloud (40k points) instead of few markers from "Golden triangle" area.

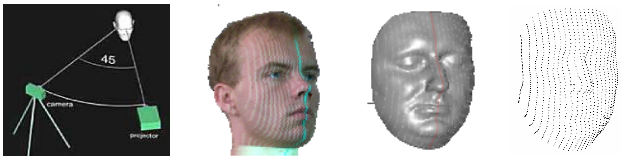

Fig. 1. Data acquisition process (from left): hardware configuration, captured image, 3D curve network, input data set (points cloud)

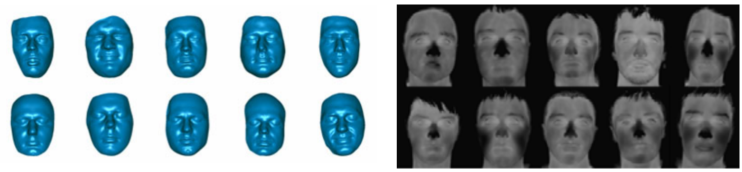

Fig. 2. An example of the models in database (from the left): 3D faces, 2D thermal images

Database for biometric PCA analysis is prepared onto the multiple human faces. There are 39 faces (Fig. 2.) with neutral expression of different persons. To improve sensitivity of presented method, three sets (6 faces) of the twin's faces in the database were included. There are two sets of identical – monozygotic twins and one set of fraternal – dizygotic twins.

Second part of input data for biometric database is set of two-dimensional infrared images (thermal images). In this research the thermal images of 17 different persons were collected (Fig. 2.). For acquisition of infrared images the thermal camera was used. All pictures were collected in the same conditions of the measurement: room (+22^{0}C) and camera settings: matrix VOx 320x240 pixels, thermal resolution +/0.03^{0}C, range of measured temperature: 26-40^{0}C.

To create an authentic 3D anthropometric database (second 3D database for PCA analysis), the set of real femur bones was used. In this work 15 femur bones were used (6 female and 9 male – bones obtained from Poznan University of Medical Science). Each bone (Fig.3.) was described by individual point cloud (1.5mln points) and triangle surface grid (30k elements).

2.2 Data Registration

The Principal Component Analysis requires the same position, orientation and topology of the data input (the same number of nodes, matrix connection, etc.) for all objects. To achieve this, each new object added to database must be registered.

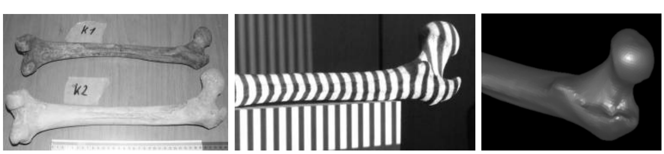

Fig. 3. Data acquisition (from left): input femur bones, measurement process, final triangle surface grid

For face the origin point of coordinate system is arranged in cross section of two lines: vertical middle line on the face, horizontal – eyes line. The registration is made in two steps. First step (preliminary registration) is the rigid registration. It consists of simple, affine geometrical transformation of object in three-dimensional space (rotation and transformation). For control of this process three points are used: two points in the centers of the eyes, one on the top of the nose. The second step is connected with curves extraction. Independently from face size, always 201 curves on face are only. To achieve this, scaling of space between curves is used. For infrared images only the first step of registration was done.

The registration of bones is made also in two steps. First step (preliminary registration) is similar rigid registration. The second step is the viscous fluid registration. For this registration the modified Navier-Stokes equation in penalty function formulation (existing numerical code [9]; source segment [8]) is used (4):

$$\underbrace{\dot{V}_i + V_{i,j}V_j - \frac{1}{\mathrm{Re}}V_{i,jj} + \frac{\varepsilon-\lambda}{\rho}V_{j,ji}}_{\text{existing numerical code}} + \underbrace{(f-g)f_{,i}}_{\text{source segment}} = 0 \tag{4}$$

where ρ - is fluid density, V_i - velocity component, Re - Reynolds number, λ - bulk viscosity. In this application, parameters ε and λ are used to control the fluid compressibility, f is the base object and g is the target object (input model). The object is described by the grid nodes. The displacements of the nodes are computed from integration of the velocity field. Computed flow field provides information about translations of the nodes in both sections. After computation we obtain dislocation of nodes of the base grid onto new geometry (Fig. 4.).

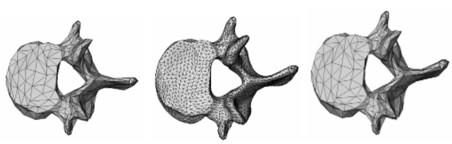

Fig. 4. Grid deformation (from the left): base object (base grid), new object inserted to database, base grid on geometry of the new objects

2.3 Principal Component Analysis – Empirical Modes

PCA transformation gives orthogonal directions of principal variation of input data. Variation is described by eigenvalue related to the first principal component. The second principal component, describe the next in order, orthogonal direction in the space with the most large variation of data. Usually only few first principal components are responsible for a majority variations of the data. Data projected onto other principal components often has small amplitude, lower than value of measurement noise. Therefore they can be deleted, without danger of decreasing the accuracy. The used algorithm is based on statistical representation of the random variables.

The shape of the each object is represented in the data base as the set of 3D point clouds. Each point clouds is described by a vector (1):

$$S_i = [s_{i1}, s_{i2}, \ldots, s_{iN}]^T,\ i = 1,2,\ldots,M, \tag{1}$$

where $s_{ij} = (x, y, z)$ describes coordinates of the points in Cartesian system, M is the number of the faces which are in database, N is the number of the points in single point cloud. In the next step the mean shape $\overline{S}$ and covariance matrix C are computed (2):

$$\overline{S} = \frac{1}{M}\sum_{i=1}^{M} S_i\ ,\ C = \frac{1}{M}\sum_{i=1}^{M} \widetilde{S}_i \widetilde{S}_i^{\ T}\ , \tag{2}$$

The difference between mean and object that is in data base are describe by the deformation vector $\widetilde{S}_i = S_i - \overline{S}$. The statistical analysis of the deformation vectors gives us the information about the empirical modes. Modes represent the geometrical features (shape) but also can carry other information like texture, map of temperature and others. Only few first modes carry most information, therefore each original object S_i is reconstructed by using some K principal components (3):

$$S_i = \overline{S} + \sum_{k=1}^{K} a_{ki}\Psi_k\ ,\ i = 1,2,\ldots,M, \tag{3}$$

where Ψ_k is an eigenvector representing the orthogonal mode (the feature computed from data base), a_{ki} is coefficient of eigenvector.

3 Modal Decomposition of 3D Objects – Empirical Modes (PCA)

The numerical experiment of modal decomposition is prepared onto three sets of input data: a) 3D human faces, b) 2D thermal images of human faces, c) 3D human femur bones. In the next sections results of PCA analysis of the input data sets are presented.

3.1 PCA Analysis of Human Faces – Biometric Database

For prepared database of human faces the PCA analysis was performed. The result of this operation is the mean face, nineteen modes and a set of coefficients (Fig. 5.).

For presented analysis the eighteen modes include one hundred percent of information about decomposed geometry (Table 1.). Nineteenth and furthers modes contains only a numerical noise. Modes describe the features of the faces. Two first modes characterize global transformation: first mode the changing of the face size in vertical direction and deep of eyes, second mode changing the size in horizontal direction. Further modes describe more complex, local deformations.

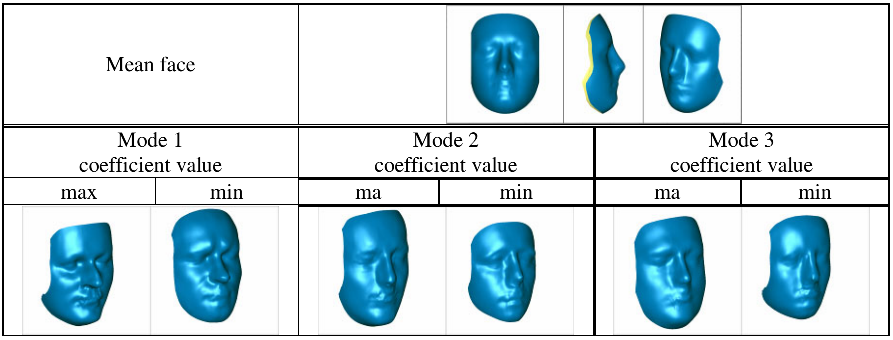

Fig. 5. Visualization of the mean face and first three empirical modes

Table 1. Participation of the first 10 modes of PCA decomposition of 3D faces

Number of the mode	Participation of the mode [%]	Total participation of the modes [%]
1	41.3730939	41.3730939
2	20.4650772	61.8381711
3	14.1903043	76.0284753
4	8.6513257	84.6798011
5	3.4490109	88.1288119
6	2.5576350	90.6864469
7	2.1880060	92.8744530
8	1.3711281	94.2455811
9	1.1804560	95.4260371
10	0.9962907	96.4223278

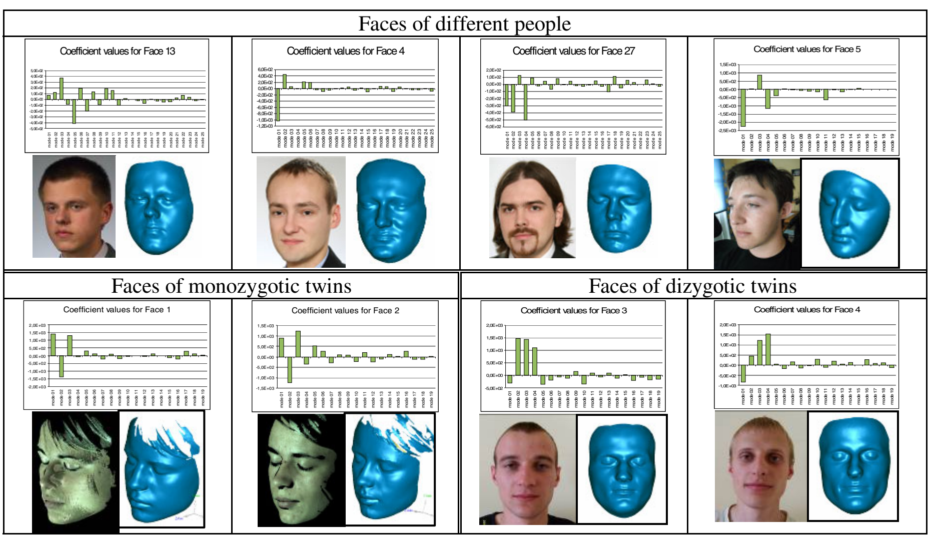

Fig. 6. Face "ID code" for few faces from database and for faces of two types of twins (for each object is presented – graph of coefficient values, original photo and 3D face model)

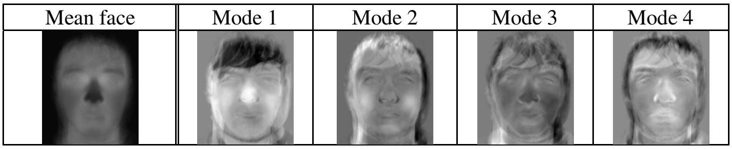

Fig. 7. Visualization of the mean face and first four empirical modes of infrared images

Each face in database has unique set of coefficient values – "ID code" (Fig. 6.). As the authorization key the set of coefficient values for the faces can be used. Each key describes individual shape of face and can be decoded and compared with the original data of user to obtain access to restricted area or data files. Also identical (for human eye view) monozygotic twins might be distinguished using these "faceprints" as well as traditional fingerprints [7].

As a support for three-dimensional face recognition, additional information – the thermal images – was used [10]. The two-dimensional infrared images can be added to database as a fourth dimension.

For prepared infrared images of human faces the PCA analysis was done. The result of this operation is the mean face (Fig. 7.), seventeen modes and set of coefficients.

Table 2. Participation of the first 10 modes PCA decomposition of thermal images

Number of the mode	Participation of the mode [%]	Total participation of the modes [%]
1	26.4191478	26.4191478
2	16.7302890	43.1494367
3	10.9104597	54.0598965
4	8.3397586	62.3996550
5	6.5525733	68.9522283
6	5.6298384	74.5820668
7	4.4142731	78.9963398
8	3.6441677	82.6405075
9	3.3063140	85.9468215
10	2.7908036	88.7376251

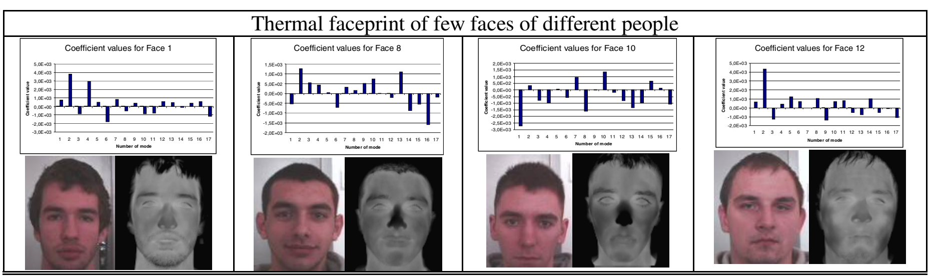

Fig. 8. Thermal faceprint for few faces from infrared database (for each object is presented – graph of coefficient values, original photo and thermal image)

For presented analysis the sixteen modes include one hundred percent of information about decomposed thermal images (Table 2.). Seventeenth mode contains only a numerical noise.

Similarly to 3D data, each infrared image of the face in database has unique set of coefficient values – “thermal faceprints” (Fig. 8.). This additional information can be associated with 3D data to increase the level of security and can complicate the trials of fake the system.

3.2 PCA Analysis of Femur Bones – Anthropometric Database

For prepared database of bones the PCA analysis was done. The result of this operation is the mean object, fifteen modes and coefficients. The first fourteen modes include 100% of information about decomposed geometry (Table 3). Fifteenth and further modes contain only a numerical noise and they are not used for further calculations.

Modes describe the features of the femur bones (Fig. 9.). The first mode describe transformation of the length of the femur bone. Second mode represent position conversion of the head of the bone, third describe change the arc of the shaft (body). Further modes describe more complex deformations.

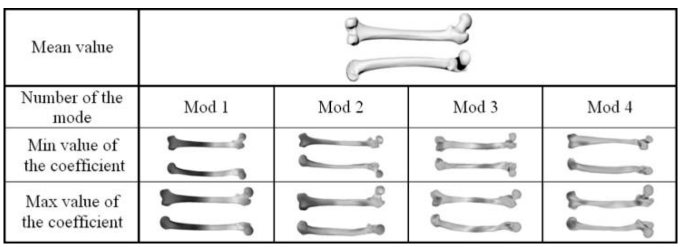

Fig. 9. 3D visualization of mean value and first eight modes of femur bones (anterior and posterior view)

Table 3. Participation of the first 10 modes in face PCA decomposition

Number of the mode	Participation of the mode [%]	Total participation of the modes [%]
1	74.9212416	74.9212416
2	10.5438352	85.4650767
3	4.2699519	89.7350286
4	3.3128685	93.0478971
5	1.6659793	94.7138765
6	1.4234329	96.1373093
7	1.0359034	97.1732127
8	0.6781645	97.8513772
9	0.5866122	98.4379894
10	0.4796167	98.9176061

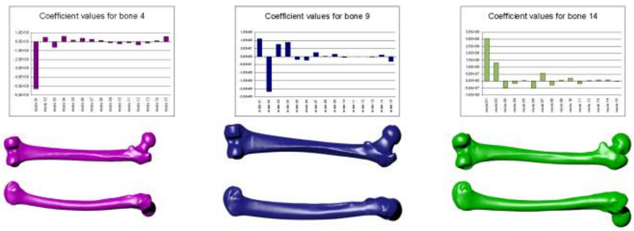

Fig. 10. Correlation between coefficient value and geometry of the bone for three different femur bones (all pictures of bones are made in the same scale)

In this experiment, the value of average error for reconstructed geometry of the bone was equal to 0,3mm (reconstruction based on 14 modes). Study of the values of the coefficients gives us additional information about the analyzed bones. For presented database, correlation between coefficient value of first mode and gender was found. Negative coefficient value "-" is connected with female bones, when positive coefficient value "+" was describe male bones.

Other interesting feature of PCA decomposition, is individual set of coefficients values for each bone. This aspect is similar to "fingers prints". Because each bone has different geometry it also has individual set of coefficient values (Fig.10).

4 Conclusions

Three-dimensional PCA analysis makes possible the extraction of mean shape and geometrical features of biological object set. Presented method as the source of data input apply full 3D information instead set of "control" points.

3D faceprints are more proof onto fake than 2D face biometric recognition systems. Further is possible to add to data base additional information's (not only geometrical data) like e.g. thermal photo (map of temperature). Application of 3D PCA into biometric security systems make possible using 3D faces as the access code. Each face has individual set of coefficient values – individual 3D biometric code. That information can be easily recorded onto electronic ID card – similar to 2D biometric data's. Advantages of this method is possibility of distinguish of identical monozygotic twins what is frequently very difficult for standard security systems. Disadvantage of infrared images is very strong influence of outdoor temperature, on a thermal map of the face.

Another application of 3D PCA analysis can be development of full 3D anthropometric database of the skeleton system. One of the advantages of that database is the possibility of quick measurement of any necessary dimension on the surface of the mean bone (mean shape characterizes whole 3D body of the bone). Additional mean shape and geometrical features (knowledge about shape and trends of deformations) can be used to create new universal types of prosthesis. Such 3D PCA analysis also can be important in anthropology, gives us information about the changes that appear in the human skeletal structure in different populations or ages.

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Part II

Older People in the Information Society

Designing Interactive Pill Reminders for Older Adults: A Formative Study

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Abstract. Introduction: The real challenge for information technologies is not content or curriculum development, but the development of interactive mechanisms by which to make information individually relevant, timely, and, tailored to promote information sharing. At first, this article reviews common technological approaches accessible to elderly that are intended to increase adherence to medication. Then, in a formative process the study proposes a novel framework to design and evaluate an interactive automated pill reminder for older adults. The proposed interactive pill reminder offers a solution by dispensing medication to the elderly in a way that is secure, routine, and monitored by their physician or pharmacist. Considering the interaction tasks between the device and a physician or pharmacist, coupled with their work schedules, the device is designed so that it is simple enough for the industry to absorb it.

Background: Non-adherence among patients has been identified as a major public health problem that imposes a considerable financial burden upon modern health care systems. This burden includes 10% of hospital admissions, 23% of admissions to nursing homes and has been estimated to cost $100 billion each year in the US. Information technology has been used both to measure and enhance adherence. Measurement has been through advanced technologies, such as smart pill-bottle caps, to capture medication-taking behavior and using information technology to collect and synchronize both frequency and time of opening of the medication bottle, with a central database.

Methodology: The development of the pill reminder includes three main stages: (1) Designing the high fidelity prototype based on heuristics and available guidelines and collecting necessary information applicable in the design of the interactive pill reminder (i.e., user requirement analysis, general requirements of small screen devices, and design principles for older adults); (2) Pilot testing the mid-fidelity interactive pill reminder prototype and analyzing the results (i.e., examining the mid-fidelity product by user interviews, a focus group, and a usability questionnaire); and (3) Proposing a list of tasks to improve the future high-fidelity prototype (i.e., proposing future high-fidelity design heuristics).

Conclusion: Non-adherence to medication is a major health burden specifically in the elderly population. Designing new automatic pill reminders for elderly can open new ways to improve adherence rates among them; however, more formative research needs to be conducted to establish preliminary design guidelines in designing such reminders. This study collected necessary information applicable in the design of the interactive pill reminder. The result was the development of a high fidelity prototype for an automatic pill reminder.

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1 Introduction

Non-adherence among patients has been identified as a major public health problem that imposes a considerable financial burden upon modern health care systems [15]. This burden includes 10% of hospital admissions, 23% of admissions to nursing homes [21] and has been estimated to cost $100 billion each year in the US [15].

Context: Adherence among older adults should be increased. This can be applied by integrating an interactive design into a pocket size pill dispenser. Furthermore, pill dispensers should be secured (e.g., no access by children). Pill dispensers should also dispense only the pills that are required for a specific dose intake. An ideal interactive device should manage the reminder and the dispenser systems simultaneously.

Use: Interactive pill reminders should focus on this problem and offer a solution by dispensing medication to the elderly in a way that is secure, routine, and monitored by their physician or pharmacist. Considering the interaction tasks between the device and a physician or pharmacist, coupled with their work schedules, the device should also be designed so that it is simple enough for the industry to absorb it.

People: Primary users will be older adult patients that are required to take a long list of medications (e.g., complex diseases) for an extended period of time (e.g., chronic patients). Secondary users will be doctors and pharmacists who could upload and maintain the data necessary to continue the effectiveness of the device; however, these users will not be studied in the scope of this proposal.

Importance of Product: Lack of complete adherence to the medical regimen transcends the boundaries of disease categories and age groups [20]. Without intervention, adherence rates to long-term medication in high income countries are approximately 50% [18], while adherence in low and middle income countries may be even lower [23]. Millions of people don't take their medication correctly [15]. The consequence of mistaking medication can be very dangerous or even deadly [9]. Many people forgot to take their medications regularly, which can complicate their medical problems and raise the chance of unforeseen hospitalized and clinical trial. Thus, non-adherence to medication is a crucial health problem. An effective automated pill reminder can reduce the aforementioned risks and problems and thus save billions of dollars for patients, insurance companies and the government.

This paper introduces a new conceptual design for an interactive automated pill reminder specifically designed to appeal the older adult population. The usability of the mid-fidelity pill reminder design will be further validated by various methods such as interviews, focus groups, questionnaires and a user evaluation study.

2 Background

2.1 Adherence to Medication

The word "adherence" is preferred to compliance by many healthcare providers, because "compliance" suggests that the patient is passively following the doctor's orders and that the treatment plan is not based on a therapeutic alliance or contract established between the patient and the physician [15]. Indeed, adherence is a more neutral term than compliance, which can be construed as being judgmental. Despite these differences, both terms are commonly used as descriptions of medication-taking behavior [15].

Winnick (2005) defines adherence as: "the extent to which a person's behavior coincides with medical or health advice" ([22], p. e718). The term compliance, defined as 'to consent' or 'to do as asked', has been used instead of adherence for many years [6]. Other definitions of adherence add components such as knowledge of medication, timely filling of prescriptions, exact dosage, accurate timing of the doses, approximate sequence of taking the drug, correct length of therapy, and on-time attendance for follow-up appointments [20].

Treatment adherence rates are typically lower among older adults, mental disorders, and patients with chronic conditions as compared to those with acute conditions [11]. Persistence with medical treatment regimens among patients with chronic conditions and elderly is also disappointingly low [12].

2.2 Importance of Adherence to Medication

The problem of non-adherence with medication is not new. Hippocrates advised physicians to "keep watch also on the fault of patients which often make them lie about the taking of things prescribed" [13]. In an extensive review of medication adherence research, it was found that approximately 50% of patients do not take prescribed medications in accordance with physicians' instruction [20]. Poor adherence is to be expected in 30-50% of all patients, irrespective of disease, prognosis or setting [14].

Medical non-adherence has also been identified as a major public health problem that imposes a considerable financial burden upon modern health care systems [14]. This burden has been estimated to cost $100 billion each year in the USA [15], including being responsible for 10% of hospital admissions and 23% of admissions to nursing homes [21]. Poor adherence to medication regimens accounts for substantial worsening of disease, death, and increased health care costs in the United States [15]. Increased health care utilization and costs are common outcomes of failure to adhere to treatment regimens [17].

2.3 Measuring Medication Adherence

There is no gold standard method to measure adherence [2]. Fielding (1999) argues that although adherence and health status are linked there have been few empirical tests of this association. Studies of adherence frequently confound these concepts, using measures of health status and adherence interchangeably [10].

Vermeire [21] expands on the relationship between health outcome and adherence to treatment and categorizes adherence measurement into process-oriented and outcome-oriented. In the process-oriented approach, medication-taking behavior is the center of measurement while in the outcome-oriented approach the clinical outcomes of adherence to treatment are measured. For example, studies measuring process-oriented adherence are concerned with the number of doses not taken or taken incorrectly that jeopardize the therapeutic outcome. On the other hand, studies that measure outcome-orientated adherence emphasize the end-result or outcome of the actions taken.

Rates of (process-oriented) adherence for individual patients are usually reported as the percentage of the prescribed doses of medication actually taken by the patient over a specified period. Some investigators have further refined the definition of adherence to include data on dose taking (i.e. taking the prescribed number of pills each day) and the timing of doses (i.e. taking pills within a prescribed period). This study of the interactive pill reminder for older adults will implement a combination of the dose taking and timing of doses in the adherence rate calculation.

2.4 Barriers to Adherence

Adherence research has focused on the extent and determinants of non-adherence, and strategies to improve adherence to treatment. Major predictors of poor adherence to medication include [15]: Presence of psychological problems; Presence of cognitive impairment; Treatment of asymptomatic disease; Inadequate follow-up or discharge planning; Side effects of medication; Patient's lack of belief in benefit of treatment; Patient's lack of insight into the illness; Poor provider–patient relationship; Presence of barriers to care or medications; Missed appointments; Complexity of treatment; and Cost of medication, copayment, or both. Claxton has argued that adherence is inversely proportional to frequency of dose [5] and thus considered the frequency of dose as a predictor of adherence rate.

Donovan [8] indicates that one of the major reasons for the lack of progress in compliance research is the absence of patient's perspective. Vermeire (2001) argues that barriers to adherence that are under the patient's control should attract more attention in research. More than 200 variables have been studied since 1975, but none of them can be considered as consistently predicting adherence: neither socio-economic nor pathology-related factors [21]. Research into a phenomenon as complex as adherence is inevitably fragmented, because of the absence of a model or theory to integrate the different studies [21].

2.5 Sample IT Applications in Medication Adherence

"Patients frequently cite forgetfulness as the most common reason for not taking medication. Therefore, interventions that improve memory are likely to enhance patient adherence. Several cost-effective strategies are available that may help patients remember to take their medication. Patients should be encouraged to develop a home dosing routine for their medication use - a routine that enables a patient to take their medication at the same time each day and that involves cues that prompt medication-taking rituals and enhance memory. Health care practitioners should encourage the use of medication adherence aids, such as calendars, pillboxes with built-in timer alarms, dosage counters, multi-alarm wrist watches, pagers with alarm and text reminders, medication diaries, phone reminders, computerized medication schedulers, and other adherence tools" [3].

Medication Reminder Software: Although various factors have been related to adherence, patient understanding of the illness and influence of treatment on it can affect treatment adherence. If information provided to the patients is individually tailored, it has a greater impact on patient behavior than providing generic information. In one such study on medication adherence in elderly patients with memory disorders, a

PC-based software application to provide individually-tailored medication information was developed. Programmed in Visual Basic, the application automates a critical part of an intervention that includes assessment of patient health care literacy, preferred language, and information needs. The application provides printed output that includes the patient's name and answers to specific questions endorsed by the patient. Output is provided at one of two literacy levels and in Spanish as well as English. Patient adherence to cholinesterase inhibitor medications prescribed for memory problems was assessed longitudinally with an electronic recording device. Preliminary data collected from the research study showed that the device had a high degree of patient acceptability. The data also indicated that the use of the tailored information device was associated with high levels of sustained medication adherence [16].

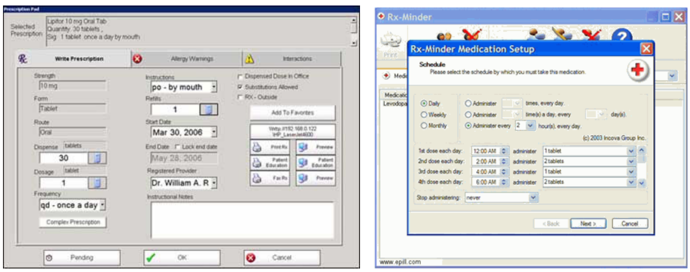

Fig. 1. PC-based Medication Reminder Software

Mobile Phone – SMS Reminders: Research has been done on wireless text messaging or SMS in improving people's adherence. It was found that innovative mobile healthcare solutions, based on portable devices like cell phones, may address some non-adherence aspects by helping outpatients to follow treatments agreed with their health providers [4]. A mobile application 'UbiMeds' has been developed to improve accessibility and support medication adherence for aging and disabled population [19]. In another pilot research study, customized messages were programmed into the user's mobile phones before they left their doctor's offices. As a result, a simulated SMS would arrive on the patient's phone when it's time to take the medication. The application on the phone also allowed them to anchor a medication event to a lifestyle event, i.e. always taken with lunch, so if your lunch schedule changes the medication reminder can, too. When it was time for a medication event the patient's phone would ring, a message would appear on the screen. When answered it asks the patient to touch the mobile phone to the medication bottle. The bottle had an embedded RFID chip, which can transfer information to the phone. The phone would then ask the patient if "X" is the medication they were taking and once confirmed, proceeds to instruct the patient on how to take the medicine. Every time the patient interacts with the application it records the event and confirms each event for clinicians to review from a Web portal in real-time or at a later date. This process resulted in an increase in 96 percent adherence in the pilot study [7].

Medication Event Monitoring System (MEMS): The MEMS monitors are drug packages with integral electronic micro circuitry designed to compile the dosing histories of ambulatory patients' prescribed medications. Each monitor consists of a conventional medicine bottle fitted with a special closure that records the time and date of each opening and closing of the container through integrated microcircuitry. Monitors are designed to be used by one patient with one drug. A reader transfers the dosing history data from the MEMS monitor to a MS-Windows based computer [1].

Fig. 2. Medication Event Monitoring System [1]

3 Methods

The design of an automatic pill reminder should go through multiple steps: (1) Collecting necessary information applicable in the design of the interactive pill reminder (i.e., user requirement analysis) and preliminary design of the pill reminder interface based on available guidelines and heuristics; (2) Pilot testing the mid-fidelity interactive pill reminder prototype and analyzing the results (i.e., examining mid-fidelity); and, (3) Proposing a list of tasks to improve the future high-fidelity prototype (i.e., proposing future high-fidelity). In the rest of this paper step 1, the preliminary design of the pill reminder interface through guidelines and heuristics, is explained. This is an ongoing research project and results of each step will be published separately.

3.1 Usability and Experience Goals of the Users

Based on the general requirements of small screen devices and design principles for older adults the following primary usability goals for users of the interactive pill reminder are developed:

Usability

- Effective - The Interactive pill reminder should aid the user by helping them load and consume the medications in exact amounts at consistent times each day. It will also have a calendar to help organize medications.
- Efficient - Loading medications should be simplified
- Easy to Learn - Using a touch screen, buttons must be clearly defined and intuitive. Appropriate feedback should be given for each action.
- Options/Flexibility - Color scheme, time, and the calendar should all be customizable to suit each user's preferences
- Safety-The user's personal and medical information should be stored in such a way that it is accessible only by the user (though with some exception to their primary health care physician, i.e. new/old prescription data, etc). And their medication must be kept safe in a secure sterilized compartment

Experience:

- Enjoyability - The user will be able to be more independent and have a greater quality of life
- Helpful - The personal calendar will allow the user to take command of not only their medications but personal life as well.
- Motivating – The Interactive pill reminder will inspire users to take their medications correctly
- Inviting – The Interactive pill reminder should be aesthetically pleasing, inviting the user to pick it up and interact with it through clear and clean menus, as well as right-brained icons and pictures.

3.2 User Requirement Analysis

Based on the literature review conducted on adherence to medication and a review of current pill reminders the following objectives and interactions are considered for the initial design of the interactive pill reminder:

Loading Medication

- Use a barcode scanner, similar to ones already used by Pharmacists to organize data - all relevant data will be uploaded to the interactive pill reminder database
- Interactive pill reminder will collection the following information:
    - Which time each day he/she would like to take medication
    - How many pills he/she must place in each compartment
- Compartments for each day of the week will possess LED's:
    - Container empty - no flash or highlight
    - LED on (but not flashing) - medication loaded
- Taking medication
    - Various alarms will go off
        - Vibration, aural, visual
        - Fingerprint will be scanned to ensure security
        - Before user is prompted to take medication, the screen will display:
            - The name, picture, dosage, and physical description of the medication
            - Display a button for a description of what the medication treats, as well as the information pertaining to the physician who prescribed the medicine
    - User will take medications, corresponding compartmental LED's will flash
        - As the medication is taken, the touch screen will prompt the user with a question, asking them if they have taken the medication
        - If "yes," compartments will stop flashing
        - If answer is "no" or user forgets specific interval - screen will flash, the alarm will sound at a higher pace, and the device itself will vibrate, as to alert the user

- Medication Database
  - Will have all known medications for reference
  - New medications can be added through Dr or Pharmacist via USB
- Miscellaneous
  - Possess a personal calendar - remind the user of personal dates (birthdays, etc), doctor appointments, and medication schedule
  - Wake-up alarm clock
  - Be small enough to fit in pocket
  - Be rechargeable

The initial list of aforementioned requirements (usability and user requirements) will be modified and updated based on the outcomes of the rest of the user requirement analyses to be performed in future steps.

4 Proposed High Fidelity Prototype

Based on the developed design guidelines based on the available guidelines for elderly the following high fidelity prototype is designed:

Fig. 3. Sample screenshots of the proposed prototype

5 Future Work

A user study is planned to complete steps 2 and 3 of the methodology:

User Interviews: 10 participants (both male and female) more than or equal to 65 yrs of age based on a convenient sample selection will be enrolled in a face-to-face interview. The interview will be based on semi-open questions.

Focus Group: 8 participants (both male and female) more than or equal to 65 yrs of age based on a convenient sample selection will be invited in a face-to-face focus group. Open ended discussion topics will be presented by the focus group leader.

Questionnaire: 20 participants (both male and female) more than or equal to 65 yrs of age based on a convenient sample selection will be enrolled in a mailed questionnaire. The questionnaire will mainly consist of Likert-scaled questions examining the usability of proposed design elements in the interactive pill reminder. The questionnaire will include open-ended questions to include any remaining issues.

User Interviews, Focus Group and Open Ended Questions of the Questionnaire: Grounded theory will be used to generate new ideas and a possible a hypothesis.

Likert-Scaled Questions of the Questionnaire: SPSS statistical package will be used to calculate the averages and possible significant differences in the facilitators and barriers to the adoption of the proposed interactive pill reminder

6 Conclusion

Non-adherence to medication is a major health burden specifically in the elderly population. Designing new automatic pill reminders for elderly can open new ways to improve adherence rates among them; however, more formative research needs to be conducted to establish preliminary design guidelines in designing such reminders. This study collected necessary information applicable in the design of the interactive pill reminder. The result was the development of a high fidelity prototype for an automatic pill reminder.

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Older User Errors in Handheld Touchscreen Devices: To What Extent Is Prediction Possible?

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Abstract. Touchscreen technology has been shown to offer advantages to older and novice users of digital products, through the relative ease of learning the interaction mechanisms and flexibility of the interface to provide explicit and contextual labelling enabling task sequences to be executed. Interaction problems caused by age related changes in sensory perception, cognition and motor skills are able to be predicted using the Inclusive Design Toolkit, however this technique is unable to predict usage problems caused by lack of prior experience of digital interaction patterns. This paper reports on the 'errors' that older users made in a pilot study using a tablet touchscreen device in the course of completing tasks such as turning the device on, setting an alarm and sending an email. An initial classification of the problems encountered by the users is made and the potential for prediction of such errors is discussed.

Keywords: Touchscreen, errors, older users, usability, prior experience.

1 Introduction

People who do not engage in the digital world, the digitally excluded, are more likely to be older, female and from a lower socio economic and educational background grouping [1]. Older users are likely to exhibit perceptual, sensory and motor skill degradations which will affect their interactions with technology devices, and in particular technology devices which are new to them, and/or exhibit unfamiliar interaction styles [2]. Differing generations also will have experienced differing interface styles during their impressionable younger years, and this can have an impact on interface expectations and expertise [3].

The proportion of the UK population who are unable to achieve certain interactions due to degradation of perceptual, sensory and motor skill performance can currently be estimated using the Inclusive Design Toolkit's exclusion calculator, by comparison of task difficulty to data collected by the ONS database [4]. For example, the exclusion calculator allows for the effects of a small sized font used on a display to be estimated in terms of the proportion of the population who will be unable to use it due to both age and disability related visual impairment. The calculator is able to predict

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the proportion of the UK adult population excluded through the visual, hearing, thinking, dexterity, reach & stretch and locomotion demands of the product. However, it does not take into account the prior technology experience of the users and their consequent expectations and familiarity with the wide variety of digital interaction patterns [5], nor of their fluidity of intelligence which affects their ability to accommodate to new ways of operating a device [6]. The fragility of learning of newly acquired declarative and procedural knowledge is also not addressed in the calculator. These effects have a very strong impact on the success or otherwise of the interactions that these users have with products with digital interfaces.

1.1 Background

Some digitally excluded people complain that technology is not for them, and hence that they don't want to engage with digital technology [1]. It is hypothesised that for people who don't have much digital 'prior experience', this perception is at least partially true: they do not have the pre-requisites to engage with interfaces that are almost always primarily designed for people with a reasonable level of digital technology knowledge. If a legitimate interaction design aim is to make digital technology accessible to people without the digital technology prior experience, it is important to understand their experiences with current technology interfaces, to see where the lack of knowledge and/or training hinders their goal achievement.

In studies with older low technology literate people using digital technology, the usual user performance measures such as time to task completion are not as important as the ability for the user to be able to make error-free progress to their goal achievement [7]. Error making can reinforce the negative feelings of confusion and stress, and frequently put the device into a state from which the user is unable to recover. Slow steady progress without error making is therefore preferable to quick error prone interactions which might be preferable for other user groups who are able to learn and recover from the erroneous steps more swiftly.

1.2 Errors

A major stumbling block for unfamiliar users using digital technology interfaces is when 'errors' are made, and the difficulty of recovering from them. These 'errors' are not the same category of error necessarily as those made by a user who is familiar with an interface or a task, who merely makes a slip in execution of a command. These 'errors' are perhaps closer in nature to those made during the process of 'trial and error' providing information to the user about the mental models required to operate the interface correctly. Although for some older people the concept of 'trial and error' as a mechanism for discovering how to use novel device can be at odds with the belief that 'playing with it will break it', and this can significantly impede the learning process for users holding this belief. Additionally, some errors are not discovered by the users, such as if an email is not sent to the correct address, or an appointment not set on the correct day or time in the schedule which can further disrupt the development of accurate mental models.

2 Method

Ten participants were recruited over the age of 55, (range 58 to 78) nine of whom had limited technology prior experience. After the initial explanations of the study purpose, and their rights during the experiment, they were asked to imagine that they had been sent the test device, a Samsung Galaxy Tab (see Fig. 1 for front view of device) as a present through the post, without instructions, nor was there available assistance to guide their interactions. It was however explained that the device was a kind of combination of computer and mobile phone, as well as the fact that it was a touchscreen device. The participants were asked to perform a selection of the following tasks:

- Turn the device on
- Enter a specific passcode to unlock the device
- Send a short email
- Set an alarm for a specific time
- Search the internet for the name of a friend or relative
- Leave the device in a state as if for half an hour
- Leave the device in a state as if going on holiday for two weeks

Fig. 1. Samsung Galaxy Tab– Front View Device Off

The participants were asked to explain what they were thinking while they attempted to do the tasks. They were also asked to explain each individual action before they actually performed it, but in practice most of the participants behaved as if they would in a conventional talk aloud protocol. All participants sessions were audio recorded and the experimenter recorded errors made, and five sessions were video recorded for more detailed investigation of user actions. The constraints of performing the majority of the sessions in the participants own homes had precluded the use of video for half the participants. Most participants were asked to complete all tasks, however for some less technologically experienced participants the experimenter made the decision that some tasks may tire the participants to the point at which they lose concentration and would not yield useful responses. At the end of their sessions the participants completed technology prior experience questionnaires (modified from Blacker ref) and signed consent forms.

3 Issues Experienced by Participants

3.1 General Issues

- Not operating the touchscreen reliably – some users inadvertently operated functions they didn't want, and on other occasions wouldn't operate desired functions despite appearing to have performed the correct action (in some cases repeated the correct action a number of times) to do so.
- Some inaccuracy in using the touch keyboard, but more cases of repeated keystrokes on touch keyboard – so two letters appear rather than one.
- Some confusion about how to move the cursor to the desired location – seen in both email and browser searching. A few participants tried to swipe the cursor from its current location to move it to the desired location, which did not appear to work. Others were intent on using the keyboard only to attempt to move it, mainly with the return key, which only succeeded in entering the current data. Some participants needed assistance to get beyond this hurdle.
- Some confusion shown between the concepts of backspace (a left arrow with an x seen on the keyboard) and back (a permanent button below the screen) which were hard for some users to resolve or remember which did what.

3.2 Issues Relating to Specific Tasks

Turning device on (see Fig. 2 for image of Power Button):

- Almost all participants struggled for some considerable time to turn the device on, for some or a combination of the following reasons: not being able to see or feel

Fig. 2. Samsung Galaxy Tab Side View Showing Power Button Location and Label

the button at all, not seeing the label on it, or not recognising the on/off button label, if they could see it, in the first instance. Since the button required a long button press to get any response from the device this lack of feedback to a shorter than required press, this contributed to participants eliminating the correct button and focussing their attentions elsewhere. Some even came to the erroneous conclusion that the button required a hard push to work, and in addition one participant said, 'I'm glad I've got fingernails – I wouldn't be able to push this otherwise'.

Entering passcode (See Fig. 3):

- Most entered number correctly first time, but many struggled to find 'OK' button to enter the number. Screen timeouts (in some scenarios only 4secs before screen timed out and deleted entered numbers) caused much frustration.

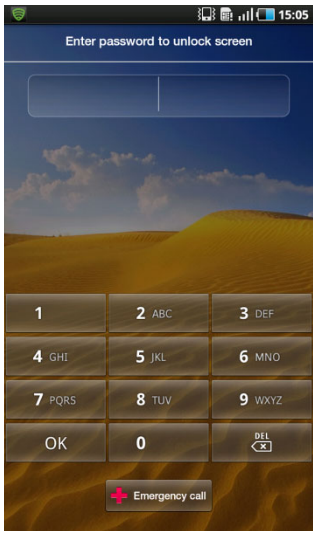

Fig. 3. Passcode Entry Screenshot

Sending email (See Fig. 4):

- One participant thought that the 'Email' button label was a verb, and therefore that something would need to be created prior to execution of the 'to email' function.
- Not recognising or understanding the function of the 'new compose email' icon/button, or as one user described it as a 'sausage in a grate'.
- No users detected the fleetingly displayed 'Sending...' notification shown at the top of the screen – so none were confident it had been sent.
- One participant correctly entered an email address, and in his attempts to move the cursor to the 'Subject' field by pressing the return key, invoked the device to verify that the email address was of the correct form. The feedback to the user that this had happened, and that the email address was accepted by the system is to put a box around the email address, or if it is a long email address to concatenate and put a box around, such that an email address typed 'longemailaddress@googlemail.com'

would become ‘longemailaddress@go...’ in a box displayed on the screen. For one participant this resulted in him re-entering the email address three times to correct the error, before the experimenter intervened.

- Finding an underscore ‘_’ to enter in an email address was found to be impossible for the two participants who tried. The interface requires that either the numerical keyboard is selected using the ‘123’ key, and then the ‘1/3’ key (which one participant believed was a thoughtful addition of the one-third key as found on some typewriters) to index the keyboard to the second screen (2/3) where the underscore symbol can be found. Alternatively the user presses the ‘.-;’ key for a long button push, and is presented with a submenu of 12 symbols to select, one of which is the underscore.

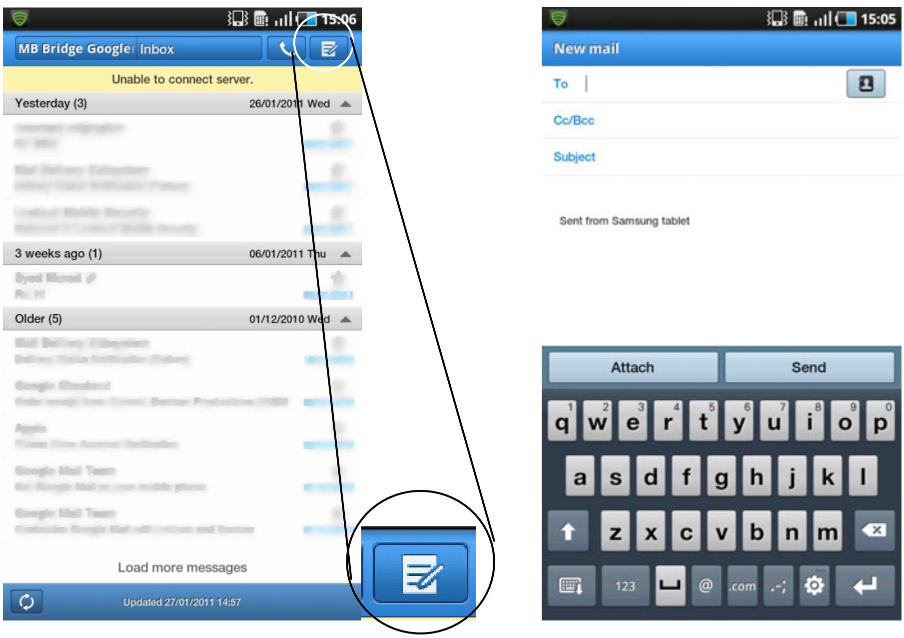

Fig. 4. Email Inbox Screenshot – inset showing Compose New Email Button Detail (Left) and Compose New Email Screenshot (Right)

Search internet:

- Most users knew Google was an internet search engine so most participants chose one two major pathways – either they selected ‘browser’ (opening a browser window with Google as home page) or they clicked on the Google search window on the home screen.
- Three participants curiously entered their relative’s name (the instruction was to search for a relative or a friend on the internet) without spaces, although Google was in each case able to segregate the names correctly.
- Some participants were sufficiently confused by the appearance of the previous searches using Google in the space beneath the search field that they assumed that they needed to correct it before being able to carry out their desired search.

Set alarm:

- A few participants struggled to find alarm clock function (it is located within the 'Applications' menu).
- Many struggled to add an alarm – touching the clock face allows user to alter its appearance but takes away the ability to set the alarm (see Fig. 5). This can be revoked by using the 'back' key or by pressing the 'Set clock style' button, but some participants believed that button would take them to a further menu of options relating to clock styles.
- Once participants had found where to set the alarm time, actually setting the time caused few difficulties (see Fig 5.), but feedback to correct activation of alarm caused many participants confusion due to its ambiguousity.

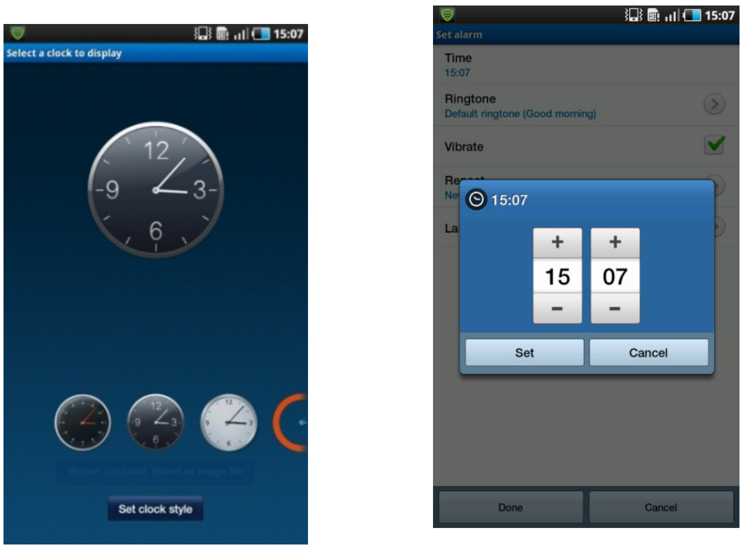

Fig. 5. Clock Face Personalisation (Left) and Alarm Time Setting (Right) Screenshots

Turning off/standby:

- Many users pressed the power button but not necessarily for the correct length of time (short press invokes standby, long press brings up Phone options menu with 'Power off' option, with then a further confirmation dialogue box). There was some confusion about the difference between off and standby, as well as one participant demonstrating antipathy towards the concept of standby; 'I don't have anything on standby... I can't bear those winking lights... I'd rather have it either off or on'.

4 Discussion and Conclusion

An initial classification of the participants' issues put them four categories within two perspectives: User side – those characteristics of the user which contributed to the issue experienced, and the Device side – the characteristics of the device which also contributed to the issue (See Table 1). This view permits the comparison and a potentially useful discussion to be had as to how to resolve the issue – whether through redesign of the interface, or perhaps through training to alter the characteristics of the user where appropriate, or indeed, possible.

Table 1. Initial Assessment of Error Causation Classification

User characteristics	Lack of prior experience	Poor vision	Poor muscle control	Searching strategy not optimal	Prior experience hinders and conflicts
Device characteristics	Lack of clarity of label meaning or overly codified	Labelling or identification characteristics too small	Too sensitive or not sensitive enough to respond	Controls or displays not where expected	Device behaves inappropriately for the user

All of the issues experienced by the participants fell into at least one of the classifications. For example the adding of the alarm function was difficult for many participants and this was categorised (on the device side) as ‘lack of clarity of label meaning or overly codified’, ‘controls or displays not where expected’ and ‘device behaves inappropriately for the user’. For this to be useful for the prediction of older user errors in such devices, it is expected that much investigation would be required to populate the understanding of expected locations of controls or displays and appropriate device behaviours for this group. The lack of clarity of label meaning or overly codified category perhaps could be assessed using heuristics from an expert’s perspective; for example it is reasonably predictable that the Compose New Email button codification is going to be problematic for some users, due to its somewhat abstract representation of the pen and lines on paper, which itself is an abstraction for the concept of starting a new email.

Further investigations will be carried out to examine the participants’ prior experience with more detailed interaction patterns and technology experiences (e.g. use or skill of using a traditional typewriter), to see if a model can be developed which can link this data to user’s expectations of interface appearance and behaviours in a predictable way.

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Affective Technology for Older Adults: Does Fun Technology Affect Older Adults and Change Their Lives?

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Abstract. Our daily lives are supported by various technologies. Generally said, however, older adults cannot benefit from technologies due to difficulties with use of them. As some difficulties seem to be related with the fact that older adults require more time to get used to a new thing, and it is suggested that affectiveness may facilitate of use of technologies, this study tried to clarify the influence of continuous use of portable game system on older adults' everyday life and emotion. By four-week continuous use of portable game system, some influence of it on older adults' everyday life and emotion was confirmed. The results suggested the possibility that older adults could utilize technologies which originally aimed at younger users and affectiveness could facilitate it.

Keywords: affective technology, long term usability, behavior observation, POMS, emotion.

1 Introduction

1.1 Fun Technologies for Older Adults

In Japan, many video game systems are developed and provided in the market. Younger generation is very familiar with such game systems. We see small children and younger adults playing with portable game systems everywhere, even in the train or on the street. They enjoy playing games very much.

Conventionally, such game systems and software aimed younger users mainly. Recently, however, some elderly-aiming games have also been developed. For example, Nintendo produces games which can be enjoyed by all the family members together, regardless to generation. Supposed difficulties for older adults are, for instance, unfamiliarity with conventional game controllers and visibility of the display of game system. Nintendo Wii with a special controller like a conventional remote controller for television or Nintendo DSi LL[1] which has larger touch panel display have potential to diminish such difficulties. With regard to software, instead of conventional arcade games, shooting games, or role playing games, so called "brain training" games or fitness training games aiming older adults have been produced.

Such games seem to be acceptable for elderly users who are conscious about physical and/or mental health. How is the reality? Recently in Japan, older adults are

[1] Product name in Japan. "Nintendo DSi XL" in other countries such as USA.

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getting familiar with arcade games or video games than before. Although games with violence (e.g. violent 'first-person shooter' games) are perceived negatively by older adults ([7]; [8]), strategy games or role-playing games may bring older adults some cognitive benefits [11]. Above mentioned brain training games and/or fitness training games attracted many older adults. Their "effects" have already been validated in some research works (e.g. [2]; [10]). Though such objective data is still limited and more empirical studies are required, it is assumed that some kind of games might have some influence on users.

What do older adults expect for playing games? Of course, it is suggested that older adults hope keeping their physical or mental health. In addition, some "indirect" effect on physical or mental health could be expected. For instance, they can talk about video games with other people, including younger generation. Or competition with other people could also facilitate to keeping physical or mental health of the elderly.

1.2 Necessity of Long Term Evaluation

If we think about the above mentioned issue, we should regard not only the first impression, but also change in impression during continuous use. Especially for older adults, the first step is hard. Game systems are not familiar for most of the older adults. Some older adults are even afraid that they may break the game player. Other older adults say "game systems are for younger adults, not for the elderly" and have no interests on such game systems at the first time. However, such impression will be changed by experience in use. An opportunity to contact with such game systems should be given to older adults at first.

Then sufficient time to gain some experiences is required. Older adults require more time to learn or to get used to something new than younger adults. Older adults tend to blame experienced or assumed difficulties with technology use on themselves [3]. Frequently they say "Yet I am not used with this system. Assumingly I can operate it better when I get into it." It suggests the problem with lack of experience. In fact, our research work on continuous use of skin lotion ([4]; [9]) showed that impression was changed by continuous use and became constant after certain period. Other researchers have also pointed out the importance of the evaluation of long term usability (e.g. [1]). Such research studies are generally accomplished by interview or subjective evaluation. On the other hand, writing diary is also applied frequently in order to get data every day.

Long term usability for older adults is not much studied. Imai et al. [5] have discussed the methodology of evaluation of long term usability by older users, but no concrete result was shown regarding effect of continuous use on impression on products. It is necessary to show how older adults get used to use an unfamiliar product.

1.3 Purpose

From the above background, this study aimed to clarify the influence of continuous use of portable game system on older adults' everyday life and emotion.

2 Method

2.1 Participants

5 males and 3 females between 67 and 80 years (average = 73.5) participated in this experiment. All the participants had never played this type of portable game system.

2.2 Apparatus

Nintendo DSi LL ("DS") was applied in this experiment. DS has two screens including one touch panel and is operated by a stylus.

Three games were mainly focused in this experiment. The first one was "Personal Trainer Walking" ("Personal Trainer"). It is a kind of health monitoring system, which collects step data from an "activity meter" via infrared interface. The data is available in various formats, such as step numbers per day and diagrams of step numbers in every hour, and health advice based on the data is offered. In addition, some games related with the recorded number of steps are also available. The second was "Brain Age Express: Math" ("BA Math"), which provided various calculations and other mathematical exercises. The last one was "Brain Age Express: Arts & Letters" ("BA Letters") including writing Chinese characters, loud reading of novels, remembering pictures, etc.

2.3 Procedure

This experiment consisted of three parts: first trial, four-week continuous use, and final evaluation.

2.3.1 First Trial

The overview of this experiment was explained to the participants at first. After obtaining informed consent, we asked the participants to answer the brief form of Profile of Mood Status (POMS). The POMS assessment provides a rapid, economical method of assessing transient, fluctuating active mood states. As results, six factors will be derived: tension-anxiety, depression-dejection, anger-hostility, fatigue-inertia, vigor-activity, and confusion-bewilderment.

Consequently, hands-on training of DS was given. The operation by participants during hands-on training was recorded by video camera, in order to identify difficulties for the participants.

After the training, the participants were asked their first impression on using DS including 7-point Likert scale. The evaluation items were as follows.

- Items related to usability
  Legibility, operatability, understandability, design
- Items related to long term usability
  Degree of mastering, familiarity, attachment, willingness to use, interest, satisfaction
- Basic emotion
  Joy, surprise, sadness, anger, fear, disgust

2.3.2 Four-Week Continuous Use

The participants were asked to use DS as they like for four weeks at home and take notes every day. The frequency and duration of using DS could arbitrarily be decided by the participants. A form for note was provided, in which tried contents and duration, experienced difficulties, and found features should be filled. Impression evaluation was also requested every day in the same way as evaluation of first impression. Additionally, the evaluation of mood by using POMS was accomplished once a week.

2.3.3 Final Evaluation

The evaluation of mood by using POMS was accomplished at first, and then the participants were asked to play DS as during four-week continuous use. At least checking the data of activity meters in Personal Trainer and playing one of BA were requested. During the participants were playing, their behavior were video recorded for the comparison with first trial. Afterwards the participants filled the evaluation form and answered to the questions about use of DS for four weeks.

3 Results

3.1 Performance in Game and Walking

The participants used the game system every day except on the days when they were away from their home due to trip etc. Log data showed that participants played DS regularly – checked the recorded number of the steps in Personal Trainer and tried several exercises in BA Math and/or BA Letters. The spent time was also relatively steady. If a new exercise was added in BA (BA offers more exercises according to the number of day played), play time tended to be longer. Other functions such as camera or dictionary were also allowed to try, but they were tried only few times by a part of participants.

Performance of walking was analyzed based on the daily number of steps. It was influenced by the activities of the participants. The data showed three levels of participants' activities: stayed at home, went out for daily activities such as shopping, and went out for healthy/sports activities such as walking. Except two participants, the recorded number of steps in each level increased.

Performance in BA was analyzed based on diagrams showing recorded "Brain age" and other performance data such as number of correct answers, required time for answer, and score. In general, the performance data showed improvement. Detailed data showed different patterns in improvement. In some cases, the performance improved steadily, whereas in other cases, the performance improved only in the early phases. Few cases showed no improvement of performance. In other cases, performance data varied very much and never stabilized.

3.2 Rating of Game Systems

Regarding items related to usability (visibility, operatability, understandability, and design), the rating showed greater change in the first one week. Change in the second to forth week was generally smaller than in the first week. The ratings of six

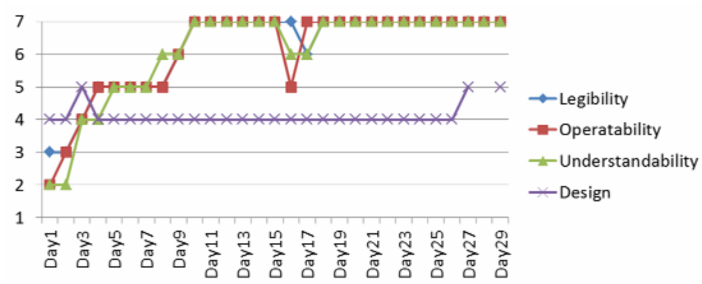


Fig. 1. Example of rating of items related to usability

participants improved (Fig. 1), whereas the ratings of two remaining participants deteriorated on the second or third day and remained low until the end of the four-week trial period.

Regarding items related to long term usability (degree of mastering, familiarity, attachment, willingness to use, interest, and satisfaction), the rating varied more than items related to usability (Fig. 2). In most cases, the rating was never stabilized even in the last phase of trial period. The rating of degree of master and familiarity showed an upward tendency.

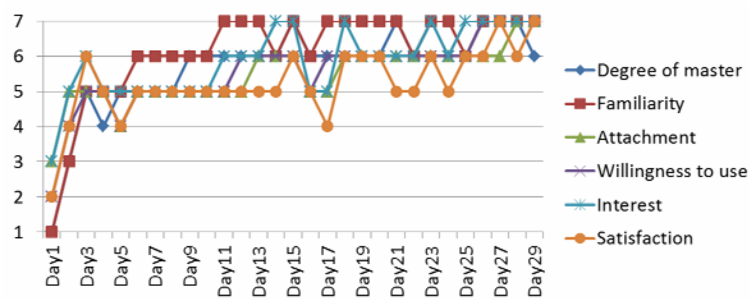


Fig. 2. Example of rating of items related to long term usability

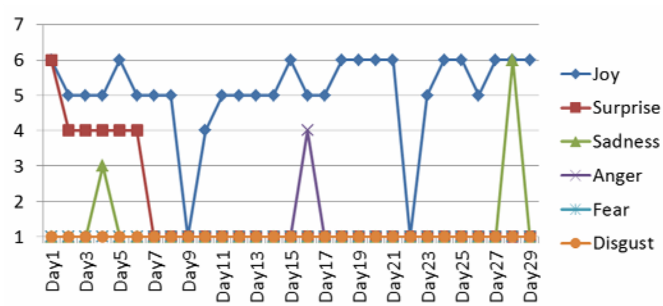


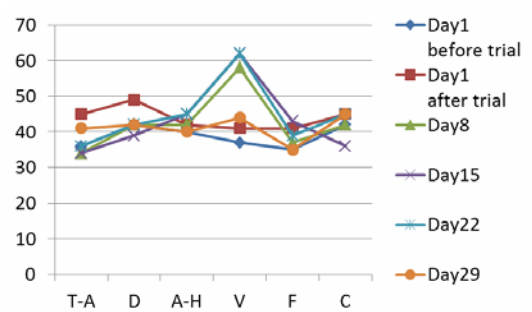
Fig. 3. Example of rating of emotion

Basic emotion (joy, surprise, sadness, anger, fear, and disgust) showed either greater change or slight change (Fig. 3). It was different according to participant and type of emotion. Joy and surprise was felt more frequently than other type of emotion.

3.3 Rating of Mood

Fig. 4 shows an example of POMS score. If the score of vigor-activity, which is the only positive factor, is higher than other negative factors, it means that the participant is vigorous. When presented on a graph, the profile assumes a characteristic shape that is called the 'iceberg' profile. This was in the case of five participants. For other three participants, the score of vigor-activity was same or lower than those of other items, which meant these participants were rather in negative mood.

Although comparison of the POMS data of four weeks showed no significant tendency, in the cases of four participants, POMS score on Day29, where final evaluation was accomplished, showed the more pronounced 'iceberg' profile than on Day1.



T-A: tension-anxiety, D: depression-dejection, A-H: anger-hostility, V: vigor-activity, F: fatigue-inertia, C: confusion-bewilderment.

Fig. 4. Example of POMS score

3.4 Behavior Observation

With regard to operation, tap with stylus was no problem, whereas hand writing was difficult for the participants. Handwritten numbers and characters were sometimes recognized wrongly. This tendency was especially strong for complex Chinese characters. The log data showed that this problem remained until end of the trial period. Even in the final evaluation, some participants had to try writing numbers and characters several times.

Difficulties with comprehension of the contents were frequently observed in the first trial. DS has two screens and only one screen is a touch panel. However, if an illustration of touch panel for the explanation of operation was displayed on non-touch panel screen, many participants tried to tap that illustration and were confused by it. Confusion was also observed with regard to a part of text instructions. Ambiguous expression or lack of detailed explanation also confused some participants. However, these difficulties with comprehension could be overcome by repeated trials. Some participants mentioned it in their log (e.g. "Gradually I understand what I should do."). In the final evaluation, no one was confused by the instructions or other contents.

4 Discussion

4.1 Influence of Use of DS on Everyday Life

In the interview at final evaluation, all the participants mentioned that they were conscious of the fact that they wore activity meter to varying degrees. Some participants who were strongly conscious of the number of steps made a great effort to walk. The feedback in various forms was perceived by the participants positively. Different from conventional pedometer, the participants could see the recorded data in graphic representation, so that they could easily compare the data on different days. Accomplishment of the target number of step motivated the participants. Advices offered by Personal Trainer attracted interests of the participants. All of these let the participants conscious of walking and keeping regular hours. As results, some participants walked more than before.

Regarding BA, the participants enjoyed them very much. Five participants played BA almost every day and some of them spent over one hour per day. "Brain age" changed differently from participant to participant: in the cases of some participants, great improvement was observed, whereas other participants showed little or no improvement. Although the participants showed different performance in BA, most of them commonly thought that it did not help them to think quicker or more flexibly. They enjoyed playing BA, but did not realize the effect.

At least, these experiences with DS let most of the participants got familiar with game system. Other influences were also confirmed in interview: they had more interest on other game systems, interest on "high-tech", or interest on something new. Generally said, all these things are regarded as products aiming at younger generation and older adults had not much interest on them. The results of this experiment showed the possibility that older adults have some interest on products originally aimed at younger adults. Not just one time, but several times or certain period for trial could help older adults to get familiar with the products. In that way, older adults are possibly motivated to use the product for longer time and such long term use can influence on their daily lives.

4.2 Influence of Use of DS on Emotion and Mood

As mentioned above, four-week experience in using DS had some influences on behavior level. Regarding influence on emotional level, common tendency was not clearly confirmed. However, in the most of the participants, joy and surprise were elicited, whereas other four categories of emotion were elicited less frequently. For affective technology, joy and surprise are very important to motivate users to use the technology. The strength of these emotions was decreased over time in the cases of some participants. It seems that the more the participants got used to DS, the more they regarded DS not as "special" but as "normal". At least, in order to elicit "surprise", something new will be required. The function of BA that offer new exercise after the user accomplished exercises certain times would be one good example for that. In order to let the users feel joy, positive feedback would be required. High scores in BA or greater number of steps in Personal Trainer delighted and motivated the participants very much. In that way, DS could affect the participants to some degree.

On the other hand, the clear effect of DS on mood was difficult to confirm. Different from rating of emotion, the score of POMS reflected not only the mood during trial, but also all other events happened. However, at least half of the participants had shown ‘iceberg’ profile in POMS after four-week continuous use. If DS was regularly used, even mood could be influenced by it.

4.3 From Usability Issue to Affectiveness

As mentioned in Introduction, some difficulties were assumed for older adults to use game systems. Actually, such difficulties were observed in the first trial. However, they could overcome or bear up the difficulties (e.g. hand-writing with stylus) by using the game system repeatedly.

Usability issue is regarded as one of the critical interferences for older adults to use technologies. The results of this experiment, however, showed that sometimes affectiveness came before usability. If a product or technology gives positive impression strongly, the users can be motivated to use it, even when the usability was not good.

Of course, it does not mean that usability can be ignored. Usability should be secured and it is minimum requirement. But a product or technology with only good usability may not be attractive. Some affectiveness would be required.

5 Conclusion

By four-week continuous use of portable game system, some influence of it on older adults’ everyday life and emotion was confirmed. The results suggested the possibility that older adults could utilize technologies which originally aimed at younger users. Affectiveness could facilitate it.

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Muntermacher – "Think and Move" Interface and Interaction Design of a Motion-Based Serious Game for the Generation Plus

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Abstract. This paper presents a holistic approach to design a media system based on a new user interface and interaction device aimed to motivate seniors of the generation plus enhancing their daily physical activity. As a result of the newly designed game, the senior finds himself within a colorful world of a game in which he interacts with small lively figures using a newly designed interaction device accounting for physical activity. The combination of both design elements, lead to a gameplay that provides adequate mechanism for cognitive and physical activity, challenging representatives of the generation plus to exercise more.

Keywords: Game, ICT based inclusion, Generation Plus, Interaction Device.

1 Introduction

With increased life expectancy in recent decades, the individual esteem and social importance of good health has increased with age [1], [2]. If health can be maintained, personal skills to enable an independent and autonomous life can be improved. However, less than 10 percent of the above 60-year-old persons perform the recommended weekly amount of exercise. Although there is a general awareness about the importance of physical activity within the generation plus, the level of activities decreases rapidly [3]. Recent intervention studies show, that an increase of physical activity within the generation plus, nevertheless, is possible [4]. New instruments to motivate seniors and raising their activity level are needed. Aside senior and motivation specific training programs, new ICT technologies have been deployed recently, most of the time concealed within games. Game based design makes use of sophisticated storytelling approaches to attract a broad range of people. Diverse surveys show, that products with a similar focus on sports and fitness like Nintendo's "Wii" or "EyeToy" as well as Sony's "Playstation 2/3" or Microsoft's "Xbox" do indeed effect end users motivation, due to entertaining elements. A sustainable long-term motivation, however, in most games is questionable, which was also revealed in our survey, we conducted as motivation for this work. Instead, it is important to put the focus on

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specialisation for the needs of elderly people. As the most competitive manufacturers have to cover a wide range of groups of players, no system is developed specifically targeting seniors. As a consequence, a completely independent use by older people without support is almost impossible. Even worse, badly realised access to game content and its storyline makes games appear to seniors as irrelevant or too complex. Aside motivational aspects also technology barriers influence the adoption of new media systems within the generation plus [5].

2 The Generation Plus

The worldwide population experiences an enormous change. Due to higher life expectancies and the rapid increase of elderly people in western countries, many of them experience a new activity phase beyond 50 years of age, the so called second dawn [6]. Those "youngsters" or active elderly people are much more likely to be identified with the homogenous crowd of "the seniors" rather than the senile, multimorbid and aged patients. Some characteristics for a segmentation of the target group addressed during this research exercise should be given here.

2.1 Stage of Life "Seniority"

Boosted by the continuously increasing life expectancy, people experience nowadays not a traditional biography with strictly defined phases "Youth/Education", "Employment/Family Life" and "Retirement", rather consider themselves at early 50 to be part of another phase, the "Second Awakening" [7]. Within this phase many people review their previous and plan their future life. The transition into this new phase of "active aging" is at the same time the dawn of the "Generation Plus" [6]. The next phase of life "retirement" is distinguished in Gerontology often as "third and fourth age". In practice, research and social reporting the so called fourth phase of life is specified as to 80 to 85 years [8].

However, it should be noted that there are 75-year-old people that are still active in life and about 60-year-old people who need daily help by others [9]. Thus, a pure classification of the elderly according to their biological age is typically not appropriate, because the physical and mental fitness vary quite strong in some cases. According to recent statistics, the first years are spent in fairly good health after retirement ("younger" age - seniors). Here, the likelihood of diseases and functional limitations are reduced but change quickly in higher ages.

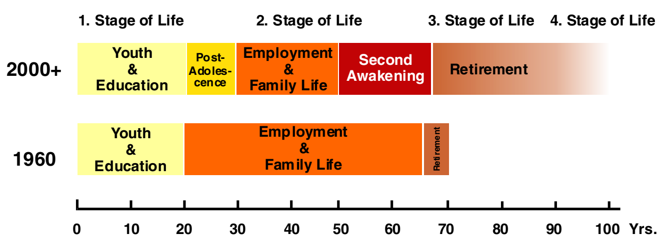

Fig. 1. From three-fold to five-fold life stages [6]

2.2 Characteristics of Aging

Nevertheless, even if people are living longer and thereby start into new phases of their life, age is still associated with biological changes, which begin very early. Those biological changes are associated to the vision, the hearing, the strength as well as flexibility and influence especially the usability of new media [11]. Therefore, and in order to design a new media system for the generation+, special attention has to be given to those boundary conditions as a violation can sometimes lead to frustrated user experiences and in consequence, in a termination of use.

Vision. With increasing age, a deterioration of all individual functions of vision can be observed. With each decade of life the visual acuity deteriorates. Thus, it reduces the visual perception of an 80-year-olds by up to 80 percent. Here, the visual acuity is influenced by a deterioration due to turbidity or discoloration of the lenses, reduction of the visual field, by limitations in the eye movement as well as depth perception. Additionally, the color perception decreases to a result that blue, blue, green and purple rendered objects are difficult to be distinguished. However, most easily distinguishable colors that could be used are red and yellow [11].

Hearing. First limitations of the capabilities of hearing typically appear at age of 45. In particular, complex language tasks (background noises, overlays) might lead to problems [12]. Language, music and sounds often need to be louder for the elderly to be perceived appropriately. Nevertheless, the perception of the full range of frequencies is often difficult, so lower frequencies are better “absorbed” than higher. Furthermore, the processing speed of the perceived tones often slows down, which means that certain syllables are only perceived reduced and fuzzified. Thus, the perception of multiple simultaneous sounds is problematic for many seniors, so that a distinction is often difficult. This implies a sensory overload (“Party syndrome”) and older people try to remain focused on certain sounds [13].

Cognitive changes. A basic requirement for mental fitness is physical health. Thus, suffering by a low vision system and without the use of visual aids, no success in reading and learning can be achieved [14]. Many elderly people don’t have problems to recall general or personal knowledge of past events from their long-term memory. However, the ability to store, organize and retrieve new information deteriorates. This is due to a performance decrease in short-term memory[1] [15]. The probability for disease-related degradation increases in higher ages. For example, 10% of Americans over 65 years, but already about 50 percent of the 85-year-old are afflicted with the, e.g. Alzheimer, disorder [15]. However, in contradiction to the persistent stereotypes of spiritually impoverished old people, it should be noted, that the mental abilities not exclusively decline at higher ages but rather are shifting. Older people have a richer knowledge of goal oriented procedures, a greater knowledge of temporal relations and developments over life, as well as better knowledge on how to deal with uncertainties and unforeseen events [15].

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[1] This should not be confused with Alzheimer's disease, afflicting only a small proportion of senior citizens.

2.3 Motivation for Activity

Intervention studies did show, that asking physically active 50- to 70-year-olds for their motives performing sports, most frequent aspects are fun of the sport, relaxation, balancing individual work life, fitness and sociability (fig. 2, [16]). With increasing age, however, the motivation to exercise more shift mostly to health related aspects, such as improving the general well-being, physical performance and exercise capacity or resilience and resistance to diseases.

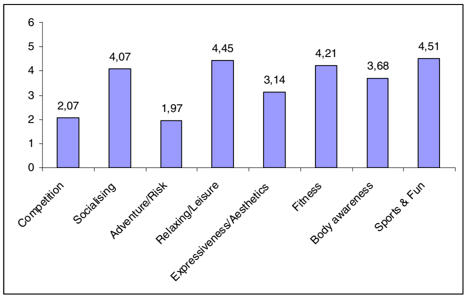

Fig. 2. From three-fold to five-fold life stages [16]

2.4 Segmentation of the Target Group

A diversity of segmentation models come from recent research activities [17], e.g. for example [18], [19] and combine socio-demographic, psychographic and behavioral characteristics. The segmentation of our target group reflects additionally on activity level and physical activity in everyday life, which are the more interesting aspects being addressed within the framework of this work. For this reason, the elderly were classified according to the features: health, accommodation, sports motivation, activity level. Thus, the system focuses on healthy, independent living people, neither being multimorbid nor suffering from dementia. They are living in their own homes and occasionally in multigenerational homes or senior housing communities. They organize their daily lives still independently and without major support from relatives or social services. Although they are aware of an increasing decline in physical fitness and the importance of physical activity, it is hard for them to maintain a motivation to exercise. They actually do not feel attracted by traditional sports activities such as seniors sports, Thai-Chi groups or senior citizens fitness studios, such as the health-oriented "Kieser Training". Also, they lack the incentive to be in regular sport or to exercise more. In general, less than 10 percent of the above 60-year-old persons perform the recommended weekly amount of exercise.

3 Methodology

Recent intervention studies show, that an increase of physical activity within the generation plus, nevertheless, is possible [20]. New instruments to motivate seniors and raising their activity level are needed.

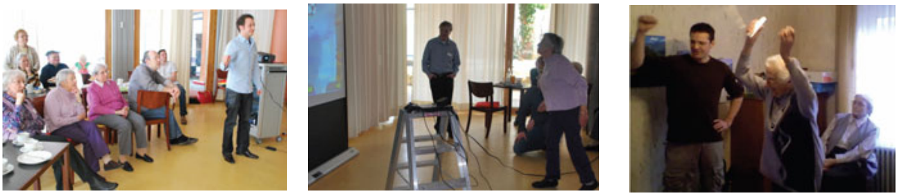

Fig. 3. Observation of older people using video games ("Wii Fit", "Eye Toy", etc.) analysing motivational aspects for enhanced physical activity

Aside senior and motivation specific training programs, new ICT technologies have been deployed recently, most of the time concealed within games. Aside motivational aspects also technology barriers influence the adoption of new media systems within the generation plus [5]. As the most competitive manufacturers have to cover a wide range of groups of players, no system is developed specifically targeting seniors. As a consequence, a completely independent use by older people without support is almost impossible. Even worse, badly realised access to game content and its storyline makes games appear to seniors as irrelevant or too complex.

In order to resolve these challenges we designed a new system using a holistic approach based on user observations, interviews and evaluation studies with senior citizens in order to gain a better understanding of the target group (fig. 3). Due to the observations we modelled a "persona" which is a typical representative of the generation plus and defines conditions for a new media system aimed at a motivational support for more daily physical activity. Our methodology included existing systems that have, themselves, been tested and analyzed in close discussion with experts from sports medicine, daily carer and seniors.

3.1 The Basis

To structure the interviews, an interview guide has been developed covering several aspects of the seniors "being" and interlinking technological aspects to their living context. Thus, questions related to the person and their everyday habits such as "watching TV", "reading or watching news", "music interest", "theatre or cultural activities" as well as "personal interests" such as "travelling" or "preferences on holiday locations" have been equally important as asking for the their technological affinity. Further on, it was important for us to find out personal biases of sports, activities and their engagement in games (real or virtual). Within a different questionnaire we also asked people within the near vicinity of the elderly persons responsible for the physical recreation and daily care in order to learn more about the target group. Those questions addressed general issues related to the use of media systems as well as dedicated questions to the recreational programmes they are conducting with the elder target group within senior housing communities. Another questionnaire has been used for informal talks with sports and exercise scientists in order to exclude dangerous movements within an envisioned game play for the older people. The following table summarizes the data basis we used during a two months period.

Table 1. Conducted interviews and observations

Method	Data			Material
Interviews	5 Persons	f=5,	73-90 yrs	Questionnaire
	4 Persons	m=3, f=1	65-80 yrs	
	3 Persons	f=3	73-85	
	2 Persons	Physiotherapist (Medical Training Therapy)		
	2 Persons	Sports Medicine		
Observations	1 Person	f=1	90 yrs	Nintendo Wii Sports
	3 Persons	f=3	73-85	Wii Fit
	4 Persons	m=3, f=1	65-80	Sony's Eye Toy

3.2 The Analysis

The analysis of the interviews in relation with the observations revealed short comings in the usability and sustainable activity motivation due to immature game concepts and bad interface design. Factors like "mental fitness" and "maintaining independent living" have also not been considered in recent commercial game concepts. Those are either targeting only physical activity within repetitive loops leading to fast signs of fatigue or being just too complicated to use.

4 "Muntermacher"

When designing a system for older people aiming for a longer use and higher acceptance it has to account for several requirements such as simple metaphors and guides (auditory, visual) avoiding seniors to be quenched of complicated technology, built on biological and training stimuli that induce an adaptation of the organism (body adapts to new/higher loads) and finally to involve seniors to actively participate in controlling the game. As part of our envisaged system we focused on the training stimuli in the area of power, coordination, balance. Major objectives:

- *Experience Goals* (experience requirements during use): want to be entertained and cognitively challenged
- *End-Goals* (goals that are pursued by the system): experience and learn something new
- *Life-Goals* (long-term goals in relation to the system): maintain independence as long as possible

4.1 System Design

The system concept foresees a video game for home TV. As television sets can be found in 99 percent of the over-50s, this medium seems particularly suitable. The system consists essentially of a console, the so-called "mbox" ("MotivotionBox"), which includes an integrated camera and captures the movements of the user. The device also supplies a power connector and a cable to connect to the TV. The camera is located above the TV in order to enable a control of the game by the user. As indicated above long-term sportive activities can only be achieved being intrinsically motivated, i.e. by a "personal drive". The analysis, however, shows clearly that this particular drive needed for physical activity is only marginally present within the target group.

In contrast to the physical motivation the target group has a strong incentive to keep its level of mental fitness. Thus our concept focuses primarily on cognitive training fulfilling the wishes of the target group for mental fitness and independence. The training however, is strongly associated to physical exercises and accounts for sports prophylactic effects, and secondly, to increase the effectiveness of the "brain jogging". This relationship between physical activity and mental impact has been particularly stressed in order to promote the intrinsic motivation of the users.

4.2 Game Design

Our gameplay consists of several mini-games of various sports categories combined with thought and some knowledge questions at general education level. Since there is in science no uniform classification for puzzle games, our design did focus on popular puzzle categories such as logic, memory, mathematics and perception. According to the requirements analysis, the game play should be performed within a humorous and sympathetic environment. Thus, the user finds itself embedded within a colourful game world, in which he interacts with small lively figures ("brain cells" that need to be alerted throughout the game). The central task of the player is to connect different brain cells together and accomplish puzzle tasks such, that the brain cells are "activated". Visual guides using shadowing metaphors and integrated auditory assistance assist the seniors in navigating.

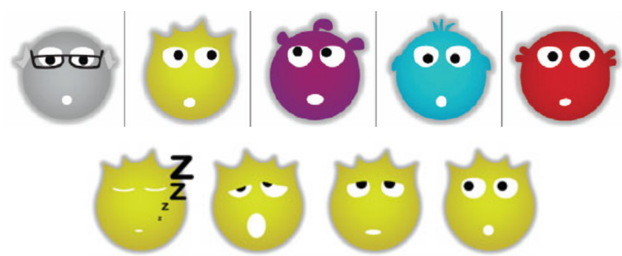

Fig. 4. Brain cells used in the mini games (above); a brain cell "wake up" if touched (below)

The most important figure represents the "gray cell" that takes the role of a moderator and as a virtual companion for the players, guiding them through all the menus and games. The results during our observations showed that a virtual companion, providing advice and support improved the operation of a game significantly. The "grey cell", is the faithful companion of the player, and provides support at any position within the game.

4.3 Interaction Design

In order to interact with the system we designed a new interaction device using a modified gymnastics band (fig.5). The modification is based on pressure balls attached to both ends of the band and deployed as end effectors. The band is actively integrated into the game and not only used in addition to a passive gesture control. This is due to the observation when using commercial games such as "Eye Toy", seniors tend to physically grab the virtual objects. Hence, the new interaction device accounts for this physical feedback as soon as virtual objects are crossing the interaction path of the end effectors of the band. The different colours of the end effectors allow our deployed image processing to segment the colours and to calculate the position of the balls within the video stream and retrieving the right 2D position within the rendering plane in order to activate the brain cells (fig.6).

Fig. 5. Modified gymnastics band, two interaction balls as end effectors (right), in use (left)

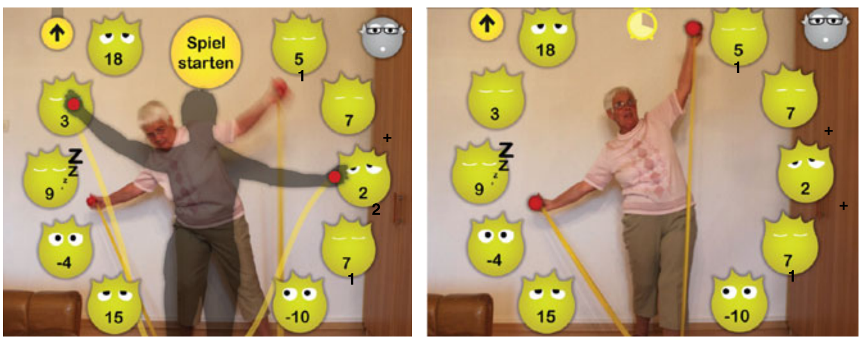

Fig. 6. Gameplay and puzzle of cells within the game; ghost rendering showing on how to pick up the position and to interact with the system (left)

5 Qualitative Evaluation

The target group being actively involved within the observations (section 3.1) has also been included in first qualitative user tests. Here, main focus has been given to the handling and understanding of the interactions using the new input device in combination with the game world.

The handling of the exercise band and finding the correct position was perceived very well by the users. In general a simple demonstration of a ghost rendering (fig.6) showing on how to use the device and what posture should be taken was sufficient for the seniors in order to start and use the game. Also, the basic procedure for operating a selection element by simply pressing a ball has been quickly learned in a short time.

One problem, however, presented the correct positioning of a ball outside the selection elements. Furthermore, the transmitted video image which should serve as a guide in positioning was barely perceived by the seniors. This caused the balls not being adequately positioned while triggering the cells. The relationship between the positioning of the balls and the mode of operation to select an element should be explained in more detail by the “grey cell”. A visual highlight of the balls on the TV screen, could also be helpful. Purely auditory instructions within games, as it was realized within the first prototype, proved to be insufficient. Despite the detailed auditory explanations of the moderator, he was not able to teach the subjects sufficiently several interaction processes within the game. This is especially true for the “hold on and press” interaction as soon a brain cell has to be activated. This implies that a further development of the prototype has to include animated demonstrations of the gameplay as well as a practical introduction with detailed instructions.

6 Conclusion

In order to resolve the challenge to intrinsically motivate elderly people for more physical activity we designed a new system for a game that can be used in daily environments. Our design is based on a holistic approach using user observations, interviews and evaluation studies in collaboration with senior citizens to gain a better understanding of the target group. Due to the observations we modelled a “persona” which is a typical representative of the generation plus and defines conditions for a new media system aimed at a motivational support for more daily physical activity. Our methodology included existing systems that have, themselves, been tested and analyzed in close discussion with experts from sports medicine, daily carer and seniors. The resulting games provides a new form of interaction which accounts for an ease of interaction within the gameplay as well as a new game concept specifically designed for the generation plus. It challenges seniors for cognitive tasks linked to physical activity. One positive aspect of the designed game is the playful nature that has been exposed to be within the focus rather than the sportive activity, which happens “aside”. Thus, the user mainly focuses on experiencing the game rather on the workload happening due to physical activity.

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Preliminary Framework for Studying Self-reported Data in Electronic Medical Records within a Continuing Care Retirement Community

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Abstract. This paper serves as a preliminary framework design for studying data that is reported by patient's living within a retirement community and how this impacts the quality of care that is received when using a telemonitoring device. It reviews concepts that are involved in usage of this type of technology and presents some initial research questions in studying this population.

Keywords: Telemonitoring, Telehealth, Aging Population, Electronic Medical Record, Home Care, Continuing Care Retirement Community.

1 Introduction

Due to the new government incentives to increase the use of electronic medical records and devices that support them, many people already have access to devices that will update their health records remotely. An electronic medical record (EMR) is an electronic version of a person's medical health record. Devices that support the ability of a patient to upload information directly to that medical record are usually referred to as Telehealth or Telemonitoring devices. According to the Centers for Medicare and Medicaid Services (CMS), Telehealth (or Telemonitoring) is the use of telecommunications and information technology to provide access to health assessment, diagnosis, intervention, consultation, supervision and information across distances [1]. The value of such devices is to support longer independent living for ageing adults [2].

The use of electronic medical records in this study will be focused within the confines of a continuing care retirement facility. The patients within these communities are referred to as residents, as they reside at the specific community. These medical records are usually updated by the care team for that resident. The care team consists of all persons that assess, treat, diagnose or impact the resident's health care. These include, but are not limited to their physicians, nurses, care coordinators, rehabilitation team, etc.

With constant changes to medication, many residents are requested to keep track of certain vitals in order to assist the care team in ensuring that the medicine which has been prescribed is working as intended. An example that is common in the medical community occurs with changes to high blood pressure medications and the request of

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the resident to keep track of their blood pressures for a given time, sometimes at specific times during the day. This information assists the physicians in determining changes that may be needed to improve the resident's health. It is at this time that medical record gets updated with information that is obtained from the resident. Another example would be a diabetic resident, tracking their blood sugars levels, similar to the blood pressure check, it would occur at specific intervals as determined by the resident's health care providers.

As with any information that is being maually documented, there is always a risk of data entry error. A suitable more efficient way would be for information to be automatically updated when taken by the resident. Using remote health monitoring in situations like these can be ideal for both the resident and the care team. This information, as mentioned earlier is used to assist with treating the resident, therefore, it is critical that it is accurate.

2 Background

In order for telehealth to be useful and successful within a retirement community setting, it must be perceived as useful by the organization, health care team and the residents. Usefulness from an organization perspective will be associated with the reduction of cost and improvement of efficiencies and effectiveness [3]. Usefulness for the health care team would provide assistance with the resident's compliance to health care protocols and a reduction of hospitalizations and readmissions. Usefulness defined by the resident would assist with increased ownership of their personal health care.

In order for an organization to invest in telehealth technologies, some cost-effectiveness will be considered. One review of 50 studies which include different telemedicine applications within a variety of departments found results that ranged from a 400% reduction in referrals for urgent assessment to no major differences in clinical outcomes [4]. This information demonstrates the inconsistency in data collected in this field due to the technology being new and not having a huge amount of data to assess its true cost effectiveness that could compare currently used protocols against the telehealth alternative.

Another key barrier for adoption and development of telehealth applications are the licensure requirements. This is governed independently by each state and has been difficult to get "buy in" from all states to allow a physician the ability to practice telemedicine [5]. The other common barriers are malpractice and the reimbursement of those providers that provide telemedicine. The high cost of telecommunications has also affected its growth. Once considerations have been made to accommodate some of these issues there will be a greater interest in performing more cost-effective reviews of this type of technology.

To support the use of telehealth within an organization for the health care team, this technology should be able to demonstrate improvement of care for the resident [6]. A couple of examples can be provided by research studies which demonstrate the improvement of patient adherence to medication of 50% when the use of an automated telephone patient monitoring application was used [7]. Another would be a 0.3% lower HbA1c level that demonstrates better glycemic control by patients who used an automated telephone disease management application [8]. To support the adoption of telehealth by the residents it should be easy to use [9].

3 Technology

Understanding how technology is viewed and used by different groups may assist with determining how it may be adopted. Some factors that will be reviewed that may play a role with groups are: gender, age, and experience with technology as these may determine the accuracy of data that is entered, depending on the user's ability to understand and use technology [10]. People's attitudes towards technology are generally an effect of their experiences with technology in general. A person that has worked on a computer for the last 30 years of their work life prior to retiring will probably have a different perspective than someone who has retired and never used a computer [11, 12].

3.1 Gender

Some research has demonstrated that genders have different perspectives when it comes to technology [13, 14, 15]. Men need to understand how it is going to be useful whereas women need to know that it will be easy to use, along with peer approvals and support. Once these differences are understood, then it is easier to determine how to educate the users of the new application.

3.2 Age

Age plays a major factor in user acceptance and usage of technology [16]. There are several psychological factors that affect learning and retention. These will need to be considered when evaluating teaching, training and accurate use of a telemonitoring system for people 65 years and older.

3.3 Experience

Additional measures of past exposure and use of technology will need to be considered as this may determine the speed of grasping new technologies. It may also be used to explain negative or positive feelings [17] towards the telemonitoring device.

3.4 Device Components

The system being studied is divided into 2 different components. The first component is a portable device that is placed in the resident's home. Connections are available for specific brands/types of blood pressure devices, pulse oximeter and blood glucose devices. There is also availability for wirelessly connected, blue tooth enabled weight scales. The device allows for manual entry through a touch screen input. The second component is the back end database which the device transmits information to and is managed by the care team. The care team can determine intervals for when the resident should participate in an activity. These range from watching videos, answering questions regarding well being and medication adherence along with taking a reading from the specific devices.

All decisions are made by the care team with respect to what information is needed, intervals etc. The device also allows the care team to contact the resident via video conferencing. This requires high speed internet connectivity in order to be maintain a stable video session. All information that is entered by the resident gets uploaded after each session into the database which is viewed by the care team. This part of the telehealth system allows for tracking and collecting information. It allows the health care team to generate reports of the resident data over time periods and displays the information in text form and through the use of graphs.

4 Study Purpose

A telehealth product must be deemed reliable and accurate before the health care team would consider it for use [18]. If information is not accurate it will negatively impact the decisions that are made by the health care team and the care of the resident. The telehealth device being studied, allows manual entry of several health measures including blood pressure and blood glucose levels. These measures, could also be uploaded directly from specified blood pressure monitor and blood glucose devices. It also transmits all entries automatically at the end of every session and stores all data being captured. The device also allows the healthcare team to initiate video conferencing to the resident.

The providers can also establish threshold violations for each resident specific to their needs. There is also a feature to immediately contact the health care team if the data that is captured is above or below a specific threshold value. The device also provided the resident with videos on chronic disease management that is related to their medical need. These devices can also remind residents' to participate in a specific activity i.e. taking medications, appointment reminders, data input into the device etc. All of these features provided a great product that included proficiencies for the healthcare team and health care ownership for the resident.

Any information that is captured by the resident is considered self-reported data. There is a concern of accuracy due to data entry errors that may occur by the resident, as this information is automatically uploaded into the database hosting the medical record [19]. This data is what the healthcare team would review and utilize in providing care to the resident and though the telehealth device prompted questions to the resident to assist with the accurate collection, there is a need for additional methods to be determined so that the healthcare team could decipher which data is accurate [20]. It is also important for some form of communication to be designed to inform the user when information was successfully transmitted or even when it was reviewed by the health care team. This would assist in providing necessary feedback to the resident and not give them a false sense of security [21].

5 Assumptions

- Information capture by a device as opposed to a manual entry will have different levels of accuracy.

- All residents will be over the age of 65.
- Every individual will have differing levels of experience based on their life experiences, age and gender.

6 Significance to Residents' Quality of Care

Quality care for residents can be improved with accurate medical records. When using alternative methods to collect data it is important to establish policies to assist with verifying that the data is correct. Some peripheral devices that can be attached to telemonitoring devices enable error messages to be displayed if it was not collected correctly. Some telemonitoring devices also contain specific ranges that can be determined by the care team. These ranges will assist the health care team to determine accurate data as they can graphically see and compare other measurements that were collected. Other benefits of successfully implemented telemonitoring programs can be demonstrated through cost savings to facilities, residents and reduced hospitalizations [22, 23].

7 Research Questions

The guiding question here is: How accurate is self reported data in an Electronic Medical Record and what is the effect on personal experience with technology on the input of data? The study will focus on answering the following questions:

How valid is data input from resident's with computer technology experience?
Does age play a factor in accurate usage of the device?
Does gender play a factor in accurate usage of the device?

8 Conclusion

Based on current clinical processes, implementing a telehealth device may be a great strategy to assist in improving the quality of life for residents. Understanding how factors such as age, gender and experience impact learning, understanding and perception of technology will provide a means of structuring training, developing interfaces and specifying feedback to the users of the technology that can assist with mainstream adoption of these types of technologies.

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Using Motion-Sensing Remote Controls with Older Adults

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Abstract. This paper examines how motion sensitive remote control devices can improve the usability of television sets for older adults. It investigates the use of a pointing remote control where the actions are read and selected on the TV screen by a group of users between 65-85 years old. It was seen that the test participants universally wanted a more usable and less complicated device in both appearance and employability. The preferences in relation to channel choice were relatively narrow, mainly in the use of only 4-7 channels. The argument is proposed that the use of differing design principles facilitates older adults in also becoming proficient users of new technologies, especially focusing on the use of digital television (DTV) and the many opportunities and options to access new features that arise.

Keywords: interaction design, universal design, pointing, motion sensing, accelerometer, Wii, remote control, older adults, aging, attractiveness.

1 Introduction

The need for an alternative to the traditional TV remote control comes from the frequent problems older adults have in choosing which buttons to use for activating a certain feature, trouble seeing and pressing the desired button without having to switch to reading glasses and interpretation of the labels on the buttons. The solution considered here is using gestural interaction, where a gestural interface is programmed to interpret human articulation, via a pointing remote control.

The empirical data in this paper is based on interviews that were conducted with older adults from 65 to 85 years of age. It addresses some of the initiatives in relation to the target group that already exist and looks at whether any of these have had success. Moreover it introduces an alternative user interface than that which is based on using a pointing remote control.

1.1 Older Adults and the Television Remote Control

During the past few decades, there has been a rapid evolution in the area of information technology, including television. New technology has been introduced for playing recorded television and commercial films, such as HDD-, DVD- and blu-ray recorders. With the advent of set-top boxes (STB) and DTV there has been the

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introduction of many new services such as cable and satellite television service, pay-per-view films and video-on-demand [1].

All these available options present challenges as well as opportunities. For example, while typical end users prefer having more options to choose from rather than fewer, this is counterbalanced by a desire for the selection process to be both fast and simple. When older adults are considered, the majority want fewer options and a simpler way to manage the control and it does not have to be particularly fast [2]. Unfortunately, though, the selection processes for many systems and media interfaces are neither fast nor simple. Since Adler introduced the world of remote control in the early 50s [3], there have been major advances in the interface design and many new technologies such as touch sensitive displays and accelerometers, but the advanced models are often too expensive for the average user. A small LCD display and an increased number of function buttons have often been the only major developments on remote controls in the broad consumer market.

Newell claims that we need to devote more research efforts to designing artefacts to control our technological homes to support older adults people [4]. An increasingly ageing population is a very pressing challenge to accessible computing [5], with the over-65 age group expected to increase sharply. By the year 2040 the over-65 age group will increase by 70% above its present level in Denmark [6]. This is not a local trend; also Europe is experiencing a major demographic shift. By 2025 the proportion of the population over 65 is expected to increase from 20% to 28% [7, 8].

At the same time, the lack of accessibility to many ICT-based products and services is a major barrier for many people. Currently 30% of Europe's population is not actively participating in the information society [9]. It is also worth noting that the expected number of people with cognitive impairment is expected to grow faster than the number of older adults people and they diverge dramatically after 2036 (see fig 1).

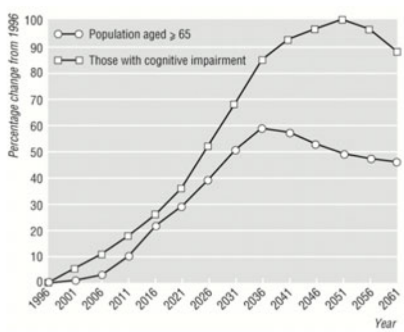

Fig. 1. Projected changes in numbers of people aged 65 and over and in those with cognitive impairment in Britain by year (1996-2061) [9]

When looking at the demand in conjunction with TV sets, a study made by the UK National Institute of Adult Continuing Education (NIACE) found a correlation between age and leisure-time activities [10]. 21% of 17-19 years olds spend more than 11 hours a week surfing the Web compared with just 2% of those aged 75+. However,

Table 1. %age of respondents by age group participating in the specified leisure time activities for 11 hours or more [10]

Age	17-19	20-24	25-34	35-44	45-54	55-64	65-74	75+
Surfing the WWW (%)	21	19	12	12	6	5	3	2
Watching TV (%)	40	43	49	52	62	71	80	80
Listening to the radio (%)	12	18	22	23	25	31	34	30
Number of respondents	221	416	803	954	761	808	545	423

40% of 17-19 year olds and 80% of those aged 75+ spend more than 11 hours a week watching TV. Radio listening was also common among the older adults.

1.2 New Digital Opportunities Impose New Demands on Interaction Design

There are many new services possibilities arising from the introduction of DTV. The services that today often come with providers of set-top boxes are all directed at improving one's programme schedule for the individual channels and provide access to more content. Services include:

- EPG (Electronic Program Guide).
- VoD (Video on Demand).
- Watch an ongoing broadcast from start.
- Scheduling upcoming broadcasts from EPG.
- Access the library of past displayed works by the Public Service channels.

This is only the beginning of the DTV era. Many new services will emerge and a many of these will bring focus on the social aspect of having the viewers interconnect and support socially oriented activities and a social network through DTV services [11]. This can provide an opportunity to bring lonely older adults out of solitude and is an important factor as to why it is so important for older people to be able to adopt DTV [12]. This then presupposes the need for appropriately designed services that accommodate the older adults' life situations, their age-related conditions and, ultimately, include the best possible interaction device to control them.

1.3 Attractive Inclusive Design of Remote Controls

Looking at the many variants of remote controls that are on the market today, there is a discrepancy between the way buttons, displays, packaging, etc. are designed and the need and the performance of the older consumer. To provide access to the potentially sizeable market share of the older adults, it is necessary to give the older adults people positive reasons to select a new product. If products and services can be designed that they feel comfortable with whilst also supporting their skills and independence, then that goal will be reached. Thoughtful, inclusive design, in most cases, creates products, services, environments that work better for people of all ages and abilities and hence produce wider appeal and revenue.

Therefore it is obvious, that a proper implementation of a motion sensitive remote control needs to follow the 7 principles of universal design. There is one further consideration that is often neglected, namely attractiveness. It is somehow embodied under the principle of Equitable Use, which deals with avoiding segregating or stigmatizing of users and makes the design appealing to people with diverse abilities.

Attractiveness covers also *aesthetic value*, which is also vital for the success of an inclusive product. When designers are told to design for old and disabled people, it appears that they have a tendency to design for stereotypes and emphasize on function rather than style. It cannot be a surprise that older adults people with functional disabilities and disabled people, just as everyone else, wish for products that offer function, dignity, and enjoyment and express their desired personality. In other words, there is a divergence between the designers and the users.

1.4 Existing Remote Control Solutions for Older Adults

Working with older people as the target group sharply identifies the restrictions that are present within this age segment. Even though most older adults are healthy, there are known variations of age-related conditions. Many people in this segment have decreases in functional capabilities, arising from changes to vision, cognition and dexterity, as well as cultural and generational differences with technology [13, 14].

This emphasises the need to take special considerations when working with design of digital applications and services to support the needs of the older adults. The best known efforts to meet the older adults generations' difficulties have primarily been focusing on making much larger buttons and thus the physical size of the device have increased (see fig. 2a and 2b). Two of the most obvious flaws are the placement of buttons and the printed text on the buttons that can cause confusion and also the physical handling of the large remotes can be problematic. The Innovage Jumbo Universal Remote Control (fig. 2a) also needs to be programmed to the individual TV set, and, according to sources on the Internet [15], this device comes with very limited directions on how to program the device. Others such as the TekPal (fig. 2b), meet the desire for a more handy device and stick to the absolute basic functionality, but omit many useful functions, e.g. switching input (DVD, VHS, etc.) and Teletext., which is used by half of those aged 65 and over [10].

(a) (b)

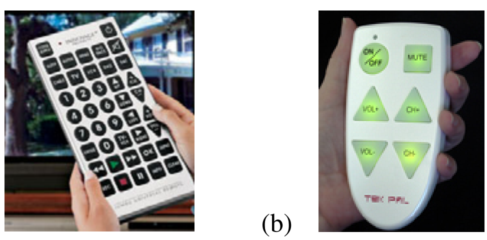

Fig. 2. (a) Innovage Jumbo Universal Remote Control and 2(b) TekPal

Looking away from the physical artefact, the configuration menus and the graphical interface on the screen are often very confusing for the older adults person. It has already been demonstrated that the older adults represent a large proportion of the TV viewing public. Simultaneously they belong to the segment of the population that is least familiar with the conventions used when presenting information digitally.

A growing number of the older population are becoming familiar with computers, but for many it can present a challenge, when interpreting icons, links, hierarchies and menus, - all items that are widely used in the television interface today. There is a solid opportunity to affect a change by studying new alternative approaches to the use of remote controls amongst the older adults.

2 Interaction Experiments with Pointing Remote Control

The design process for this paper used Design Research Methodology (DRM) of Blessing and Chakrabarti as the methodical research strategy [16]. Using this method a correlation of the empirical data, the theoretical development and the practical work was gained.

Stage 1 – defining the problem: a picture of the target group for the research was provided using literature combined with surveys and 6 semi-structured interviews.

Stage 2 – developing a solution: the conceptual design process and development of a solution to be used for the final user test.

Stage 3 – evaluating the solution: performing the final user tests. During this stage paper prototyping and extended use of the Think-aloud method, although Dickinson claims that the method can be problematic with older adults, especially if conducted under laboratory conditions. [17]. Consequently, the sessions in stage 3 were held in the test participants' own private homes.

2.1 Stage 1 – Defining the Problem

The results of the interviews with 6 older adults led to a clearer understanding of the target group and provided valuable input that was used in the design process. Furthermore it revealed the severity of the participants' disabilities. Table 2 shows the categories that describe the respondents' TV habits.

Table 2. The 6 interview respondents' TV viewing habits

Results from 6 participants	Age	Gender M/F %	Television usage h/week	Watching tv	Using TeletextTV	Sum of watched channels
Average	74	50/50	32.8 hours/week	5.8 days/week	seldom	5

A disability survey was presented to the respondents to classify their age-inducted disabilities. The answers from the six respondents were quantified after Keates and Clarkson's disability scoring table [18], as shown in Table 3.

The average time of watching TV per week was 32.8 hours, with a span from 8 to 80 hours. This was about 10% over the public average according to a Danish survey [19] and expected for the age segment according to the NIACE survey [10] and Stein Institute for Research on Aging [20]. The participants watched TV on average 6 out

Table 3. The disability severity levels for the 6 interview respondents – lower numbers are more severe impairments

Value	A (F77)	B (M72)	C (F75)	D (M66)	E (M81)	F (F69)
Locomotion	L4	-	L2	-	-	-
Reach & Stretch	RS8	-	RS3	-	-	-
Dexterity	D11	-	D5	-	-	-
Vision	S8	S9	S7	S9	S9	S8
Hearing	H8	-	-	-	H6	-
Communication	-	-	-	-	-	-
Intellectual	I7	-	-	-	I1 + I7	-

of 7 days. Teletext was not as commonly used among the respondents as expected, with only seldom use. Many of the participants said that they were very selective when it came to selecting which channels they watched and were especially keen to avoid the reality TV shows on the commercial TV stations. The mean number of channels that they liked to follow was 5 (range: 4 to 7).

2.2 Stage 2 – Developing a Solution

In order to find the choice of preference for the test, an evaluation was made on some of the larger participants on the market of motion sensing remotes. These devices included the Nintendo Wii Remote (WiiMote), Hillcrest Freespace Technology (Hillcrest Loop, Kodak Theatre HD Player and the LG Magic Motion Remote) and Philips uWand. Based on device availability and expressed user preferences, the Hillcrest Labs Loop (fig. 3) was selected for further research.

Fig. 3. A participant holding the Hillcrest Loop remote

Exploratory test sessions were held as a combination of a Think-aloud test, where existing solutions were evaluated, combined with a creative workgroup exercise, where the objective was to perform a conceptual modelling of a pointing TV interface. Flex framework for Flash was then used to create a prototype for a TV interface that could be controlled by moving a pointing device around with a single button to confirm actions. The prototype has four active areas, which can be activated by hovering the pointing device on one of the sides.

A TV Channel selection bar with program description on the left side (fig. 4), Volume and mute on the right side, the top bar showing available options (TV, radio, photo album, settings) fig. 5, and a Pause / Play button at the bottom.

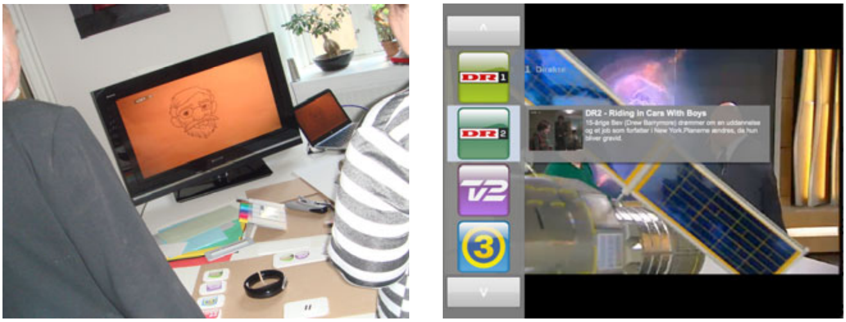

Fig. 4. From paper prototype to Flash prototype

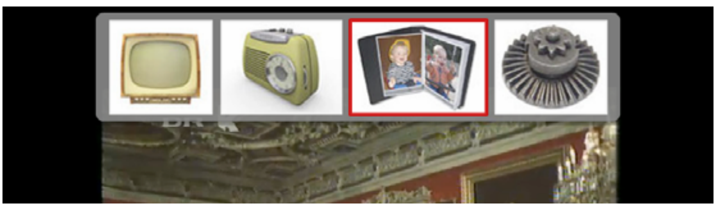

Fig. 5. Option bar on top

The reason for building the prototype in Flex was simply because it allowed for clean separation of layout and code not unlike HTML/JavaScript. MXML is a markup language based on XML which in Flex offers a way to build and layout a graphical user interface using many standard user interface elements. For the interactivity, Actionscript was used, just like in Flash. Flash Builder (previously named Flex Builder) was the tool used to build Flex based apps. Besides programming in a text environment, it also contains a graphical editor to quickly layout an application and quickly allows assembling a working prototype.

The challenges with pointing remote controls

If a person is skilled with a particular remote control, there is no doubt that traditional tasks can be done a lot faster than using a point and click paradigm. However, speed was not the goal here, instead it was to enhance television usage.

Gesture based remotes are evolving rapidly. The Philips uWand has contributed with many new developments in this area, giving the user the ability to drag a picture from the television screen to a digital photo frame and easily zooming in by just dragging the remote towards away from the screen. The possibilities are great and, if the principles from inclusive design are adopted, then there is a great opportunity with this technology to create solutions for all.

Motion-sensing remotes all need some kind of receiver, and until there is more evidence of next-generation television sets with built-in receivers like the LG sets, the external sensor bars or RF-receivers need to be connected to a computer / set-top box. Introducing pointing technology to an older adult, where the only functionality they require is channel and volume control, requires an external computer with TV tuner. This can be a major obstacle for the implementation.

2.3 Stage 3 – Evaluating the Solution

User trials with the prototype were conducted with 6 respondents.

Feedback: test remote (Hillcrest Loop). There were confused minds about the form factor of the Loop remote. There were several who stated that the design was too modern compared to their taste. Many of the respondents then later realised that the alternative shape was practical to hold on to and felt more natural in their hands compared with conventional remotes. Regarding the weight, the respondents were divided in three categories; but the majority found it to be satisfactory. A small experiment that was conducted with three different prototypes of remotes also identified the importance of making remotes for older adults lightweight to allow for arthritic hands. Habituation to the round shape was difficult for the older adults, since it was not easy for them to adjust to new shapes for familiar artefacts.

Working with cursors caused a bit trouble for a few of the participants since it was an entirely new experience for them. Half of the respondents were frustrated by the sometimes sloppy pointer recognition, which required occasional reorientation.

Feedback: screen interface. The respondents were surprisingly fast in understanding the pictograms displayed on screen. They quickly adapted to the hidden four active areas and knew which area they had to activate by hovering the pointing device over the side. One of pictograms, the mute button, did give rise to some misunderstanding. Most of the participants had trouble finding the mute button on their own traditional remote, and several did not know if they had one. A smaller proportion of respondents did not understand the mute button's function. Two users chose to switch off the whole TV set to mute the sound.

One participant was not quite sure where she had a specific channel (DR2) placed, and she was generally positive to the clearer interface in the flash prototype, where she could see 4 channels simultaneously.

Feedback in general. After the respondents had been allowed to get accustomed to the new system, they had an overall positive attitude towards a pointing remote control solution. Two respondents were so comfortable with the situation and got so used to manage the remote control that they began to explore the upper feature menu and the hidden extra four channels that appeared when they pressed the down arrow.

2.4 Redesign Recommendations

The circular form of the Hillcrest Loop presented problems for many of the test participants when lifting it from a flat surface, such as a coffee table, with the users often picking it up upside down. This problem could be eliminated with a coloured marking on the black ring indicating ideal hand placement and direction. An arrow was temporarily attached to the Loop that alleviated this problem, but this cannot be considered an adequate permanent solution.

Finally, the loop form needs to possibly be discarded and a return to a straight and narrow form is re-adopted, as exemplified with the LG Magic Motion Wand. In this instance it needs to be appreciated that such a device is often used in only a semi-lit environment and so a certain texture need be applied to the controlling surface so the user's hand can feel its way to the user position.

As for the interface, the text size should be enlarged for the program information pane in the next version and improved icons should be developed for the mute and settings functions.

3 Conclusion

First and for all, it is essential to realize, that it is close to impossible to provide a design which fall into everyone's taste. Even though the concept of inclusive design for "everyone" here means the older adult test participants, there are so many differences when it comes to describing their physical, sensory, motor and cognitive abilities. It is simply not possible to include these broad amounts of differences in one design process. Nevertheless it was pleasing to acknowledge the acceptance of the novel remote, although it would have been much more likely to receive an even more positive feedback, if a motion sensing remote as the LG Magic Remote was used, since it shares the form factor with the remote they are familiar with and contain the possibility to adjust volume on the remote.

There is a strong indication that the older adults have the distinct opportunity to employ motion sensitive remote control devices. The only concession, as with any TV user, is that any particular TV interface must be customised to individually suit their needs. Also it has been seen that older adults persons are able to adapt to a novel remote, which was confirmed when five out of the six respondents showed interest in the new TV interface presented in this paper.

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Design Lessons for Older Adult Personal Health Records Software from Older Adults

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Abstract. Online Personal Health Records (PHR) software has the potential to provide older adults with tools to better manage several aspects of their health, including their use of medications. In spite of this potential, we still know little about how to make PHRs accessible for older adults. We also know little about how to design PHRs in a way that will enable older adults to get a valuable return on their time investment in using such systems. In this paper, we present our experience partnering with a group of older adults to obtain design guidelines for the design of a PHR with a focus on medication management. We discuss the outcomes of our design partnership and provide an overview of the design of a web-based PHR we designed based on these outcomes.

Keywords: Older adults, personal health records, medication management, design guidelines, privacy, personalization.

1 Introduction

Access to accurate and up-to-date health records, including medication records, is crucial for doctors to provide adequate care for older adults. When older adults use the services of multiple health providers, the potential for doctors making decisions with inaccurate information increases. This is compounded by cognitive declines many older adults face, which can hamper their ability to recall information on medications, conditions and so forth.

Online Personal Health Records (PHRs) have the potential of alleviating this problem by providing older adults with a repository of health information that is easy to edit and share. However, little information is available on how to design them taking into account the needs and abilities of older adults.

In this paper, we present our experience partnering with a group of older adults to obtain design guidelines for the design of a PHR with a focus on medication management. We discuss the outcomes of our design partnership and provide an overview of the design of a web-based PHR we designed based on these outcomes.

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2 Related Work

2.1 Challenges in Designing for Older Adults

As adults get older, declines in cognitive, perceptual and motor abilities affect their use of computer technologies. Some relevant examples of declines in cognitive abilities include those in fluid intelligence [3][29], working memory [3][19][28][30], learning [28][1][23], and the ability to filter irrelevant information [29][35]. These declines have led, for example, to recommendations of longer training times for older adults [16][24][33] and minimizing visual clutter in user interfaces, including the number of options available at a given time [36][17][37].

Declines in perceptual abilities often result in older adults having vision problems [13][27], as well as hearing problems [4][26]. These declines can affect interactions with computer technology as most software communicates with users through a visual display often accompanied by the use of sound. Using larger fonts and a higher contrast between text and background can help remediate some of these problems [37][2][9][12]. Multimodal feedback (e.g. using visual, audio and tactile means) has also been recommended [10][32].

Age-related neuromuscular changes combined with cognitive and perceptual challenges affect the performance of older adults in pointing tasks [7][34][21]. Not surprisingly, results from a number of studies have found that older adults have difficulty using computer pointing devices such as a mouse, with various strategies proposed to address this problem [8][14][15][31].

The lack of experience many older adults have in using computer technology poses additional challenges, for example, in being confident in their use of computers [11][20][6].

The challenges outlined in the previous paragraphs suggest that older adults require user interfaces designed specifically for their background, needs and abilities. User interfaces designed for young adults who are heavy computer users are unlikely to provide older adults with effective, efficient and satisfying interactions. Software for older adults should be designed using user-centered design techniques, directly involving older adults in every step of the process.

2.2 Online Personal Health Records

Dozens of online PHRs are listed in the myphr.com website, with some major players joining the list recently, including Google Health and Microsoft HealthVault. In spite of the availability of all these systems, little research has been conducted on PHRs designed specifically for older adults [25].

3 Research Goals

Our primary objective was to obtain requirements and specifications for the design of a PHR targeted at older adults with an emphasis on managing medications.

4 Description of Activities

We held twelve one-hour sessions over four weeks in July and August of 2009 with a group of eight older adults at the adult retirement community where they resided. Four of our participants were male, four female. Their median age was 78 (min=71, max=82). All participants reported taking at least one medication daily, using the web for at least 30 minutes on a typical week, and having an email account.

In each session, we introduced a question and then broke up into small teams of two to three older adults and one researcher. The small group activities involved older adults providing feedback on low and high-fidelity prototypes by writing on sticky notes things they liked, did not like or would like to change. We conducted similar "sticky note" activities to gather information on specific questions. After gathering sticky notes from small groups, we put together affinity diagrams on a whiteboard, and discussed the outcomes with the entire group.

In addition, we later held three one-hour sessions of a similar format with a different set of eight older adults to validate our system as we designed it. This group was also gender balanced, had a median age of 75 (min=65, max=81), and reported taking at least one medication daily, using the web for at least 30 minutes on a typical week, and having an email account

5 Principal Findings

5.1 Older Adults Want to Keep Track of a Lot of Information but Are Willing to Enter Very Little

Participants listed over 20 separate items they wanted to track for each medication. These included:

- name and contact information for doctors and pharmacists,
- the purpose of the medication,
- how to take it (including restrictions),
- all dates associated with the prescription (e.g., date filled, expiration date, when to refill),
- strength or dosage, medication form (e.g., tablet),
- how long to take the medication,
- the name of the manufacturer,
- information on side effects and interactions,
- the condition for which the medication is being taken,
- what to do if a dose is missed or too much is taken,
- an image of what the pill looks like, and
- side effects observed by patient

At the same time, the participants saw having to enter all that information as a major barrier in using a PHR. This was clear in a session in which participants saw three prototypes to enter the data they had identified. Their feedback was that they would be highly unlikely to enter all that information.

During a separate session, we showed participants an online system that could enable them to print out a list of their medications with a minimal amount of information about each. The lesson learned during this session was that participants were willing to enter limited amounts of information (e.g., six items per medication), and that PHR designers should identify the most important items to keep track of and ask users to enter only these.

For medications, the top items participants wanted to track were: name, dose, how to take it, why it was prescribed, and information on precautions and interactions.

5.2 Medication Warnings Written for Health Care Providers Are Not Appropriate for Older Adults

In order to learn about how to deliver medication warnings to older adults, we began by showing adults warnings written for health care providers. The first session we discussed warnings, we obtained feedback from participants on two unmodified ACOVE [18] warnings. While participants found the warnings generally understandable, they had issues with some of the vocabulary (e.g., what is a "vulnerable elder").

In addition, they were concerned by some of the implications of a warning that said that older adults should not take a particular medication (propoxyphene). Our participants wondered why doctors would prescribe such a medication in the first place, and why a pharmacist would not have caught the problem. This discussion occurred prior to recent withdrawal of this drug from the US market.

In this session and others, participants were concerned about the validity of the warnings, as they could be perceived as a way of promoting a competing product. It was difficult for some participants to understand how warnings would be generated, a problem that was related to an overall lack of understanding of how the Internet works. In spite of these concerns, there was strong belief that patients should receive these warnings.

Suggestions for changes included using shorter sentences and less technical vocabulary (e.g., using "pain relief medication" instead of "analgesic"). In subsequent sessions, we obtained iterative feedback from high-fidelity prototypes to study how warnings should be delivered to older adults. We learned that it helped to provide three levels of information. The first level, always visible, consists of a short phrase that provides a good idea of what the warning is about. Participants agreed strongly that this first level should clearly explain what the safety concern is. Clicking on this first level warning, pops up a window with a one to two paragraph warning, which can in turn be expanded into a scrollable, detailed, third-level warning.

5.3 Perceived Privacy and Security Are Crucial for Adoption

We heard a lot of concerns about the privacy of the data, which were exacerbated by a lack of understanding of how the Internet works. Many participants had difficulty understanding where and how data would be stored and how it would be secured. There were many mentions of "big brother" looking over their data and of employers or pharmaceutical companies taking advantage of the data, in detriment of patients.

Some of the participants appeared to remain suspicious of our true motivations through all three weeks of interactions with them. This provides a sense of the great challenge in getting older adults to trust PHRs, and in particular, the way they handle privacy and security. The lesson we learned is that no matter how good the privacy and security features of a system are, perceived privacy and security are just as important. Older adults will not use a PHR if they do not perceive that it will keep their data secure and private.

Participants also had concerns about where content provided by the system would come from. This was the case for medication warnings, as mentioned in the previous section, but also for any other advice provided through the system.

Affiliating the PHR with a trusted institution and/or making use of appropriate metaphors may help in both regards. For example, our participants appeared to trust Medicare and insurance companies with handling their health information. Likewise, metaphors could be used to present the PHR as an extension to their memory or as a virtual version of the information they would like to keep in their purse or wallet.

5.4 Adapt to the Needs of Specific Patients

Presenting a PHR that is customized to individual needs would make it more likely for our participants to adopt it. For example, a PHR for someone with diabetes would put a greater emphasis on tracking blood sugar and diet. This was apparent from discussions in several sessions, where participants would suggest features that were tailored to their specific needs, but would not be relevant to others who do not share similar health concerns. It was also clear that participants would be unlikely to customize the user interface if given the chance, and that this could lead to further confusion. Instead, participants said they would be most comfortable if they could access pre-designed user interfaces for the most common ailments.

6 Discussion

6.1 Participatory Sessions at a Retirement Community

We found great value in engaging older adults over three weeks in discussions on how to design better PHRs for older adults. The depth of the discussions and the depth of the recommendations and guidelines that we arrived at would not have been possible with shorter engagements. In particular, with a population that in many cases is not technically savvy, we learned that meeting over several days helped them understand our goals better, and helped us understand their needs and concerns better. As such, we believe we obtained great value from working with older adults in this manner, and expect that we would have been unlikely to reach similar conclusions had we hosted fewer sessions.

Another advantage of hosting sessions concentrated over three weeks, as opposed to spread out over a longer period, is that it made it easier for the older adults to concentrate on the task without having to reintroduce the project.

Hosting the sessions at the retirement community where the participants live also provided advantages in making them feel comfortable and at home. In addition, by seeing and speaking with fellow participants while we were not there, participants continued to be engaged in the project, thinking about it even while we were not present.

In spite of these positives, we also found challenges with our approach. The main challenge was likely caused by a combination of cognitive declines in the participants and the fact that they spoke to each other about the project when we were not present. We found that at the beginning of every week, a few participants raised the same set of questions regarding the true objective of the project and risks to the information of the participants. They thought we may be agents of pharmaceutical companies trying to push medications, and they had concerns about how their personal health data would be used, even though we never asked them for this information.

We addressed this challenge by respecting the concerns of the participants and honestly answering all their questions. Even though we were often asked the same questions on a weekly basis and provided the same answers, we understood this to be necessary given the population we were working with.

Similar projects working with older adults should plan for time to address issues related to project goals and ethical concerns, and would likely benefit from having an upfront discussion of these issues when first engaging with a group in a similar setting.

7 Translating Lessons into the User Interface

Following our sessions we iteratively designed an online PHR with the purpose of obtaining longitudinal data from its use by older adults. Because we identified problems with the medication components of available PHR products, we have concentrated particularly on a module to help older adults keep track of their medications and obtain warnings related to the medications they are taking. As we have developed this online PHR based on the guidelines and specifications described above, we have consulted a separate group of older adults on three occasions, asking them to complete basic tasks with iterations of the system and obtaining feedback from them.

7.1 Keeping Track of Medications

To keep track of medications, we have followed the advice of our participants and kept the data to be entered to a minimum. Users are only asked to enter the name of the medication, which they can enter in free text or select from an auto-complete list that includes thousands of prescription and over-the-counter medications. They also can enter the strength of the medication, how they take it, and the reason they take it. See a screenshot of the user interface in Fig 1.

Our biggest challenge in this respect has been in providing a flexible auto-complete user interface that makes it easy to find medications. This is critical in order

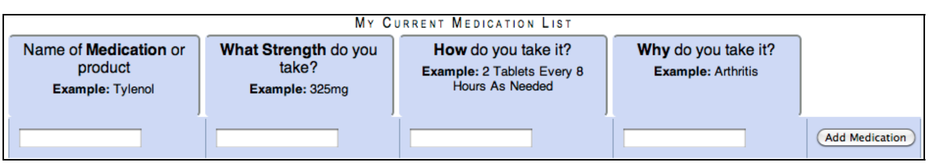

Fig. 1. User interface to enter medications

to be able to generate warnings, as medications need to be correctly identified for that purpose. The challenge is that pharmacies use different kinds of abbreviations for medicine names, with no standards.

Our current design reflects the lessons learned from concentrated sessions working with older adults, with a minimalist design that captures the most important data about medications, and thus makes it more likely that they will be entered by older adults.

7.2 Warnings

The warnings, as mentioned earlier, are provided with three different levels of detail. The first level uses just a few words and shows the warning under the name of the medication. See an example in Fig 2. This first level warning is intended to provide a general idea of the reason behind the warning. It is also meant to catch user attention, using easy to understand vocabulary.

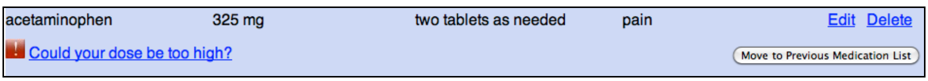

Fig. 2. Example of first level warning showing under medication

Clicking on the first level warning pops up a window showing the second level warning. See an example in Fig 3. This second level warning provides more details as to why the warning was triggered, in this case providing basic advice on how to avoid overdosing on acetaminophen.

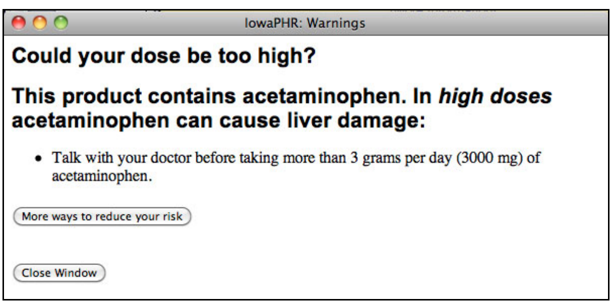

Fig. 3. Second level warning pops up in separate window when first level warning is clicked

Clicking on the "More ways to reduce your risk" button shows additional information on the pop up window. In the additional feedback we have obtained in the three meetings with the other group of older adults, our three-level warning approach has been well received, providing the right level of information at each point. It does not overwhelm users with all details at once, provides useful information at all levels, and enables older adults to obtain further information in case they are interested in learning more.

7.3 Use of Video for Expectations and Training

We are also making use of video to describe and present how to use our system. In our focus groups, we noticed that being able to see a very quick demonstration of how to use the system made it significantly easier for older adults to navigate and use our PHR.

8 Future Work

We have deployed our PHR and are currently conducting a longitudinal trial with hundreds of older adult participants to learn about how they use our PHR and about the impact of using the PHR on their use of medications. We expect this experience will help us better understand the features of PHRs that are most relevant to older adults and how these can translate into health benefits.

9 Conclusion

Working with a small group of older adults provided valuable insights on the design of a PHR targeted to them that would have been very difficult to obtain otherwise. We have developed a web-based PHR system based on the lessons described above. Our PHR follows a minimalist approach, tracking as little information as possible while enabling meaningful use in order to increase adoption. Our medication warnings emphasize specific recommended actions that patients can take.

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Design and Development a Social Networks Platform for Older People

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Abstract. According to the previous clinical studies, the social contact will be influenced on the life quality and health of elders. Hence, in health care for elders, how to maintain their social relationship is of primary importance. Recently, Morris proposed a conceptual model to address social isolations in a way similar to social index which can assist the elders to perceive and maintain their own social network with others whom have been previously strong ties. However, we found some drawbacks in Morris's study in display, function, cost, etc; therefore we proposed a novel social network platform attempting to display one personal social situation by using the simply behavioral feedback from the members in his/her social network. This platform includes the following properties: Addressing different information literacy and culture gap between two generations by integrating existing communication and VOIP (Voice over IP) application software into our platform, Allowing both online and offline communication, Displaying social feedback in the users' screen directly. Finally, in our study, we will adopt the TAM (Technology Acceptance Model) to validate the user's acceptance in using our developed platform.

Keywords: Elders social engagement, social networks, information literacy, culture gap on communication.

1 Introduction

Nowadays, aging of population is generally a social problem. Some elder people live alone because family members moving out for the employment or marriage. If these people live without any friends or relatives to chat with and concern, they will feel lonesome. It might bring about social disengagement. In order to improve elders' social engagement, Morris purposed a method to address social isolation as social indexes and then proposed a conceptual model to transform social networks as health feedback displays. She presented a solar-inspired display to depict trends of social interaction which are measured from sensor data of phone and infrared badges associated with the elders. By doing so, elders can make themselves aware of the social relationship and eager to improve or promote the interaction between people. However, there are some problems she did not consider.

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This paper reconsidered Morris's model and found some drawbacks as follows. First, Morris did not consider different information literacy. People involved in real social networks generally might be different generations. Different generations have different information literacy. For example, elders used to rely on traditional technologies (e.g., telephone) or methods (e.g., face-to-face) to interact with others, while younger might rely on emerging technologies (e.g., instant messaging). An idea social network should reduce the gap between the elders and younger. In other words, two generations are not in the same social network or platform. In order to promote social interaction between two generations, we need younger generations to participate in social network of this platform for elders.

Second, Morris's model does not consider different culture gap on communication. In social networks, different generations have their best ways to express themselves. For example, some elders are good at face-to-face interaction, while younger aren't. Most of younger are over reliant on emerging technologies (e.g., instant messaging) which causes them not to be good at expressing their true mind by direct communication (e.g., telephone), face-to-face communication. An idea social network should reduce the gap between the elders and younger. In other words, communication barrier between two generations should be overcome.

Third, Morris's display feedbacks only considered and displayed simple social relationship. Social index is generated by the movement toward and away from the elder. The elder is only impressed by perceiving the relationship. If the display can further show some critical social information, it can help the elders to improve his sense of joy. For example, if the system can display who actively pays concern for elders, elders will know who is concerned for them. They will get higher impression from it.

In this paper, we purposed some methods to solve the above problems. First, we integrated VoIP, instant messenger into our social platform. Through our social platform, two generations can participate in the same social network. In this social network, younger can send instant message to elders, while elders can make a phone call on internet to younger. The information gap between two generations can be converged.

Second, by integrating instant messaging, younger can use instant messaging to express their true mind to elders. In that case, two generations can interact with each other without feeling embarrassed. Therefore, we overcome the communication barrier between two generations.

Third, in our display feedback, our solar system can display more metaphor messages. For example, our system can display who is actively concern for a person by the size of planets. User can know which friends are concerned for him and feel a sense of existence. The sense of existence will pleasure elderly user.

2 Literature Review

2.1 Social Networks as Feedback Display

How to display one's social networks? In 2005, Morris [1] applied principles from cognitive-behavioral and mindfulness therapy to address social isolation as social indexes and then proposed a conceptual model to transform social networks as health feedback displays. She presented a solar-inspired display to depict trends of social interaction for the elderly. Social activities are measured from sensor data of the phone and infrared badges associated with the elders. This means that the measures are based on the amount of interaction by face to face and telephone. By doing so, elders can make themselves aware of the social relationship and eager to improve or promote the interaction between people. The elders can then increase social interaction by interacting with family or friends and furthermore improve their quality of life and health. However, she did not consider different information literacy between two generations and different culture gap on communication. Those problems might bring less interact between family members, young members and elderly member especially.

2.2 Different Information Literacy

Different generations have different technology using. Zoe Roupa et al [4]. found that the result of using technology by the elderly. The research reported that elders were familiar with using TV, washing machine, vacuum, iron, cooker, wireless phone. More in detailed, women were more familiar to using washing machine, vacuum cleaner, electric iron, stove than men, while men were more familiar to using wireless phone than women. Young generation was familiar to the use of computer and internet. Young people are associated with web and internet. In other words, two generations are not in the same social network or platform. Therefore, they can't always have a same space or opportunity to communicate or share some information with each other to promote family social interaction.

2.3 Different Culture Gap on Communication

As the growing of the internet, more and more people are relying on internet, especially young people. On internet communication, young people can express themselves without anxiety. People who easily get social anxiety also can fluently express themselves by internet. The internet seems to have this value to help people overcome communication problems like feeling nervous reported by Tom R. Tyler(2002)[5]. However, most of young people are over reliant on emerging technologies (e.g., instant messaging) which causes them not to be good at expressing their true mind by direct communication (e.g., telephone), face-to-face communication. On the other hand, elders are good at face-to-face interaction or direct communication (e.g., telephone). In this case, two generations might have a communication problem.

2.4 Technology Acceptance Model (TAM)

Technology Acceptance Model is a method to explain and anticipate a user's acceptance of IT. TAM is based on a theory called Theory of Reasoned Action (TRA), which purposed by Fishbein and Ajzen. TRA suggests that an individual's behaviors are determined by personal intention. Personal intention is determined by attitude. In 1989, Davis[6] purposed TAM which suggests that perceived usefulness and perceived ease of use of IT are major factors of IT usage. The definition of perceived usefulness defined by Davis is "*the degree of which a person believes that using a particular system would enhance his or her job performance*." The definition of perceived ease of use is "*degree of which a person believes that using a particular system would be free of effort*."

3 System Design and Practice

3.1 Social Communication Platform Practice and Design

In this paper, we reconsidered Morris's model and purposed some methods to solve Morris's problems. In order to remove the difference of the information literacy between two generations, we integrate VoIP, instant messenger into our social platform. Moreover, we designed a friendless user interface for elders. Elders can operate the application by laptop or tablet PC easily. They could just use one finger to select a one of their family members and make a phone call shown in figures 1 and 2.

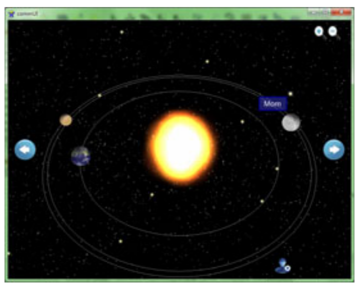

Fig. 1. Main user interface. This shows a user can pick a planet to get into a communication tools interface. A planet represents a family member or a friend. When users interact with their friend as more as possible, planets will come closer to sun. It represents that the friend is closed to you.

User needn't bother dialing phone number because every friend's contact information has been set up when user added a friend. In addition, elders can easily read messages from family members. When one of elders' family members sends a message from MSN or E-mail, elders will be notified by system shown figure 3. Therefore, through our social platform, two generations can participate in the same social network. In this social network, younger can send instant message to elders, while elders can make a phone call on internet to younger. The information gap between two generations can be converged.

Second, by integrating instant messaging, younger can use instant messaging to express their true mind to elders. In that case, two generations can interactive with each other without feeling embarrassed. Therefore, we overcome the communication barrier between two generations.

Third, in our display feedback, our solar system can display more metaphor messages. For example, our system can display who is actively concerned for a person by the size of planets shown figure 1. A planet become bigger, which represents a friend being actively paying concern with elders. Elders can know which friends are concerned for him and feel a sense of existence. The sense will pleasure elders. Moreover, when elders have more and more talks with their family, their screen will be full of shining stars. In that case, we expect that it can promote and eager a user to interact with friends or family members.

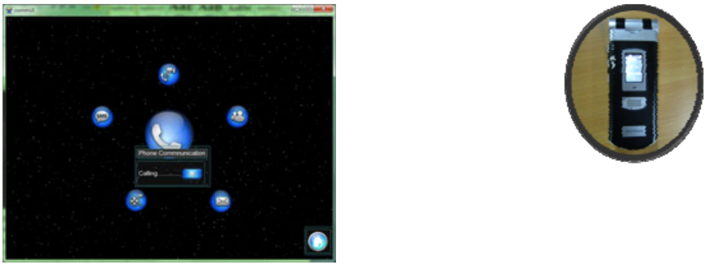

Fig. 2. Communication tools. This shows a user pick a phone button on the center of the screen. Then friend's phone you call will start ringing.

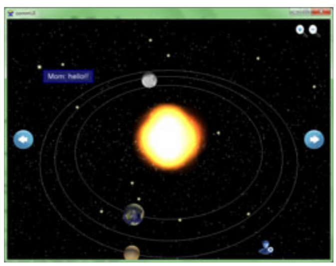

Fig. 3. Message receiving. A friend leaves a message, user can receive message by this interface. System will also notify user by showing newest message.

Table 1. The classification of communication tools

Online	Internet-Disable	Multimedia Message	None
		Text Message	None
	Internet-Enable	Multimedia Message	Skype phone
			Skype Video phone
		Text Message	Skype message
			E-mail
			MSN
Offline	Internet-Disable	Multimedia Message	MMS
		Text Message	SMS
	Internet-Enable	Multimedia Message	Video Message
			Voice Message
		Text Message	E-mail
			MSN

3.2 Communication Tools Selection

Our system included several communication tools: MSM, Skype, E-mail, Video message, Voice message, SMS, MMS, etc. We chose these representative communication tools as a sample based on our model shown table 1.We defined and classified the characteristics of all communication tools. In our classification, all communications can be classified according to online or offline interaction. Online interaction and offline interaction are classified into internet-disable and internet-enable. Internet-disable and internet-enable are aslo classified into multimedia message and text message.

4 Discussion

In this paper, we used TAM to verify whether this system can be accepted or not by user. The model for our research shown figure 4 is an extension of the TAM. Perceived friendliness, the extended part of TAM, is construct of feeling concerned because it brings the question of how seeing social concerned feedback display affect the individual's acceptance of our social platform. The assumption is that perceived friendliness will have a positive effect on the individuals' attitude toward using our social platform and users' behavioral intentions to use our social platform. Feeling concerned from others, we call it Perceived Friendliness, is necessary in our system. In social platform, feeling concerned is an important factor of effect on attitude toward using social platform.

Therefore we state Hypothesis 1. Perceived Friendliness will be a positive relationship to Attitude toward Using. Perceived ease of use and perceived usefulness is the basic of TAM. We also verify the following hypothesis.

Hypothesis 2. Perceived Ease of Use will be a positive relationship to Attitude toward Using.

Hypothesis 3. Perceived Usefulness will be a positive relationship to attitude toward Using.

Hypothesis 4. Perceived usefulness will be a positive relationship to Behavioral Intention to Use.

Hypothesis 5. Attitude toward Using will be a positive relationship to Behavioral Intention to Use.

4.1 Sample

The sample consisted of 32 students aged 20 to 24, who were majoring information management. The data were gathered by means of questionnaire. 32 usable questionnaires were used for analysis.

4.2 Internal Consistency Reliability

The coefficients are represented for each of the constructs in Table 2. The values of reliability range from 0.64 (for perceived ease of use) to 0.90(for Behavioral intentions to use). According to the exploratory nature of the study, reliability of the scales was deemed adequate.

Table 2. Consistency Reliability

Constructs	Definition	Mean	Standard Deviation	Reliability
PEOU	Perceived ease of use	3.92	0.57	0.64
PF	Perceived friendliness	4.03	0.62	0.84
PU	Perceived usefulness	3.92	0.61	0.76
ATT	Attitude toward using	4.02	0.46	0.68
BIU	Behavioral intentions to use	3.88	0.64	0.90

4.3 Construct Validity

Table 3 shows that the result of the factor analysis with varimax rotation. Five factors were extracted.

Table 3. Scale factorial validity

Scale items [a]	Factors				
	1	2	3	4	5
ATT1	-.106	.392	.155	.679	.331
ATT2	.399	.458	.055	.576	-.156
ATT3	.223	-.112	-.002	.836	.104
BIU1	.740	.262	.068	.217	.169
BIU2	.928	.075	.175	.099	.045
BIU3	.835	.185	.272	.111	-.071
BIU4	.720	.183	.137	.074	.197
PEOU1	.205	-.015	.005	.007	.809
PEOU2	-.013	.281	.008	.223	.836
PF1	.341	.820	.077	-.059	.157
PF2	.052	.891	.153	.163	.182
PF3	.550	.634	.069	.113	-.064
PU1	.099	.158	.845	.187	-.016
PU2	.549	.103	.738	-.100	-.047
PU3	.541	.009	.551	-.060	.168

[a] ATT1-ATT3, attitude toward using; PL1-PL3, perceived friendliness items; BIU1-BIU3, behavioral intention to use; PEOU1-PEOU2. perceived ease of use items; PU1-PU3, perceived usefulness items; n = 32.

4.4 Analysis Results

The hypothesized relationships were tested using regression analysis. Table 4 shows a result of the hypothesis test.

Hypothesis 1 examines the relationship between the perceived friendliness and attitude toward using: perceived friendliness is significantly related with attitude toward using (β= 0.372, p-value =0.055, $p<0.1$). Hypothesis 1 was supported.

Hypothesis 2 examines the relationship between perceived ease of use and attitude toward using: perceived ease of use is insignificantly related with attitude toward using (β= 0.193, p-value=0.269, $p>0.1$). Hypothesis 2 was not supported. This result said that users might perceive ease of use, but users did not think the ease of use can change their attitude toward using our system.

Hypothesis 3 examines the relationship between perceived usefulness and attitude toward using(β= 0.084, p-value=0.640, p>0.1). Hypothesis 3 was not supported. This result said that users might perceive system usefulness, but users did not think the usefulness of system can change their attitude toward using system.

Hypothesis 4 examines the relationship between perceived usefulness and behavioral intentions to use(β= 0.526, p-value=0.001, p<0.001). Hypothesis 4 was supported.

Hypothesis 5 examines the relationship between attitude toward using and behavioral intentions to use(β= 0.272, p-value=0.072, p<0.1). Hypothesis 5 was supported.

Table 4. Results of hypotheses tests

Dependent Variable [a]	Independent Variable [a]	Beta	P-value	Hypothesis result
ATT(R^2=0.175)	PEOU	0.193	0.269	H2 was not supported
	PU	0.084	0.640	H3 was not supported
	PF	0.372*	0.055	H1 was supported
BIU(R^2=0.382)	ATT	0.272*	0.072	H5 was supported
	PU	0.526***	0.001	H4 was supported

* p<0.1; ** p<0.05; *** p<0.01.

[a] ATT, attitude toward using; PEOU. perceived ease of use; PU, perceived usefulness; PF, perceived friendliness; BIU, behavioral intentions to use.

5 Conclusions

Due to the situations of aging society, we believe that the health care service for elders will become a trend in the future. According to previous clinical studies and literatures, we find the social contact will be a critical factor in determining the life

Table 5. System comparison with Morris

System Model		Morris	Our system
Display Part	Social distance showing on screen	○	○
	Displaying who are actively concerned about myself	x	○
Function Part	Online Communication	○	○
	Offline Communication	x	○
	Internet-Disable Communication	○	○
	Internet-Enable Communication	x	○
	Text Message Communication	x	○
	Voice Communication	○	○
	Face to Face Communication	○	○
	Media Communication	x	○

Table 6. Benefits comparison with Morris

Benefits	Morris	Our
Promote social contact	○	○
The elderly life quality improvement	○	○
converge information gap, promote two generations interaction	x	○
converge interaction gap, break communication barrier	x	○
Interacting at anytime and anywhere	x	○
Waiting and traveling time cost	High	Low

quality and health for elders. In this study, we first review Morris's study and identify some drawbacks in his research. We further proposed a novel social network platform and compared some critical properties in the platform with those in Morris's as shown in Tables 5 and 6. As shown in these tables, our proposed platform provides more functional properties and benefits than those of Morris; moreover, our platform also reduces the waiting and traveling time cost.

In conclusion, our social network platform provides unique, friendly, simple, and useful functional properties. We believe it can promote the younger generation to pay more attention to the elders and to reconstruct an available communication channel between the two generations.

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Appendix A

Perceived ease of use [five-point Likert type scale]

(1) It is easy to operate the system
(2) Using the system requires a lot of mental effort

Perceived usefulness [five-point Likert type scale]

(1) Using this social system can help me to concern with those friends I forget.
(2) Using this social system can let me interact with my family member actively
(3) Using this social system can let me know the social condition with my family member

Perceived friendliness [five-point Likert type scale]

(1) Using this social system can let me know who is paying concerned with me
(2) Using this social system, I will have a sense of being concerned
(3) I will be enjoyed seeing my relationship

Attitude toward using [five-point Likert type scale]

(1) Using this system is a positive idea
(2) Using this system is a wise idea
(3) Using this system is pleasant idea

Behavioral intentions to use [five-point Likert type scale]

(1) I will use this system to control my social condition
(2) I will use this system to promote me and my family to interact
(3) I will use this system to promote me and my friends to interact
(4) I will suggest my family using this system

In Search of Information on Websites: A Question of Age?

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Abstract. To fight against info-exclusion in an aging society, it is important to make website information available to all generations. If we want to achieve this goal we need to know the impact of not only age but also gender, educational background and frequency of internet use. Therefore, this paper presents the results of an explorative Dutch eye-tracking case study, which focuses on information search behaviour (navigation patterns and use of the search box, effectiveness, efficiency and user satisfaction). 29 younger and 29 older participants completed a search task on three websites. It was found that the greatest factor impacting on information search behaviour is not always age. In one case, heatmaps showed clearly that the navigation patterns of older participants using internet daily were quite similar to those of younger ones. Finally, I present some implications for organisations wanting to (re)design their own website.

Keywords: eye-tracking, web design, usability, information search behaviour, navigation patterns, age differences, digital natives, digital immigrants, digital gap, digital spectrum.

1 Introduction

The number of older people is increasing quickly. The use of new media is also on the rise in our information society. The supply of digital information through new media, such as websites must be available to older users, so that they have guaranteed access to the digital information sources provided by public and private organisations offering products and services they need.

Some researchers argue that there is a widening generational ‘digital gap’ between those people who are able to use new media and those who are not. It was Prensky [1] who coined the notions of ‘digital natives’ and ‘digital immigrants’. Do they really exist, these ‘digital natives’, who have grown up with new media? And is there really an older generation of ‘digital immigrants’ playing catch-up by trying to learn how to use new media? Other researchers, e.g. Lenhart and Horrigan [2], take a different perspective. They introduced the notion of a ‘digital spectrum’, which acknowledges that people use new media to varying degrees.

If we want to fight against info-exclusion by making digital information through websites readily available to all generations, we need to know the impact of age on

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information search behaviour. This paper therefore starts with a quick scan of the empirical studies that have examined the question of whether older people do indeed navigate websites differently from younger people. As we will see, these studies are based on a limited number of users and do not consider other factors than age. Therefore I will present the results of an eye-tracking study I conducted in the Netherlands, which is based on a larger number of participants and which focuses, not only on age, but also on factors such as gender, educational background and frequency of internet use. Finally, some implications for organisations wanting to (re)design their own website will be presented.

2 Information Search Behaviour and the Role of Age: A Quick Scan

At the 4th International Conference on Universal Access in Human-Computer Interaction at Beijing in July 2007, Tullis [3] presented empirical research results about differences between 10 younger and 10 older U.S. users in the way they scan web pages. The heatmaps from his eye-tracking study showed that older users need more time and follow a different navigation pattern. Another example with similar results is that of Houtepen [4], who conducted an eye-tracking study in the Netherlands with 13 younger users and 7 older users. He concluded that the older users need more time to complete search tasks (almost 6 minutes, compared to the 2.5 minutes the younger users spent fulfilling their task) and that older users read more and make less use of the website's search box facility.

More facts about the ways younger and older people navigate websites to find information can be found in overviews offered by Chisnell and Redish [5] and Andrew [6]. Their overviews of empirical studies (which made use of methods such as observation, reading aloud and self assessment) give us insight into how information search behaviour affects e.g. efficiency of different users (older people are on the average slower than younger ones) but they do not give us insight into the navigation patterns themselves.

I therefore decided to conduct an explorative case study focused on the effects of information search behaviour, including navigation patterns.

3 An Explorative Case Study: Research Design

It should be borne in mind that the studies mentioned above involved a limited number of participants, which would point to the need for more research on more users. The studies also only focused on age, omitting to take into account the role of factors such as gender, educational background and frequency of internet use. It is for this reason that I carried out an explorative eye-tracking study among 29 younger and 29 older users (aged, respectively, 21 or thereabouts, and 65 and older). This number of participants far exceeds the minimum of 8 participants per user type in usability tests as specified by the NIST CIF [7]. They fulfilled a search task (related to health information) on three websites in the Netherlands: an association for older people (I asked the younger participants to fulfil a search task for their grandparents), a municipality and a health insurance company. To offset learning or fatigue effects, the order in which the three websites were presented was alternated during the 6 days the eye-tracking study was carried out (participants who fulfilled their search task on day 1: 1 → 2 → 3; day 2: 1 → 3 → 2; day 3: 2 → 1 → 3; day 4: 2 → 3 → 1; day 5: 3 → 1 → 2, day 6: 3 → 2 → 1).

Table 1. User groups

User groups	N
All users	58
All older users	29
All younger users	29
All female users	28
All male users	30
All younger female users	14
All younger male users	15
All older female users	14
All older male users	15
All older users with higher education	19
All older users without higher education	10
All older users using internet daily	18
All older user not using internet daily	11

The information search behaviour (navigation patterns and use of the search box) of the participants was then analysed, paying specific attention to effectiveness (search task completed successfully or not within 5 minutes), efficiency (the time they needed to fulfil their search task) and user satisfaction (ranking usability). For more information about the focus on effectiveness, efficiency and user satisfaction in usability tests, I refer to Frøkjaer, Herzum and Hornbaek [8] and Johnson and Kent [9].

To gain insight into the navigation patterns and use of the search box, I used the heatmaps of the eye-tracking study. These heatmaps were colour coded (red, yellow and green: respectively very intense, moderate and low intensity) to show how intensely navigation areas are visited, based on the number of fixations of individual users or groups of users. The detailed results of this explorative case study can be found in Loos and Mante-Meijer [10].

In the next section of this paper, I will present the most important differences related to the information search behaviour of the participants to see if age or other factors such as gender, educational background and frequency of internet use have the biggest impact on navigation patterns, the use of the search box, effectiveness, efficiency and user satisfaction. I was *not* concerned with comparing these aspects of *the three websites* to one another, as they differed in overall structure. I compared the information search behaviour of *different groups of website users* exhibited on different websites. Identifying differences in the information search behaviour of younger users compared to that of older users is particularly important for public and private organisations seeking to attract older people who are willing and able to use the internet to their site. Website designers, too, can thus gain information on how to build better, user-friendlier websites for old and young (see also section 5.2).

Compared to previous empirical (eye-tracking) studies conducted in this area, the number of participants in my eye-tracking study was relatively large. Nonetheless, the groups were still not huge and the risk of bias remains. It is therefore an exploratory case study in which, instead of significant relations, I merely present trends. For this reason, I have confined myself to examining only the major differences between groups of website users showing up on more than one website. If, despite the different structure of the websites, salient differences are then seen in the use of the search box, effectiveness, efficiency and user satisfaction, the chance that this is a trustworthy finding is much higher than in the case of a search task on one website.

4 Results: Younger and Older Users' Information Search Behaviour

4.1 Younger and Older Users: Different Worlds?

Older users were less likely to make use of the search box than younger users on the websites of the municipality and the health insurance company. The same phenomenon was found in Houtepen's eye-tracking study. Younger users generally managed to accomplish the search task successfully more often than the older users, on all three sites. The same held for the amount of time needed to successfully complete the search task. The younger users were much faster than their older counterparts; a finding that corresponds with the results of the eye-tracking study conducted by Houtepen and Tullis. The older users moreover assigned higher marks to the website of the association for older people and that of the municipality than did the younger group. Hence, there is some difference between older and younger users where use of the *search box*, *effectiveness*, *efficienc*y and *user satisfaction* are concerned. No noteworthy differences could be found regarding gender, educational background and frequency of internet use.

Can we now, therefore, on the basis of the eye-tracking studies carried out by Houtepen and Tullis and by myself, declare age to be the true explanatory variable? Some caution is warranted, as before making a statement of this kind we must first take a look at the role of age in *navigation patterns*. The navigation patterns on the homepage of the website of the association for older people are illustrative in this respect, showing apparent differences for younger and older users. Though many of the participants in both the younger and the older group looked at the correct place to click (the upper part of the third column) to arrive at the web page containing the information they were looking for, the red (dark coloured in this book) area on the older users' heatmap 1 is much larger than on the younger users' heatmap 2. This confirms Tullis' finding that older people examine navigation areas more intensely than do younger people. Another difference is that older users look longer at the wrong place to click, i.e. the second column, than younger users. This is shown by the red (dark coloured in this book) zone seen in that navigation area on heatmap 1, which is absent on heatmap 2. So, at first glance, the navigation patterns of older people appear to differ from those of younger people:

Fig. 1. Heatmap 1: All older users

Fig. 2. Heatmap 2: All younger users

However, if we compare the navigation patterns of older people *using the internet daily* (heatmap 3) with those of the younger age group (heatmap 2), these patterns are, in fact, not as dissimilar as first thought.

This would seem to imply that the frequency of internet use impacts more heavily on our navigation patterns than does age. Chisnell and Redish (2004: 62) refer to Hawthorn [11] en Zajicek and Morrissey [12], who argue that the lack of internet experience strongly affects the capability of older people to use PCs and websites.

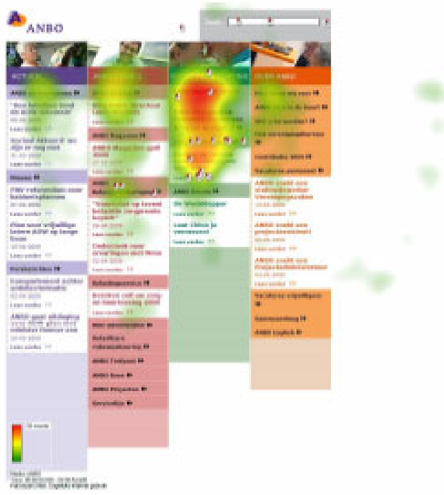

Fig. 3. Heatmap 3: All older users making use of internet daily

Sections 4.2 and 4.3 will now focus on the role of gender, educational background and frequency of internet use within the group of younger users and within the group of older users.

4.2 A Homogeneous Group of Younger Users?

To determine any possible variation in the group of younger website users, I also looked at gender differences within this group. As all participants in the younger group were highly educated and daily users of internet, the factors educational background and frequency of internet use could not serve to determine any possible variation within this group. A greater number of young men than young women succeeded in successfully completing the search task on the websites of the association for older people and that of the municipality. Young men rated the user friendliness of the websites of the association for older people and that of the health insurance company more highly than the young women did. Hence, as far as effectiveness and user satisfaction is concerned, some variation turned up within the younger group of website users.

4.3 A Homogeneous Group of Older Users?

Gender. On all three websites it was found that older men used the search box significantly less often than older women. The search tasks performed by the older men on the websites of the association for older people and of the municipality were more often successfully completed, compared to the older female participants. In the case of the municipality and the health insurance company, the older men who successfully completed their search task were, on average, faster than the older women.

Educational background. Some variation in the older group of website users as regards the successful completion of the search task was found to be caused by the factor educational attainment. The percentage of older users who successfully managed to accomplish the search task was higher among those with a high level of education than among those without such a background.

Frequency of internet use. Older people who daily surfed the internet utilised the search box to execute the search task on the site of the health insurance company considerably more often than did the older people who did not make daily use of the internet. Over a fifth of the older participants going daily on the internet made use of the search box on the website of the association for older people, but no one of the older participants not using the internet daily made use of the search box. The older participants who utilised the internet daily and who successfully fulfilled the search tasks on the websites of the association for older people and the municipality were also, on average, faster than the group of older participants who succeeded in completing the search task, but who did not use the internet on a daily basis. With respect to user satisfaction, the websites of the municipality and the health insurance company received a lower rating from older users navigating the internet on a daily basis than from the group of older users who did not visit the internet daily.

5 The Role of Age Revisited

5.1 Conclusions

From this explorative case study the following conclusions can be drawn:

1. Younger and older users differ to a certain extent in *the use of the search box*, *effectiveness*, *efficiency* and *user satisfaction*, but gender, educational background and frequency of internet use played no important role (see section 4.1).
2. At first glance, the *navigations patterns* of older people appear to differ from those of younger people, but in the case of the website of the association for older people, the navigation patterns of older people using the internet daily compared to those of the younger age group are, in fact, not as dissimilar as first thought. The frequency of internet use also has its impact on navigation patterns (see section 4.1).
3. Within both the group of younger users and the group of older users, differences in information search behaviour can be distinguished (see sections 4.2 and 4.3).

We can conclude that in this explorative case study, the black-and-white distinction between Prensky's 'digital natives' and 'digital immigrants' was absent. Instead, what emerged was something far more resembling a 'digital spectrum' (Lenhart and Horrigan), rather than a 'digital gap'. If future empirical research confirms the findings of this explorative eye-tracking study, the implication for web designers (who often belong to a younger generation) might be that they should take into account diversity between and within generations by designing for dynamic diversity [13].

5.2 Designing for Dynamic Diversity: Implications for Web Designers

Finally, I would like to mention a few implications of this explorative case study for those who want to (re)design their own website:

1. Assume that the user group is a diverse one.
2. Be wary of the assumption that age is the most important criterion. Frequency of internet use may, at the very least, be just as relevant as age.
3. 'Intra-age variability' is a good guiding principle (Dannefer [14]).
4. This does not imply that it may be taken for granted that everyone can 'just like that' make sense of a website. Therefore, test a (new) website on different types of users, and do so in several rounds, each time on different users (Krug [15]).
5. Do not be concerned that modifications made to the website for a specific group could undermine the user-friendliness of the site for another group. Research performed by Johnson and Kent into the design of user-friendly websites has shown that younger website users, as well as website users with a functional limitation and older people using the internet all had the most appreciation for the user-friendly websites (also see Chadwick-Dias [16], McNulty and Tullis [16]).

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Preliminary Findings of an Ethnographical Research on Designing Accessible Geolocated Services with Older People

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Abstract. Older people run the risk of being socially excluded due to the numerous barriers they need to overcome when interacting with Information and Communication Technologies (ICT) to perform an ever-increasing number of daily activities. This paper presents preliminary findings of a rapid ethnographical study, conducted with around 90 older people during 1 month, which aimed to explore the potential of geo-located ICT services to foster social inclusion and support independent living. This paper discusses potential scenarios of use for technologies that have largely been overlooked in HCI research with older people, such as Google Maps; key aspects of how they (want to) use these technologies and relevant interaction barriers that limit their interactions with them.

1 Introduction

An increasing ageing population and the need to use Information and Communication Technologies (ICT) to avoid social exclusion have reinforced Human-Computer Interaction (HCI) research with older people. This paper discusses ongoing work conducted in Life 2.0 (Life 2.0), a research project aimed at making the network of social interactions more visible to older people (60+) by providing them with an accessible platform consisting of collaborative ICT that track and locate relevant members of their social networks (i.e. relatives, friends and caregivers). According to our review of previous work in the area (Section 2), these technologies have received scant attention in previous HCI research with older people, despite their likely potential to support social inclusion and independent living.

The Life 2.0 platform will allow older people and their social networks to communicate amongst themselves through phone calls, text messages, advanced multimedia content distribution systems (e.g. IPTV, interactive digital signage and webTV) and video telephony/conference solutions. The platform will also provide older people with a number of services supporting independent living and social inclusion. Some services will enable relatives and caregivers to monitor their position either at home and on the move, while others will allow older people to cook, shop and drive for

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others (e.g. giving their neighbors a lift to the local train station), and to interact with personalized information of the local area.

With the aim of informing the design and development of an accessible and useful platform, Life 2.0 is conducting ethnographical research in four EU countries (Finland, Denmark, Italy and Spain). We have argued before that ethnography has seldom been used in HCI research with older people, but the findings of a classical ethnographical study we conducted (Sayago and Blat, 2010) revealed that ethnography improves our understanding of older people as ICT users. In this paper, we report on the preliminary findings of ongoing research carried out in Spain (namely, Barcelona).

During a month, we have been conducting a rapid ethnographical study (Millen 2000) with around 90 participants (aged 60-80) in a community group that fosters social inclusion through the use of ICT. By recording and analyzing fieldnotes of our in-situ observations of, informal and formal conversations with, the participants while using different ICT, we have identified potential scenarios to increase social inclusion and support independent living through geo-located and other ICT fostering communication. We have also revealed a number of interaction barriers and key aspects of how older people (want to) use these technologies.

The rest of the paper is organized as follows. We first review previous work related to the objectives of the paper, including previous projects on ICT and ageing, the coverage of technologies addressed and the research approach adopted. We describe next our ongoing ethnographical study and present preliminary results. Finally, we discuss the findings and describe future activities.

2 Related Work

2.1 Life 2.0 and Previous Research Projects on ICT and Ageing

Whilst most of the Life 2.0 technologies already exist and many projects have previously focused on ICT and ageing, such as those funded under the European Ambient Assisted Living (AAL) program (AALIANCE) and by the UK New Dynamics of Ageing, what distinguishes Life 2.0 is the integration of available ICT into an online platform that will (i) offer accessible services to older people and their social circles based on geo-positioning ICT and (ii) allow all of them to create, and interact with, digital content in different settings (e.g. at home, in the adult association).

Most of previous AAL projects have considered older people as passive users of services provided by someone else. The information flow in the technologies developed can be regarded as unidirectional and being codified to be used at home. In Life 2.0, we consider older people both users and prosumers (Martin et al 2009). Also, building on our previous experiences (Sayago and Blat 2010), we consider that social inclusion through ICT should be achieved by promoting activities that older people can conduct out of their homes.

This view of inclusion lies also behind the philosophy of the UK projects SUS-IT (SUS-IT) and SiDE (SiDE). SUS-IT is addressing the question of sustaining ICT use with changing (i) age-related capabilities decline, (ii) interaction contexts and

(iii) ICT. Amongst other research being conducted in SiDE, prototypes of accessible indoor navigation tools for older people and people with disabilities are being developed (Montague 2010), together with research on cognitive modeling for older adults[1]. Neither the potential of geo-positioning for increasing social inclusion nor the accessibility / use of these technologies by older people have been addressed in these projects.

2.2 Life 2.0 and Previous HCI Research with Older People

Some technologies addressed in Life 2.0, such as Digital TV (Rice and Alm, 2008) and social networking sites (Burmeister 2010, Gibson et al 2010), have received attention in HCI research with older people. Much less research has been done related to Google Maps, online collaborative document editing (Google Documents) and weblogs (Blogs)[2]. However, they are becoming pervasive (e.g. websites with embedded Google Maps in them).

Methodologically, a relatively recent HCI trend has turned to ethnography to understand the important interactions of users with ICT in out-of-laboratory conditions. However, very little of this research has been conducted with older people (Sayago and Blat 2010). In that paper, we adopted a classical ethnographical approach, which requires at least 6 months to 1 year of fieldwork (Fetterman 2010), and showed that socialization, independence (not relying on anyone else) and inclusion are key aspects of e-mailing everyday use, and that interaction barriers due to age-related changes in cognition limit much more severely their interactions in out-of-laboratory conditions than those related to vision or difficulties using the mouse.

In this paper, we have adopted a rapid ethnographical approach due to (i) time constraints in R&D projects, (ii) our goal of understanding better ethnography and exploring other technologies. As stated in (Millen 2000), the three most important ideas of rapid ethnography are: 1) narrow the focus of the field research before entering it; 2) use multiple interactive observation techniques, and 3) use collaborative and computerized iterative methods to analyze data combining techniques. Next we describe our ethnographical study.

3 Description of the Ethnographical Study

3.1 Context: Àgora

We have conducted this study in Àgora, a 20-year-old association[3] in Barcelona. Àgora aims to integrate into Catalan society immigrants, non-educated and older people, who are, or run the risk of being excluded from it. This is done through informal

[1] http://www.computing.dundee.ac.uk/staff/dsloan/projects.htm

[2] A survey we conducted of four leading HCI journals (Interacting with Computers, first issue-2011; International Journal of Human-Computer Studies, first issue- 2011; Universal Access to the Information Society, first issue-2011; ACM Transactions of Human-Computer Interaction, first issue-2011; ACM Transactions of Accessible Computing) and CHI ACM Proceedings using keywords such as “older people”, “geography”, “google maps/earth”, “blogs”, revealed that no studies have been published to date addressing these technologies.

[3] Within Escola d’Adults La Verneda – St. Martí (an adult centre), http://www.edaverneda.org

learning in free courses (e.g. languages, mathematics and literature) with over 1000 people (using Àgora's terminology, participants) taking part in them monthly. Àgora, and its participants, consider that mastering ICT is an essential inclusive element, so courses in computing, Internet access and workshops are also provided. Participants decide what ICT they want to (learn to) use according to their needs and interests. Courses and workshops are also geared towards supporting daily life activities.

3.2 Rapid Ethnography: Participants, Technologies, Methods

We have conducted 32 hours of fieldwork over a 1-month period. The fieldwork activities consisted of in-situ observations of and conversations with around 90 older people (aged 60-75) while using several technologies, ranging from Google Maps to weblogs, in two workshops we run for the project and five courses already organized by Àgora with no connection with Life 2.0. The fieldwork was conducted in the Àgora's computer room. Approximately 50 participants were familiar with basic and more advanced tasks, such as when to left- or right-click and look for information online. Table 1 summarizes the fieldwork activities.

We have also conducted two focus groups (1 hour, 6 women, 2 men) to elicit everyday life stories[4], and one participatory design workshop (1 hour, 5 women, 5 men[5]) to suggest ideas for the design of Life 2.0 scenarios. As discussed later, part of our ongoing activities is to analyze diaries written by the participants about the activities they have conducted over a 2-week period and the involvement of relatives, friends, and ICT in them.

We have also carried out a semi-structured interview with the director of the social services for the local area in her office as our first activity with caregivers. We expect to talk with some key relative of the participants (their children and grandchildren) in the next few months.

We have recorded fieldnotes by using inclusive technologies: paper and pencil, and photographs. All our participants took paper-based notes in the courses and workshops. This was done because laptops and video cameras were intrusive; there are no laptops in the Àgora's computers room and participants are not used to being videoed during their everyday interactions with them.

We wrote most of the fieldnotes at the end of the sessions. The active involvement of the participants in the activities suggested, such as creating a collaborative map of their neighborhood, hindered note-taking while interacting with the participants. Whereas this finding might challenge the 'veracity' of the fieldnotes, it also indicates the engagement of the participants in the research, however.

Different members of the research team were involved in different fieldwork activities. Their fieldnotes were shared as online documents with the rest of the team. We have been analyzing the fieldnotes by using Grounded Theory (Charmez and Mitchell 2007), i.e. while gathering the data. We have conducted initial open, axial and selective coding. We have discussed the different results during the course of the research and describe them in an integrated way below.

[4] This method is often used by Àgora in other research projects in which they work.
[5] 3 of them (2 men, 1 woman) also participated in the focus group.

Table 1. Ongoing fieldwork

Activity	Description	Technologies	Participants	Implementation
Workshop on Google Maps	Hands-on introduction to Google Maps and collaborative creation of an annotated map	Google Maps	12 (6 men / women)	2-hour session
Workshop on weblogs	Hands-on introduction to blogs and creation of a blog with Blogger[6]	Blogger	11 (5 men / 6 women)	2-hour session
Course on Gardens of the World	Downloading and e diting picture aout gardens of the world from the web and creating documents (e.g. calendars) with them	Internet Explorer, Mozilla Firefox, MS Office tools, picture editing tools	9 (4 men / 5 women) 11 (6 men / 5 women) 9 (4 men / 9 women)	3 sessions. 1 session per week. Each session lasting 2 hours
Course of Wild life and Nature	Same as above (about wild life and nature)	Same as above	12 (4 men / 9 women)	2 sessions. 1 session per week. Each session lasting 2 hours
Course on advanced aspects of ICT	Topics of computer management, online communication and document sharing	File and windows management, Internet Explorer, Mozilla Firefox, MS Office tools, webmails (Yahoo!, Hotmal, Gmail), Google Docs, Blogger	17 (7 men / 10 women)	4 sessions. 1 session per week. Each session lasting 2 hours
Course on Women and ICT	Downloading pictures from the web, creating MS Word documents, calendars and cards	Internet Explorer, Mozill Firefox, MS Office tools	16 women	2 sessions. 1 session per week. Each session lasting 2 hours
Course on Introduction to ICT	Introduction to computers, file and windows management	Desktop tools	13 (6 men / 7 women)	4 sessions. 1 session per week. Each session lasting 2 hours

[6] "*Un blog para compartir*", Blog created by the participants, http://blogsantmarti.blogspot.com/

4 First Analyzed Results

4.1 Potential Scenarios of Use: Technologies, Social Actors and Inclusion

A map of my life. Reminiscence is common in communication in ageing. Whereas this might lead to negative stereotypes (e.g. older people talk too much about their 'stories'), we can turn it into an inclusion opportunity. For instance, annotating a digital map with places which had been important in their past by using technologies familiar to relevant members of their social circles, such as grandchildren, can help us achieve the goal of improving social inclusion. Whilst this scenario exploits an idea that is not new, i.e. life or oral stories and historical memory of older people (Klemmer et al 2003), using digital maps is a novel approach to the best of our knowledge.

What I like and dislike about my local area. Older people pinpoint areas where walking could be dangerous or identify and comment about worth visiting places. This could be socially shared through several channels (e.g. a website, DTV), which can generate further comments and thus, enhancing the role of older people in the community by sharing their valuable knowledge.

What is going on in my town? Older people play a less active role, they open their web browser or switch their (D)TV on and 'read' a map containing information created by relevant members of their social circles. For instance, Àgora recommends reading books and partaking in activities organised by the association; caregivers and social relatives remind older people of walking at least 1 hour in the park. Older people can also track the places visited by close friends and read their comments (e.g. you have to see this: the water leak in the street has not been fixed yet!). This scenario can promote socialization by encouraging older people to 'go out'.

4.2 Some Requirements Common to the Scenarios

All our participants aspire to be in control of the technology because of privacy concerns. They are reluctant to be located through geo-positioning ICT when they want to be 'invisible'. However, tracking partners with Alzheimer's is considered useful. Specific times for being 'visible and 'invisible' are also important with respect to their communication with relatives and close friends: our participants want time for themselves. All participants were also unwilling to reveal what they considered private data (e.g. contact details) to unknown people by using blogs. This finding concurs with our previous study of e-mailing and other studies of social networking sites (Gibson et al 2010).

There is a rich flow of the role older people play in their interactions with ICT. Sometimes, as we have indicated in the scenarios, older people are active and wish to create content; on other occasions, they just want to interact with content created by others without contributing to it.

The appearance of the content that they create on maps and blogs (or e-mails and calendars) is much less important to them than how easy it is to actually create the content, since their most important aspiration is to be able to interact with the technology independently. However, when they are able to do so, they are interested in the aesthetics of their content, which concurs with our study of real-life e-mailing, but adding the evolution when competence is acquired.

Fig. 1. Participants interacting with Google Maps

As we also found in our previous study, the interactions are social (reduce isolation and informal (e.g. making jokes while using Google Maps). The interactions are also non-utilitarian (e.g. none of our participants want to use ICT for productivity purposes).

4.3 Interaction Barriers and Opportunities for Strengthening Social Inclusion

We argued before (Sayago and Blat 2010) that cognitive-related interaction barriers limit more severely the interactions of older people with ICT than other types of barriers. We have also pointed out that note-taking is their strategy for overcoming them. We have found very similar results in this study, despite having been working with different participants and technologies. Next we show some examples.

Whereas Google Maps allows us to edit the comments and areas of interest created by other users, Blogger does not enable us to modify posts written by others. This ‘lack of consistency’ resulted in all our participants making mistakes and asking us questions about what could be edited and what could not in these technologies. We observed that all our participants relied on their previous experience with ‘one’ technology in order to (learn to) interact with another. By contrast, no participant had difficulties publishing a new post in Blogger. Overall, participants reported that Blogger was ‘very similar to MS Word’, with which they were familiar. We observed that all participants took notes during the sessions, independently of their experience with ICT.

When working with Google Maps, we started with the Map view, which we considered the simplest and less cognitive demanding geographical representation. However, we observed that participants switched to the Satellite view. This seems to indicate that the latter view, which is less abstract, provides older people with information that helps them interact with digital maps more effectively (e.g. finding streets and defining routes), and is less demanding cognitively. We also observed a general preference for Google Earth, which offers context with a real representation of geographical information. We will explore further this finding in our future work, as we discuss later.

Whereas participants did not add any entry or comments to the blog after the session in which they created it[7], information conversations with them revealed that they had actually accessed the blog in the following two days after the class. However, they reported not remembering how to add or edit an entry. Moreover, they asked us to repeat the workshop in order to memorize the steps and be able to 'write things' in the blog. This result seems to stress once again the relevance of cognition and note-taking.

5 Discussion and Future Work

We have focused on geo-positioning and other pervasive ICT because we consider that these technologies can (and should) help us foster social inclusion and support independent living amongst the older population.

The preliminary results have revealed a number of research challenges and opportunities to achieve these goals. As for the challenges, it is worth mentioning some requirements and interaction barriers, which seem to confirm results of our previous research. Regarding opportunities, the engagement of older people in the research, the scenarios and different representations of geographical information can potentially stimulate further research.

We have not included the voices of the participants we have gathered so far in this paper because we need to conduct more ethnography in order to ascertain how valid our first observations and conversations are. Whereas part of the interaction barriers and elements of ICT use can be somewhat quick to understand by building upon a previous and extended ethnographical study, and we feel confident about the relative validity of the findings, new results which have emerged from this ongoing research and devising scenarios with new technologies which have not been explored before, and with which (older) people are not familiar, requires much more ethnographical data and analysis, we believe, and we thus feel less confident about these initial findings.

We are currently analyzing diaries written by the participants in an attempt to get a more holistic view of their everyday lives. We are also gathering more data related to in-situ observations of and conversations with the participants, and we plan to conduct interviews or questionnaires with their grandchildren and children, who are very relevant members of their social circles, as well as of caregivers. We are going to address the important question of how to communicate effectively ethnographical data to user interface designers and developers, who are working in Life 2.0. We also expect to analyze cultural differences and similarities in the accessibility, use and potential of geo-positioning ICT for supporting social inclusion and independent living as the project is run in Italy, Denmark and Finland. All these activities, which are related to ethnographical research, should help us provide much deeper insights into the

[7] 6 participants accessed the Google document created in the course on Advanced Aspects of ICT (Table 1) up to five times in the following four days after the session. 3 participants created new documents and shared them with the participants.

challenges and opportunities of geo-positioning ICT to foster social inclusion and independent living amongst the older population.

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An Experiment for Motivating Elderly People with Robot Guided Interaction

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Abstract. It is important for elderly people to be involved in local community to reduce the risk of being isolated. The authors are building a framework for encouraging elderly people to participate in more activities by providing local news that may be interesting. Nowadays, there is a lot of information on the Internet; however, few elderly people can obtain the benefits of this information. The Internet is used less by elderly people. It has been reported that one reason for this is diminishing cognitive performance. It is not easy for elderly people to learn a new mental model for a new IT system. Thus, the authors propose a robot-guided interaction framework for elderly people. Once the user initiates an interaction, a communication robot initiates the following interaction sequences. The user can simply follow and respond to the guiding robot, and is not required to learn any operational sequence or mental model. An experiment on such guiding robots was performed with ten elderly subjects, and investigated as to how long elderly people can use the system. As a result of a 12-day experiment, all subjects kept using the system almost every day until the end of the experiment period. According to this result, we can conclude that the robot-guided interaction framework is effective for elderly people.

Keywords: regional activation, operation of information systems, robot guided interaction.

1 Introduction

Recently, the isolation of elderly people has been considered an important social issue. The number of elderly people who have less connection with their neighbors and don't have a connection to their local community is increasing [1]. The authors are building a framework for encouraging elderly people to participate in more activities by providing interesting local news [2]. Communication robots are delivered to each elderly person's home and placed at common places where people gather. By providing news of local activities through the robots, it is expected that participation of elderly people in the activities will increase. First, the robot at home provides news, and encourages participation in an activity, so that the elderly people have more opportunities to go out and meet others. Then, a robot at a common place proposes topics to enhance conversation among people who meet at that location. Finally, the robot at

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home also encourages the exchange of on-line messages with people who met at the common place in order to maintain longer and better relationships.

The framework is intended to support elderly people in meeting with others and becoming friends. Levinger reported that there are steps in the process by which people become friends [3]. An opportunity to meet comes first; people get to know each other and gradually become friendly. Since the process takes time, the community support framework also has to work for a long time. As a guideline for information systems for long term usage, Fogg proposed that the work load of using the system should be natural enough to be embedded in everyday life [4]. Once it becomes a part of the user's daily custom, it can be used for a long time without being boring. Thus, the authors designed the interaction scenarios of the robot to be short enough each time and to occur only a few times a day so that elderly people can use them long-term.

It is also important that the system be easy enough for elderly people to use. It is difficult to determine whether information systems such as the Internet are easy for elderly people to use. For instance, more than 90% of 13-49 year-old people use the Internet; however, the number of Internet users over 50 significantly decreases [5]. More than half of people 60 or older claim that operations of such a system are too difficult [6]. Etsuko et al. reported that the reason for this difficulty is decreasing cognitive performance according to age [7]. To help solve this problem, the authors propose a "Robot-Guided Interaction Framework" for elderly people to support them in obtaining information from the Internet. Once the user initiates an interaction, a communication robot initiates interaction sequences. The user can simply follow and respond to the guiding robot, and is not required to learn any operational sequence or mental model.

To investigate the efficiency of the "Robot-Guided Interaction Framework," an experiment with such guiding robots was performed with ten elderly subjects, and we investigated how long elderly people can use the system. As a result of a 12-day experiment, we found that all subjects continued using the system almost daily. According to this result, it is possible to conclude that the robot-guided interaction framework is effective for elderly people.

2 Framework for Enhancement of Communication among Elderly People

2.1 Three Stages for Enhancement of Communication

The authors are building a framework for encouraging elderly people to participate in more activities in three stages [2]. Levinger reported that there are steps in a process by which people become friends [3]. An opportunity to meet comes first, followed by people gaining knowledge about each other, after which they gradually become friendly. Thus, the authors suppose three major stages of activities for creating and maintaining good human relationships: (A) meet, (B) talk, and (C) repeat. Information systems can help elderly people at each stage (Fig. 1).

The authors suppose approaches in each stage as follows. At stage (A) meet, the information system at home provides news and encourages participation in an activity, so that elderly people have more opportunities to go out and meet others. At stage (B) talk, the information system at a common meeting place proposes topics to enhance conversation among people who meet there. At stage (C) repeat, the information system at home also encourages exchange of on-line messages with people who met at the common place to maintain longer and better relationships.

2.2 Functions on of Each Stage

The three functions of the information system achieve the above-mentioned approaches. The information systems have (a) announcement, (b) mediation, and (c) message exchange on the stages of (A) meet, (B) talk, and (C) repeat, respectively.

(a) Announcement. This function provides local news and the amount of physical effort required to elderly people at home to increase opportunities to meet others. The authors considered that local news is efficient because it has been reported that one of the main reasons elderly people don't participate in local community is a lack of knowledge about events. The authors also considered that it is efficient to visualize the amount of physical exertion because visualization is an effective method for causing behavioral change [8].

(b) Mediation. This function assists a group of people in having a conversation at common places where people gather to build a relationship with others. Specifically, this function leads to introducing each other, provides topics of common interest, and speaks up when an angel passes by. It was reported that there are steps in the process by which people become friends [3]. The step of becoming friendly comes after the step of gaining knowledge about the other. The step of gaining knowledge has problems because some people feel uncomfortable talking to strangers. In such a case, a

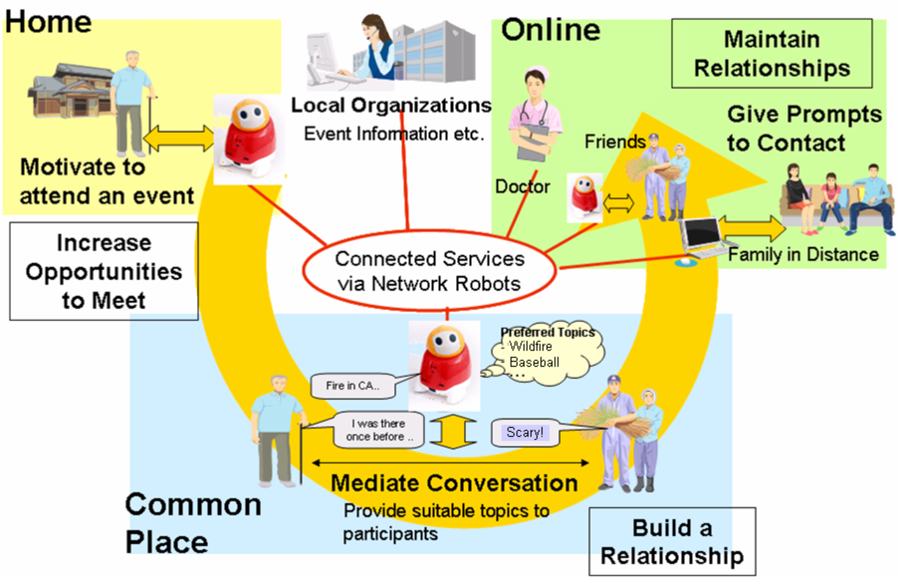

Fig. 1. Framework for enhancement of communication among elderly people

bit of assistance by another person who is well known or gregarious is very helpful for increasing comfort. The authors have confirmed the efficiency of mediation in a group conversation [9, 10].

(c) Message exchange. This function encourages exchange of on-line messages with people who met at the common place for maintaining longer and better relationships. Some elderly people are not good at using a keyboard to input text messages. Thus, this function encourages exchange of on-line messages in the form of voice mail.

3 Robot Guided Interaction

3.1 Design of Robot Guided Interaction

The authors propose a "Robot-Guided Interaction Framework", which supports elderly people to obtain information as mentioned in 2.2 with robot interface. Once the user initiates an interaction, an information system begins the following interaction sequences. The user can simply follow and respond to the guiding system, and is not required to learn any operational sequence or mental model.

The authors decided to use a robot as the interface for the information system, aiming at taking advantage of the intuitiveness which robot interface naturally has as Yukiko et al. have reported [11]. In fact, people facing the robot try communicating with same manner as to human without learning how to use.

3.2 Support for a Day of Elderly People with Robot Guided Interaction

The framework is intended to support elderly people in meeting others and becoming friends. It was reported that there are steps in the process by which people become friends [3]. An opportunity to meet comes first, after which people gain knowledge about each other, and gradually become friendly. Since the process takes time, the community support framework also has to work for a long time. As a guideline for information systems for long term use, Fogg proposed that the work load of the system should be simple enough to be embedded in everyday life [4]. Once it becomes part of the user's daily customs, it can exist without boring the user. Thus, the authors designed interaction scenarios for the robot to be short enough in each time, occurring only a few times a day, so that elderly people can use them for a long time. Specifically, the length of one interaction is around one minute, and the number of interactions per day is around five.

The authors designed the "Robot-Guided Interaction Framework" for one typical day for elderly people, from getting up to going to bed, because we aimed to incorporate this interaction in the everyday life of elderly people. Communication robots were delivered to each elderly person's home and placed at common places where people gather. The robots interact with elderly people as follows.

Morning

1. At home: the robot greets the elderly, and reports yesterday's record of her/his pedometer.

2. At home: the robot provides news of the day to encourage the elderly to go out for activities. The robot also asks questions to assess the physical conditions of the elderly.

Daytime

3. At home: the robot reminds the elderly of the arranged schedule for going out one hour advance so that they won't miss the activities.
4. On the road or at the place of activity: another robot is located there. It introduces another activity to provide an opportunity to visit another place for more exercise. It is connected with the robot at home, and the activity to be introduced is chosen based on the interaction history obtained from the robot at home.
5. At the common place: there is another robot for meditating between people. While visiting the common place, people have good opportunities to meet others. The robot helps them enjoy conversation.
6. At home (after coming back from outside): the robot greets the elderly coming back home. It reports the record of its pedometer, and asks a few questions about the impressions of the activities.

Evening and Night

7. At home: the robot checks online messages to the elderly from others, guides them in checking the messages, and asks the elderly whether to send a reply. The robot guides the sending of a message if the elderly wish to do so.
8. At home: the robot reminds the elderly of people met during the day and asks the elderly whether to send a message to them. The robot guides the sending of a message if the elderly wish to do so.
9. At home: the robot provides information about activities of the next day. It also asks questions to determine the physical conditions of the elderly.

4 Experiments

4.1 Environment, Subjects and the System

To investigate the efficiency of the "Robot-Guided Interaction Framework," an experiment on such guiding robots was performed. Ten subjects (seven males and three females) participated in the experiment. The experiment was performed with the cooperation of Uda City, Nara Prefecture, in Japan for 157 days from February 1 to March 31, and from June 24 to September 30. The function of message exchange was improved once during the interval from April 1 to June 23. The experiment consisted of two stages. In the first stage (March 1-12), physical robots called "PaPeRo" made by NEC were delivered to each subject's home. In the second stage (March 13 to September 30), the robots were replaced with a CG (Computer Graphics) version of PaPeRo. In each subject's home, a robot and a tablet-type terminal ("Web terminal") with touch screen were delivered. That equipment was connected by WLAN to the Internet. Figure 2 shows an actual setting in a subject's home.

In the "Robot-Guided Interaction Framework," PaPeRo speaks to a subject and the subject inputs his/her response to the web terminal. The subject touches the display of the web terminal with his/her finger to answer a question from PaPeRo. Subject also touches a pedometer to the data-reader on the web terminal to start interaction as shown in figure 2. The pedometer has a proximity wireless communication function. Figures 3 and 4 show screen shot examples of the web terminal. Figure 3 show screen shot examples of the web terminal with PaPeRo. Figure 4 show screen shot examples of the web terminal with CG version of PaPeRo. A subject can start the function of announcement or message exchange by touching either button on upper-right portion of the display as shown in figure 3. Announcement topics or destinations of message can be chosen by touching a button on middle-right portion of the display. When PaPeRo asks a question, the subject can provide a response to the robot simply by touching the "O (yes/good)", "△(unsure/neutral)", "X(no/poor)" buttons on lower-left portion of the display as shown in figure 3.

Examples of daily interaction at home are shown below.

Morning

Subject: Touch his/her pedometer to the data-reader on the web terminal as shown in figure 2 to start a session.
PaPeRo: "Good morning, Mr. Yamada"
PaPeRo: "Today, tea party will be hold at the community place from 10 A.M."
PaPeRo: "Will you go this event?"
Subject: Touch "O (yes)" button to answers the question
PaPeRo: "Please enjoy this event"
PaPeRo: "How about your condition today?"
Subject: Did not answer within a certain expected time (e.g. five seconds)
PaPeRo: "If you are good, please touch "O(circle)" button. If you are normal , touch"△(triangle)" . If you feel bad , touch "X(cross)"".
Subject: Touch "O (good)" button to answers the question
PaPeRo: "You look like quite well."
PaPeRo: "See you later" to imply the end of the session.

Daytime (after coming back from going out)

Subject: Touch the pedometer to the data-reader on the web terminal.
PaPeRo: "Welcome home, Mr. Yamada."
PaPeRo: "You have a message from Mr. Suzuki. Do you hear this, now?"
Subject: Touch "O (yes)" button to answers the question
PaPeRo: Play back the voice massage, "(recorded voice) Hi, This is Suzuki. Today's party was wonderful. Let's go together agein."
PaPeRo: "Do you reply to this message?"
Subject: Touch "O (yes)" button to answers the question
PaPeRo: "Please leave your massage for thirty seconds after the beep ... (beep)."
Subject: "This is Yamada. The green tea was delicious. I'm looking forward to the next party."
PaPeRo: "Is it OK to send it?"
Subject: Touch "O (yes)" button to answers the question
PaPeRo: "I finish sending it."
PaPeRo: "See you later."

Night

Subject: touch the "Announcement" button on the web terminal.
PaPeRo: "Tomorrow, sale of vegetable will be hold at the supermarket from 4 P.M."

PaPeRo: "Will you go this event?"
Subject: Touch the "△ (unsure)" button,
PaPeRo: "Please tell me, if you change your mind."
PaPeRo: "See you later."

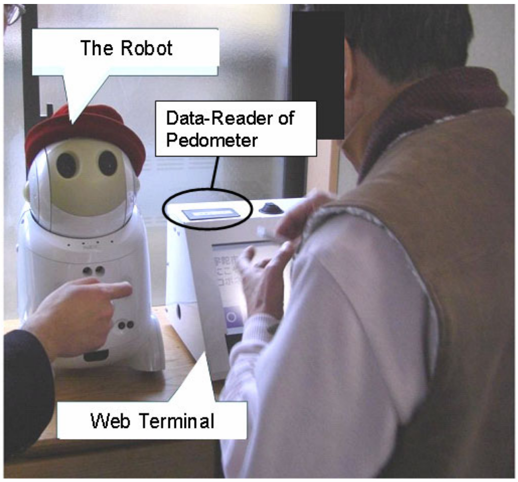

Fig. 2. Robot and terminal with subject

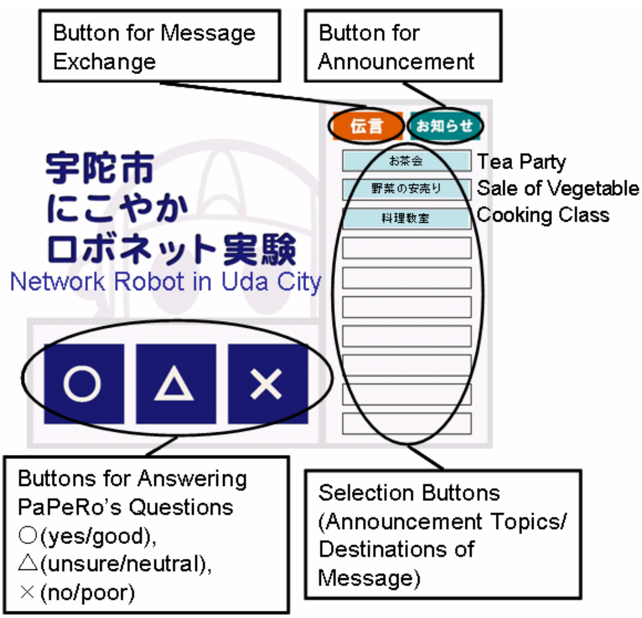

Fig. 3. Screen shots of the terminal with PaPeRo

Fig. 4. Screen shots of terminal with CG version of PaPeRo

4.2 Results Overview

As a result of the experiment in the first stage, all subjects kept using the system almost daily for 12 days. On the other hand, Four of ten subjects stopped using the system before the experiment period of 157 days. Table 1 shows the number of days from the beginning of the experiment to the day when the robot was last used.

If subject could not obtain new knowledge and mental models for our system in the experiment, the subject would stop using the system or ask how to use it. The authors interviewed the subjects who stopped using the system about reasons. No one claimed that the reason is difficulty of usage. Reasons why subjects stop using the system are described later.On the other hand, subjects who kept using the system didn't ask how to use our system. Thus, it may be concluded that subjects could obtain new knowledge and mental models for our system.

From the questionnaire results, behaviors and impressions of the subjects were revealed. Nine of ten subjects answered the questionnaire, which was collected immediately after the first stage of the experiment to investigate changes in the subjects' behavior. Figure 5 shows changes of subject behavior. Three subjects clearly stated that they increased opportunities for socializing with the system. Additionally, communications with family members increased. This is a good side effect of the system.

There were two reasons why subjects stopped using the system before the experiment period by the interview. One of the reasons is a difficulty in understanding speech of PaPeRo because of unfamiliarity with synthesized voice. The other reason is physical weakness of body. Three subjects mentioned the difficulty in understanding speech. Two subjects mentioned physical weakness.

Table 1. Number of days from experiment beginning to day when subject stopped using robot

	subject 1	subject 2	subject 3	subject 4	subject 5	subject 6	subject 7	subject 8	subject 9	subject 10
the number of days	157	155	155	154	154	153	127	111	74	16

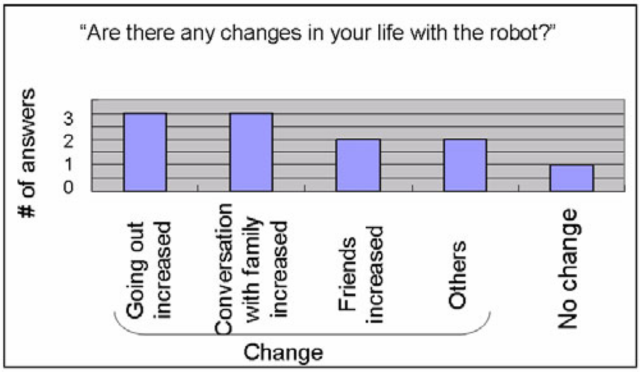

Fig. 5. Change of behavior

5 Summary

A "Robot-Guided Interaction Framework" was proposed, and the result of an experiment with a community support system for elderly people based on the framework was reported. It was observed that all ten elderly subjects used the system daily for the first 12 days. According to this result, we concluded that the framework overcomes the issue of obtaining new knowledge and mental models, and allows all subjects to use the system. On the other hand, four of ten subjects stopped using the system before the experimental period of 157 days. More refinement of the interaction framework is required for higher acceptability in the long term.

It can also be supposed that the design of the interaction framework was not the only reason for subjects to stop using the system. A multi-perspective investigation is necessary for creating long-term information systems.

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Connecting Communities: Designing a Social Media Platform for Older Adults Living in a Senior Village

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Abstract. In order to develop an appropriate social computing application for senior users, the salient point of this research was to explore social and physical environments of a senior living community and social interaction between aging residents, and to investigate the key factors of technology acceptance for those older adults with little or no computer knowledge. The next step was to give an appropriate alternative communication technology applicable to the elderly and their living milieu, and thereby enhance their social interaction. The area of study was also concerned with determining social communication, perceived ease of use, enjoyment, and satisfaction for the new digital social platform via the technology acceptance model.

Keywords: elderly social model, user interface, smart social platform.

1 Introduction

The elderly are the fastest growing sector of society. The concomitant increase in burden from aging-related illness and impairments, such as chronic disease, physical disability and sensory impairment, psychomotor impairments, mental health, memory loss and learning disabilities, dementia, and others, makes it vitally important for older adults to remain independent and productive for as long as possible. While the majority of attention in aging research has focused on physical factors and functional requirements, a growing number of studies have presented evidence that suggests that psychological and sociological factors also have a significant influence on increased individual life expectancy and quality of life in older adults [1].

There are many studies of the role that the elderly play in society. Cumming and Henry [2] have proposed the Disengagement Theory which refers to reduced interaction between elderly and other people, a change in interpersonal relationships and a significant decrease in level of external participation at the same time as increased age and feebleness. According to the Activity Theory [3], people tend not to choose jobs with acute competition when they get old; they spend time on leisure and social activities instead. Related studies have pointed out that the interpersonal relationships and social interactions of the elderly report an extremely close impact on their

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physiology. For example, leisure activities help enable a more positive physiology, and greater participation in social activities is beneficial to health and helps foster improved quality of life [4-5]. Bennett [6] indicated that social activities are considerably associated with the maintenance of physiological operations of the elderly, which help reduce the risk of Alzheimer's.

However, according to a related questionnaire survey on the daily activities of the elderly conducted by Gottesman & Bourestom [7], elderly people mainly follow regular daily activities. They report that for many elderly, 56% of the hours of the day are free time, 24% are spend on eating, washing, sleep, and other necessary behaviors, and only the other 20% are spent on social activities. As a consequence, this easily leads to mental factors such as boredom and loneliness. According to a discussion on daily life of the elderly by Harper Ice [8], the elderly mostly live alone in their daily lives, with 43% of their time spent on bedroom activities while only 4.2% of the time spent in the activity room, where they mainly engaged in passive leisure activities (55.5%), followed by necessary behavior (28%), social contact (12%) and convalescence (4.5%). Bondevik & Skogstad [9] found that the elderly reported low intention to participate in collective activities; they like to stay in public areas decorated with old furniture and plants and spontaneously chat with staff or few acquaintances around the table. Zimmer & Lin [10] also mentioned that the elderly in Taiwan reported less than a quarter of their time spent on participation in social activities and emphasized the importance of encouraging the elderly to participate socially.

1.1 Leveraging Technology to Encourage Social Interaction

The use of computers and online technologies has the potential to enhance social connections and communication in a variety of ways [11-17]. Such communication technologies provide new ways to help seniors remain socially connected with their peers and family members. However, these technologies are often designed for people who are familiar with using such technology, and so present barriers for the majority of older adults who are inexperienced computer users [16-17]. Unlike young or middle-aged people, many elderly people are not used to interacting with computerized devices and may encounter great difficulties in operating a system with a mouse or keyboard.

Since the announcement of Microsoft Surface [18], multi-touch interaction with computationally enhanced surfaces has received considerable attention. Instead of "direct" operation with a mouse or a keyboard, this is tangible manipulation with a finger. Tangible manipulation offers advantages over conventional workstations, especially for those older people who are unfamiliar with computer input operations. For this reason, multi-touch sensing technology may be an ideal solution for the elderly users in this study. However, mainstream multi-touch research has focused on showcasing its innovative functionalities, and often limits access opportunities for the elderly, virtually neglecting the needs and expectations of older people. Hence, a fundamental rethink of how communication technologies help to solve the challenges of an aging population, the match between what is available and the needs and expectations of older people, and more importantly, how users interact with digital technology, is required.

In order to develop an appropriate social computing application for senior users, the salient point of this research was to explore social and physical environments of a senior living community and social interaction between aging residents, and to investigate the key factors of technology acceptance for those older adults with little or no computer knowledge. The next step was to give an appropriate alternative communication technology applicable to the elderly and their living milieu, and thereby enhance their social interaction. The area of study was also concerned with determining social communication, perceived ease of use, enjoyment, and satisfaction for the new digital social platform via the technology acceptance model.

2 Sharetouch Design and Development

Our Sharetouch program (seen in Fig. 1 and Fig. 2) presents an alternative social community platform designed for older people and for senior communities. Starting from "table" which uses social activities with which Taiwanese seniors are familiar, it emphasizes having conversations and interacting with users in a closer-to-life attitude than was ever available before. Moreover, instead of the commonly-used mouse cursor and keyboard, it invites the user to touch the onscreen objects directly and allows elderly users to interact with it easily without a barrier. In order to cater to the demands of social activities in Multi-User and Multi-Touch, a 52-inch touch panel planned by Sharetouch can be easily operated by 4 people at the same time.

Fig. 1. Sharetouch prototype

Fig. 2. Real screenshot of communication interface

2.1 System and Hardware Functions

The Sharetouch system (shown as Fig. 3) is primarily composed of a large touch module, control mainframe, identity module and remote server. The platform constructed by the entire system enables multiple users at the same time and provides multi-touch function. It supports Bluetooth technology to share information from a cell phone or PDA, USB portable hard disks, and has multiple inputs for files and information from digital cameras and other sources through the control PC. In addition, in order to allow users to carry no extra IT products and share data, we introduce

Web HD and RFID technologies to allow users to access their own Web HD data as long as they carry an RFID card (integrated into the ID cards of residents). They can jointly enjoy personal music, videos, documents, share images with other people, and even conduct file exchanges with others using a fast and convenient sharing interface via Sharetouch. The Sharetouch hardware includes a voice control system, 4-in-one card reader, RFID Identification System, touch screen and the following devices:

- **Touchscreen.** the mouse, keyboard, stick and other products all belong to high-tech products. These are reported to introduce a certain level of difficulty in learning for many elderly people. Therefore, Sharetouch starts with the image of a pond on a touchscreen. The product will be demonstrated in casually, where the elderly are allowed to conduct social interaction in a natural way via the touchscreen function.
- **Voice control system.** a voice control system device is hidden in front of the seat of every user. Each user's voice can be clearly received no matter the background noises or special effects of interface or personal data.
- **4-in-one card reader.** considering the need of users to share pictures and other files, the system incorporates a 4-in-one card reader. This will support many types of cameras, V8 and other products.
- **RFID Identification System.** the elderly community experiences a certain level of in mingling with new persons. Therefore, through RFID identification, a personal database such as personal theme music, personal sayings etc. can be established to help elderly people to take their first steps of social contact to make the opposite party understand and also get to know every user who used Sharetouch through interactive interface, as the records of each person will stay in the system.

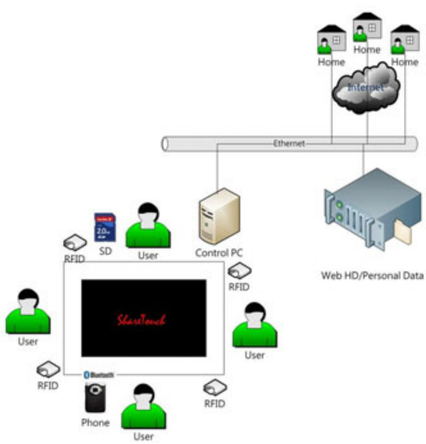

Fig. 3. Functions of Sharetouch system

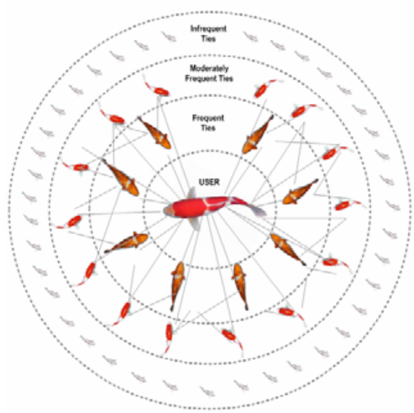

Fig. 4. Concept map of Sharetouch program

2.2 Interface Design and Social Interaction

Following a "pond" oriented concept, there are microphones established at four edges of the table. There will be a change in waves which varies upon sound direction when a voice is detected. There will be a change in water flow if the user gently stirs the water surface; the direction of water flow changes along the direction the user stirs, and the objects on the surface of the water will move accordingly when there is a change in water flow. Among the symbols on the pond will be lotus flowers, lotus leaves, turtles, frogs, dragonflies, and bees, as well as fishes of different kinds and quantities (seen in Fig. 2).

The definition of Sharetouch program is a special type of a social network that is centered around one senior community and community residents, in other words, it is viewed as the system of relations between residents' personal networks. In terms of social networks, size and density are two important characteristics [19]. Social size refers to the number of nodes in a network; and social density is the relative amount of contact (ties) in a network, and also can be presented as the number of connections divided by the maximum possible number of connections for sociocentric networks [19]. In addition, the role and distribution of ties in social networks are considered. Haythornthwaite[20] indicated that there is a range of ties of different strengths in any individual's network ranging from weaker tires, more instrumental tires to more intimate, strong tires. Hence, the analysis of residents' social network, including the role and distribution of ties in personal networks, is taken into account in this study. Fig. 4 maps the egocentric network of a Sharetouch user and shows layers of different tie strength. The Sharetouch program simplifies a social network as layers of frequently, moderately frequent, and infrequently ties; and furthermore a relationship between the strength of ties and the frequency of interaction as well as the number of contacts.

Fig. 5. Real screenshot of a user's social network on Shaertouch platform.

Fig. 6. Generation of personal image while clicking on the bubble**.**

According to the concept map drawn in Fig. 4, each fish represents a user who once logged in this table; when the user logs in, his/her fish will swim from the bottom to the top of the water. Big fishes on the top represent the users present at the table while the small ones underneath are other users (as Fig. 5). The amount of fish represents a quantity indicator of social interaction which is equal to the community size; the dimensions of the fish are a qualitative reference of social interaction and also represent the frequency of social contact between users, i.e., the bigger fishes are friends with frequent interaction while the smallest fishes are less familiar friends or those with less interaction. The interactive model of Sharetouch lies in direct touch on the fishes in the pond, where the fishes will spit out two bubbles. An image of that fish owner will be shown when the user clicks on one of the bubbles; clicking on the other one allows the user to listen to or leave a message to the fish owner (seen in Fig. 7 and Fig. 8) .

Fig. 7. Exhibition of bubble: You have a new voice message

Fig. 8. Exhibition of bubble: Send a voice message to the other participant

3 Technology Acceptance Model Measurement

The Technology Acceptance Model (TAM) has been widely employed to explain user acceptance and usage based on perceived ease of use and perceptions of usefulness [21-24]. The extended model, referred to as TAM2, was employed in this study. TAM2 encompasses social influence processes (subjective norm, voluntariness, and image) and cognitive instrumental processes (job relevance, output quality, result demonstrability, and perceived ease of use) as determinants of perceived usefulness and usage intentions [23]. Based on the TAM2 measurement scales and reliabilities, we proposed 6 hypotheses attempting to examine user acceptance of Sharetouch for older people. The hypotheses are listed as below:

H1*: Intention to Use has positive impact on intention of older people using Sharetouch.*

H2: *Perceived Usefulness h has positive impact on intention of older people using Sharetouch.*

H3: *Perceived Ease of Use has positive impact on intention of older people using Sharetouch.*

H4: *Enjoyment has positive impact on intention of older people using Sharetouch.*

H5: *Output quality has positive impact on intention of older people using Sharetouch.*

H6: *Result Demonstrability has positive impact on intention of older people using Sharetouch.*

3.1 Method

The TAM measurement was conducted in a senior housing community, Chang Gung Health and Culture Village, Taoyuan Taiwan. 52 elderly residents aged 64 to 91 years, including 17 males and 35 females, participated in this study. After a short demonstration conducted by the researchers, a TAM questionnaire was distributed to assess the participants' acceptance and satisfaction. There were 18 items in this TAM questionnaire. It is noted that all items were measured on a 7-point Likert scale, where 1=strongly disagree, 2=moderately disagree, 3=somewhat disagree, 4=neutral (neither disagree nor agree), 5=somewhat agree, 6=moderately agree, and 7=strongly agree.

Questionnaire analysis was based on SPSS for Windows 10.0. Participants' basic information and score distribution of the items in the questionnaire were shown by descriptive statistics analysis with mean and standard deviation. The influences of gender and educational level on scores in the questionnaire were compared by independent t test, and influences of educational level and age on questionnaire scores were compared by one-way ANOVA. P value in the article is two-tailed and the significance level is 0.05.

3.2 Results

Average age of the participants is 78.33±7.53 years old. According to the ages, the elderly are classified into young-old, (65-74 years old), old-old (75-84 years old), and oldest-old (above 85 years old), as shown in Table 1. Table 2 shows the educational level of the 52 participants.

Table 1. Frequency distribution of participants' ages (n=52)

	Male	Female	Total
Young-old (65-74)	1	13	14
Old-old (75-84)	14	15	29
Oldest-old (≧85)	3	6	9

Table 2. Frequency distribution of participants' educational level * (n=52)

	Male	Female	Total
Elementary school	1	4	5
Junior high school	1	6	7
Senior high school	3	9	12
Above university	12	14	26
* Two participants' information is uncertain			

Table 3 and Table 4 show the percentage of 52 elderly participants' scores on itheir questionnaire. The; participants' subjective evaluations on the interactive table were refer to levels "excellent" and "good." In terms of influences of gender on scores of the 18 items, the subjective scores of gender refer to level "good." There is no significant difference in scores resulting from gender. It is demonstrated that educational levels have a significant influence on scores among these participants. In this TAM analysis, influences of age on scores demonstrated no significant effect among 52 elderly participants.

Based on the findings of the TAM measurement, all proposed hypotheses, such as intention to use, perceived usefulness, perceived ease to use, enjoyment, and output quality had a positive and significant impact on the intention of older people to interact using Sharetouch.

Table 3. Subjects' distribution (%) in each item in Sharetouch (n=52)

	Item	Distribution in percentage (%) strongly agree 7	moderately agree 6	somewhat agree 5	neutral 4
1	Using "Sharetouch" improves the quality of interacting with others.	46.2	30.8	15.4	3.8
2	Using "Sharetouch" enhances my ability to interact with others.	32.7	21.2	17.3	23.1
3	I find "Sharetouch" helps me interact with others.	30.8	25	15.4	19.2
4	Using "Sharetouch" enhances the interaction with others.	26.9	25	19.2	15.4
5	My interaction with "Sharetouch" is easy for me to understand.	21.2	32.7	23.1	15.4
6	I find it is easy to learn to use "Sharetouch."	23.5	35.3	21.6	11.8
7	Overall, I find "Sharetouch" easy to use.	21.2	25	23.1	15.4
8	I find it easy to get "Sharetouch" to do what I want it to do.	21.2	28.8	17.3	21.2
9	I find it WILL be interesting using "Sharetouch."	15.4	32.7	21.2	19.2
10	It is a pleasant time when using "Sharetouch."	15.7	25.5	23.5	15.7
11	I find it interesting after using "Sharetouch."	53.8	21.2	15.4	5.8
12	If I got a chance, I would use "Sharetouch."	51.9	23.1	17.3	3.8
13	If you gave me "Sharetouch," I would definitely use it.	26.9	28.8	15.4	19.2
14	Overall, I am satisfied with the quality of "Sharetouch."	38.5	32.7	19.2	9.6
15	I have no doubt about the quality of "Sharetouch."	38.5	36.5	19.2	3.8
16	I am glad to share the benefits of "Sharetouch" with others.	23.1	40.4	23.1	5.8
17	I will exchange the experience of using "Sharetouch" with others.	21.2	28.8	19.2	17.3
18	I find it hard to distinguish between advantages and disadvantages.	11.5	11.5	11.5	19.2

4 Conclusion

Sharetouch aims to enable elderly persons to engage the benefits of IT and enhance their social interaction, and also presents an alternative digital social communication technology for older people and senior communities. Unlike most of the digital devices on the market, the Sharetouch social community platform attempts to merge the digital desktop and physical table into one, and provides pre-elderly and elderly a simple, easy-to-learn, easy-to-use and friendly user interface. In addition, a simplified of social network map as a concent of Sharetouch social media platform is presented in this study. Finally, the TAM was employed to measure user acceptance and usage of the Shaertouch social platform and received positive feedback from those residents living in a senior community. Further research is needed to continue analysing the other factors that will also influence social interaction and the inclinations of the older adults' intention in using a particular interaction technology, such as Sharetouch.

Table 4. Subjects' distribution (%) in each item in Sharetouch (n=52)

		Distribution in percentage (%)			
		somewhat disagree	moderately disagree	strongly dis-agree	**Mean average**
	Item	**3**	**2**	**1**	
1	Using "Sharetouch" improves the quality of interacting with others.	3.8	0	0	6.12±1.06
2	Using "Sharetouch" enhances my ability to interact with others.	0	5.8	0	5.46±1.45
3	I find "Sharetouch" helps me interact with others.	3.8	1.9	3.8	5.38±1.59
4	Using "Sharetouch" enhances the interaction with others.	3.8	3.8	5.8	5.21±1.71
5	My interaction with "Sharetouch" is easy for me to understand.	0	7.7	0	5.37±1.39
6	I find it is easy to learn to use "Sharetouch."	3.9	3.9	0	5.51±1.30
7	Overall, I find "Sharetouch" easy to use.	11.5	3.8	0	5.17±1.44
8	I find it easy to get "Sharetouch" to do what I want it to do.	7.7	3.8	0	5.23±1.41
9	I find it WILL be interesting using "Sharetouch."	9.6	1.9	0	5.19±1.30
10	It is a pleasant time when using "Sharetouch."	9.8	5.9	3.9	4.88±1.62
11	I find it interesting after using "Sharetouch."	3.8	0	0	6.15±1.13
12	If I got a chance, I would use "Sharetouch."	3.8	0	0	6.15±1.09
13	If you gave me "Sharetouch," I would definitely use it.	1.9	5.8	1.9	5.35±1.55
14	Overall, I am satisfied with the quality of "Sharetouch."	0	0	0	6.00±.99
15	I have no doubt about the quality of "Sharetouch."	1.9	0	0	6.06±.96
16	I am glad to share the benefits of "Sharetouch" with others.	3.8	3.8	0	5.62±1.24
17	I will exchange the experience of using "Sharetouch" with others.	5.8	7.7	0	5.19±1.50
18	I find it hard to distinguish between advantages and disadvantages.	13.5	19.2	13.5	3.77±1.94

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A Telehealthcare System to Care for Older People Suffering from Metabolic Syndrome

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Abstract. As individuals live longer, the social structure is rapidly changing, resulting in problems such as shortages of medical resources and reduction of quality in healthcare services. Hence, this paper presents a telehealthcare system for user-friendly and long-term healthcare applications for older people suffering from metabolic syndrome. The system can transfer and manage medical data at a distance via a wireless sensor network. The integration of these technologies allows personal stand-alone vital data to become a total telehealthcare solution in home-level care.

Keywords: Telehealthcare system, metabolic syndrome, older person.

1 Introduction

With the aging of the world population, the United Nations reports that is 21 percent of the world's proportion will be over the age of 60 by 2050 [1]. As in most other countries, the proportion of older people are increasing every year in Taiwan due to decreased birth rates and increased longevity. The proportion of those 65 years and older in Taiwan was approximately 10.2% in 2007 [2], and is expected to rise 36.71% in 2050 [3]. Average life expectancy has increased from 76.45 years in 2000 [4] to 78.54 years in 2008 [5].

As individuals live longer, the social structure is rapidly changing, resulting in problems such as shortages of medical resources and reduction of quality in healthcare service. In addition, many older people have at least one or two chronic diseases. Consequently, governments and researchers around the world have to seriously consider health issues [6]. One of the key issues is considering how to look after older persons' health, to keep them healthier, maintain their functions and independence, and improve their quality of life.

There are some studies regarding distributed health care [7-11]. However, many discuss the algorithms and technologies involved in maintaining the capability and

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functionality of distributed healthcare systems, but less has been done to determine to what extent users understand their capacities and functionalities. While it is crucial to improve the capacities and functionality of any healthcare system, a highly advanced system is likely to be rejected by users if it does not fulfill their expectations. The importance of other factors contributing to the acceptance of a telehealthcare system should not be neglected [12]. It is important to investigate users' needs and requirements before designing new systems so true user needs can be satisfied, allowing those systems to have a better chance of gaining user acceptance and adoption. Consequently, there are few systems available for thorough evaluation. In addition, we lack a distributed healthcare model for scientific evaluation from different perspectives (clinical, technical, economic, social, legal, etc.) requiring a multidisciplinary approach. Therefore, a telehealthcare system to care for older people suffering from metabolic syndrome has been proposed.

For elderly individuals suffering from metabolic syndrome, the proposed system provides a user-friendly solution through an integrated telehealthcare environment. Medical data is transmitted and managed at a distance using WSNs (wireless sensor networks). The integration of these technologies allows personal stand-alone vital data to become a total telehealthcare solution in home-level care. The remainder of this paper is organized thus: section 2 described metabolic syndrome. A telehealthcare system is proposed in section 3 and a system validation method is described in section 4. Finally, some conclusions are provided in section 5.

2 Metabolic Syndrome

Metabolic syndrome has received increased attention in the past few years. The syndrome is a constellation of interrelated risk factors of metabolic origin—*metabolic risk factors*—that appear to directly promote the development of atherosclerotic cardiovascular disease (ASCVD) [13]. Patients with metabolic syndrome have a twofold increased risk of mortality from coronary heart disease and an increased risk for developing type 2 diabetes mellitus [14]. Another set of conditions, the *underlying risk factors*, give rise to the metabolic risk factors. Understanding how to identify and address the problems of metabolic syndrome can make a significant difference in an older person's health. An older person can realize significant improvements in his or her health status when metabolic syndrome is identified and the problems associated with it are addressed.

In the past few years, several expert groups have attempted to set forth simple diagnostic criteria to be used in clinical practice to identify patients who manifest the multiple components of metabolic syndrome. These criteria have varied somewhat in specific elements, but in general they include a combination of both underlying and metabolic risk factors [15]. Table 1 lists three criteria of metabolic syndrome from three different organizations.

Due to the increasing number of older people with chronic diseases, there are many studies based on different network technologies that propose various designs and applications for telehealthcare service systems [16]. However, most of those systems address their particular situation and specific applications, which does not consider in detail the actual needs of users.

Table 1. The Criteria of Metabolic Syndrome

Factor	**WHO 1999**	**ATP III * 2001**	**National Health Council, Taiwan 2007**
Obesity	WHR: Male > 0.9 Female > 0.85 BMI > 30	Abdominal circumference： Male ≧ 102 cm Female ≧ 88 cm	Abdominal circumference : Male ≧ 90 cm Female ≧ 80 cm
Triglyceride	≧150 mg/dl	≧150 mg/dl	≧150 mg/dl
Blood pressure	SBP ≧140mmHg/ DB P≧ 90 mmHg	SBP ≧ 130 mmHg/ DBP ≧ 85 mmHg	SBP ≧130mmHg/ DBP ≧ 85 mmHg
Glucose	IGT, IFG, or DM	FG≧ 110m g/dl	FG ≧ 100m g/dl
HDL Cholesterol	Alb/Cr ratio >30 mg/g AER > 20μg/min	Male 40 mg/dl Female < 50 mg/dl	Male < 40 mg/dl Female < 50 mg/dl
* There may be three or more diagnostic factors. This definition is recognized by US NHLBI, ADA, and CDC.			

To achieve the goal of telehealthcare, and to look after older people suffering from metabolic syndrome, we propose a telehealthcare system to integrate stand-alone medical devices into WLAN networks and use it to construct a telehealthcare network infrastructure.

3 A Telehealthcare System

The section addresses how the proposed system is developed according to the analysis on the needs of distributed health care at home. The system not only receives physiological signals, but also transfers physiological data through the wireless network to the back-end health management server, so that complete and continuous personal physiological data can be recorded.

A three-layer structure of user base, function base, and data base was proposed. The user-based layer has two types of interfaces, web-based and client-based. On the web-based interface, users can connect to the server via HTTP protocol and need only a general browser to log into the system; on the client-based interface, users can log in with a RFID card provided by the study. The function-based layer consists of the application system, external program interface, and system interface. The system interface shows animated scenarios based on physiological data that the intellectual medical apparatus receives. The data-based layer is an information database that records vital sign parameters that the intellectual medical apparatus receives as personal information of users, voice messages, etc.

The programming languages of the system implementation are ASP.NET and PHP, built on Windows Server 2005 with IIS as the site server and Microsoft SQL as the database. The operating environment of the system mainly consists of the user interface, web server, and database. The system development information is summarized in Table 2.

In response to user needs, this study develops a telehealthcare system for long-term care at home. The system is divided into four modules: communication transmission module, membership management module, information integration module of health education for the elderly, and personal health management module.

Table 2. The System Development Information

Development language	ASP.NET, PHP
System environment	Windows Server 2005
	Microsoft .NET Framework
	IIS Server
	Microsoft SQL Server
Development software	Microsoft Visual Studio 2005, Flash

The system provides different logged identifications with different authorities. The authority design is depicted below (Figure 1):

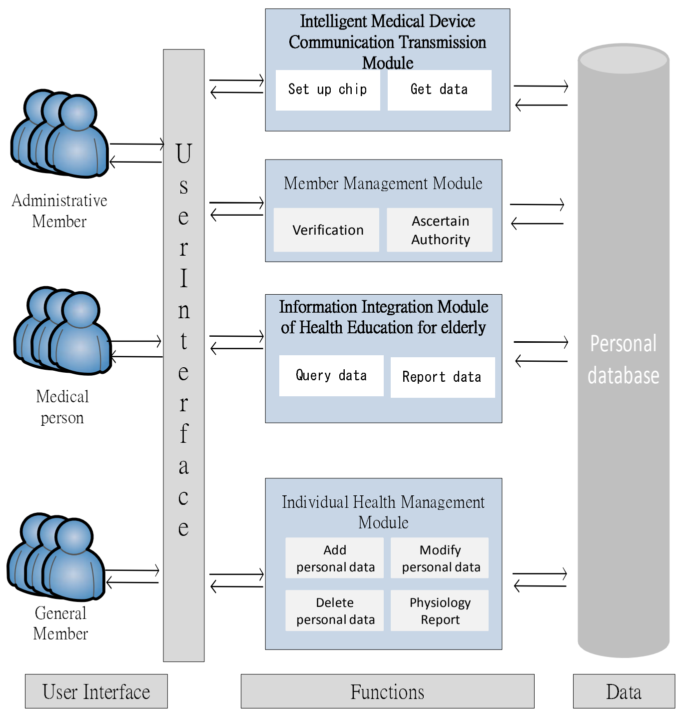

Fig. 1. The System Structure of a Telehealthcare system

Communication Transmission Module. The study employs the Wireless Sensor Network (MSP430) module, developed by the National Taiwan University (NTU) [17]. The structure of the NTU developed wireless sensor networks hardware platform is comprised of three levels: base node, advanced node, and universal gateway. A PC can thus be easily connected via USB interface, and the computer hardware does most of the work transmitting instructions and data. Since the computer has direct power, there is no need to consider energy issues such as nodes [18]. The chip is installed in the medical apparatus so that when a user uses the physiological data measuring instrument, the information will be sent to the system chip via the installed chip and saved. The information integration module of health education for the elderly then comprehends collected user parameters and accordingly provides information about health education on the system. The system also stores data as XML format via XML Parser to facilitate the physiological data acquisition for the elderly who log in on the web-based system.

Membership Management Module. The module mainly verifies users' identities and sends a successful login message to users. The RFID card specification that the study employs is depicted in Table 3. Through RFID communication technology, user physiological measurements and card identifiers can be used to send user voice messages.

Table 3. RFID Reader Specification

Communication specification	
Frequency	2.4GHz-2.5GHz ISM microwave band
Channel	125
Channel bandwidth	1MHz
Modulation	GFSK
Identification method	Omnidirectional identification
Recognition distance	Within 80m
Recognition speed	Within 80m/second
Anti-collision	Simultaneously identity more than 100 cards
Interface specification	
Ethernet	10M/100M Ethernet (RJ-45)
RS-232	RX, TX
Communication protocol	TCP
Communication speed	9600Bps ~ 115200Bps
Power requirement	
Power	<120mA,7.5V
RF power	0dBm
Sensitivity	-90dBm

Information Integration Module of Health Education for the Elderly. There are two types of system displays, one on the interactive system (Figure 2) and the other on the web-based page through the network login system. On the interactive system display, the physiological data is divided into three levels based on the diagnosis mechanism of metabolic syndrome (Figure 3): sunny day (normal), cloudy day (cautious), and rainy day (severe) to show the current physical conditions of users. On the intuitive interface, operation is easy, and the context interface is supplemented to notify the physiological conditions of users. In addition, the system provides web functions to assist web users in logging in via the general Internet or mobile phones to view messages that families leave and their physical records. Through detailed information from the electronic records, clinical staff or family members get to know the health conditions of their patients or elderly family members. Moreover, electronic records instead of handwritten ones not only allow the clinical staff to manage the patients easily, but also can be sent to hospitals to assist in diagnoses and to reduce the possibility of tampering with physical records (see Figure 4).

Personal Health Management Module. The module provides the medical centre with the personal information of the elderly patient and also allows authorized clinical staff to add, delete, and modify such information based on the clinical diagnosis.

Fig. 2. The Interactive Platform

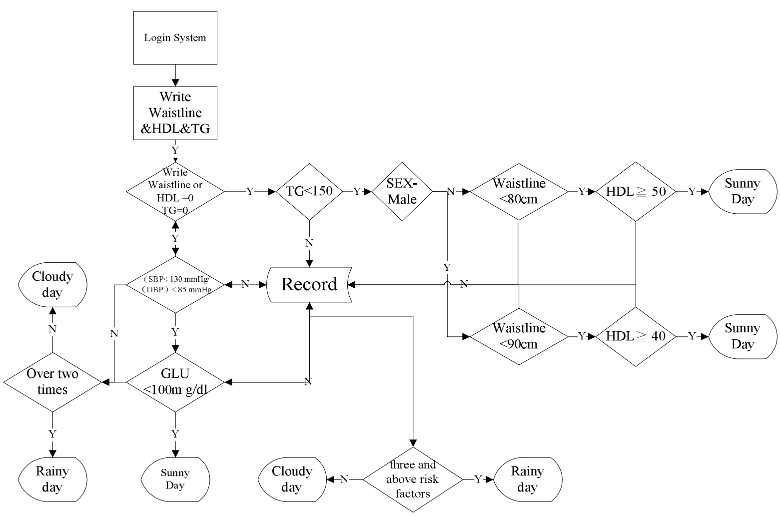

Fig. 3. The Diagnosis Mechanism of Personal Health Management

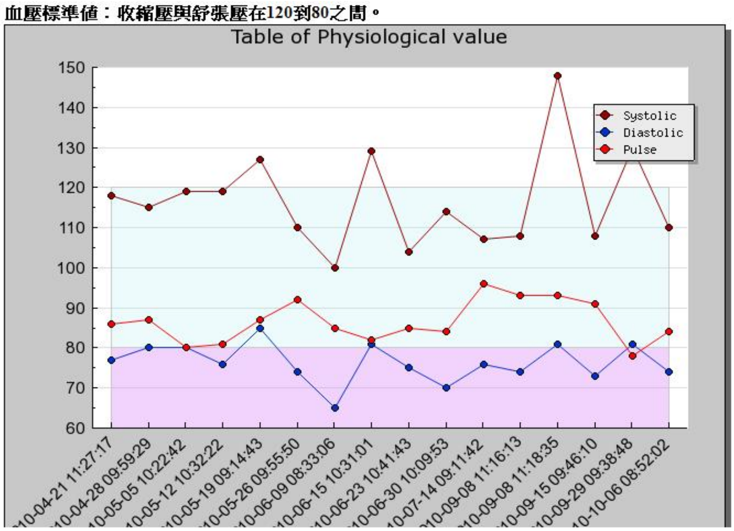

Fig. 4. The Record of Blood Pressure

4 System Validation

An experiment was conducted to test the effectiveness of the system. We set up two different environments, an area without any furniture and an area with furniture (see Figure 5). The system could send and receive wireless signals at distances of 3, 6, 7, 8, 9m and 10m to connect to the blood pressure devices. We found that better transmission quality was offered in 7m or less. Regardless of whether the area was furnished, data transfer had up to 100% integrity (see Table 4).

According to the results, the transmission quality was affected by some obstructions such as furniture when the signal path was long. Thus, device placement within 7m should be considered when implementing a system in a home in which there are many chairs and tables.

Fig. 5. The Experimental Environment

Table 4. Transmssion Quality in Distance

Distance (m)	Completion Rate %
0	100%
3	100%
6	100%
7	100%

The experiment showed the system could maintain good data transmission with an effective radius of 7m, which is the size of a living room size in an ordinary home. Hence, the system can be set in the living room or bedroom to help an older person suffering from metabolic syndrome record his/her physiological data and send it to his/her family doctor.

5 Conclusion

In this paper, we proposed and implemented a telehealthcare system integrating stand-alone medical devices in the form of a ubiquitous network providing a service platform to provide older persons suffering metabolic syndrome with physiological monitoring. As shown by the experiment, the system could maintain good data transmission with an effective radius of 7m, which is the size of a living room size in an ordinary home.

The system is a health management system. Professional medical personnel evaluate the daily or weekly measurements of every family member suffering from metabolic syndrome managed by our system. As for family members who upload physiological signals normally, our system will calculate the health curve for each case. This system will subsequently classify the health status of the family member as "sunny", "cloudy", or "rainy" according to the variation of his/her physiological signals and transmit the information to family members, the member's relatives, and the health manager for health-care management.

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Narrating Past to Present: Conveying the Needs and Values of Older People to Young Digital Technology Designers

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Abstract. In this paper we discuss preliminary findings from the first stage of our SEEDS study (SEEDS: An Organic Approach to Virtual Participatory Design), a collaborative research project between Universities of Dundee, Kent and Leeds, United Kingdom. This feasibility study investigates how to motivate older people to engage with digital technology, as well as how to improve understanding of older people's needs and requirements amongst young designers. As part of this study we recorded interviews with older people which investigated their motivations to use or not use digital technologies and themes pertaining to their (dis)engagement. A virtual repository was created to make collected interviews, which were presented as social stories, available to engineering, technology and design students. In this paper we discuss the findings from a prototyping exercise with undergraduate and postgraduate students which took place in stage one at the Universities of Kent and Leeds.

Keywords: design, older people, young designers, motivation, inclusion, education.

1 Introduction

Digital technologies pervade many aspects of modern life; benefiting large proportions of society; enabling people to shop, work, relax, stay healthy and communicate in increasingly convenient, cost-effective and rich ways. However, not everybody engages with digital technologies such as the Internet, creating a digital divide [1]. The Economic Case for Digital Inclusion, which highlights the links between social and digital exclusion [2] identifies 10.2 million UK citizens as being digitally disengaged (having never accessed the Internet), with the largest group, comprising 62% of

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the total, of people over 65. This age group is growing in both numbers and wealth [3] [4]; it is attractive to capture their interest in digital products and services. However, merely enabling people to physically connect to the Internet may not, by itself, be sufficient, as it may not make the technology appear any more relevant or worthwhile to those who already do not use it.

In order to both learn what encourages older people to become digitally connected, what dissuades them, and what can encourage young designers to consider these needs and desires, the SEEDS research project investigated methods of involving older people in the design process. We considered mediated intergenerational methods, using virtual frameworks to present social stories captured from one generation to another. We report upon this process in this paper.

1.1 Older People and Technology

It may be argued that older people are less likely to use digital technologies due to lack of previous exposure, and that this will decrease over time, yet we propose that there are additional issues that result in a lack of use amongst older people; peer-opinion, cost and maintenance, previous negative experiences, lack of understanding and fundamentally a lack of perceived need [5]. In our research the theme of digital technologies as being for “others”, “clever” or “younger” people and not aimed at the older self is oft heard. Such technologies may seem to be both irrelevant and problematic, a negative or neutral influence that results in disengagement.

Older people are a wide and diverse group, associated by only their physical age; individuals may not hold the same values as another and each person’s abilities, motivations and understandings can differ widely. Thus, not all older people have the same relationship with digital technology. Older embracers of digital technology vary from those who gain much publicity due to their age and relatively prolific web presence (e.g. geriatric1927 on YouTube [6], and the late ivybean104 on Twitter [7]), to those who wish to communicate, shop and bank online, or simply use the Internet as an information tool. People who do not engage also vary, from those who refuse to participate, to those who simply don't feel the need for digital technologies or are dissuaded by various factors [5].

1.2 Designing for the Young Generation

Digital products and services are primarily designed by and for younger people, who may find it hard to imagine life without them. Few do not use the Internet or own a mobile phone, which are designed and advertised as facilitating the lives of busy, sociable people, requiring good eyesight and agile fingers to use them successfully. Products aimed at older people may be limited, simplified adaptations of the mainstream product, with large buttons and poor aesthetics, advertised in specialised catalogues. Downgraded features mean that older people may feel stigmatised; the digital products aimed at them are not something that others would wish to use. Designers can tend to create interfaces for homogenous groups of people, for example a “design for older people” whereas this group is very diverse.

1.3 Bridging the Gap between Young and Old

We propose that this misalignment between what older people may wish to use and what they are marketed is due to a lack of understanding of and empathy with their wants, needs and values at the outset of the design process. Instead of considering these factors as a starting point for design (as one may do when designing for people like oneself), designers tend to redesign and adapt existing products and services into lesser versions, best considering a single physical impairment (e.g. reduced vision and digit dexterity), rather than lifestyles and values. Experiential and cultural gaps also exist between younger and older people, thus communicating ideas that involve technological jargon between parties can be difficult, leading to a situation where designs are based upon the developer's interpretations of an older person's needs , "a solution that can be ineffective and patronising" [8]. As the natural relationships between these generations have become progressively disconnected from each other at an individual, family and community level [9], there is an urgent need to educate young designers about the needs and values of older people.

SEEDS originated against a background of intergenerational activities [10] [11] [12] which aim to foster understanding between older and younger people.

2 Background to SEEDS

Our project is a collaborative research study between the universities of Dundee, Kent and Leeds, funded by the Engineering and Physical Sciences Research Council (EPSRC) UK. It is concerned, among other things, with how might the disengaged older people, young designers, and other interested parties be brought together to create solutions that address the needs of individuals.

3 Design Projects

The aim of our feasibility study is to establish a design methodology which can be used to bring the voices of individual older users, from digitally disengaged communities, into the very early stages of a design activity, before solutions have been explored or proposed. Another consideration is to build the developed methodology into the educational curriculum available to technology designers.

To that effect, we recorded 29 audio interviews with older people in the form of social stories; 14 at Kent and 9 at Dundee, with digitally disengaged people, and 6 at Leeds with those who had recently started learning IT. The digitized stories were uploaded to a repository in a protected on-line community. They were subsequently made available to groups of students on the undergraduate multimedia technology and design degree at Kent and a postgraduate engineering design degree at the University of Leeds. Our aim was find out whether or not access to such social stories would enhance the understanding of older people's needs among young designers and result in better design solutions.

3.1 University of Kent

At the University of Kent, the SEEDS project was integrated into an optional module entitled Digital Culture which was taken by 48 final year multimedia technology and design students in 2010. This multidisciplinary degree is strongly technology-focused and encompasses a wide variety of modules, from visual communication and interaction design to software engineering, animation and film-making. An important part of the degree involves imparting the knowledge of user-centred design to young digital technology designers. All 48 students were given the same design brief: a) to read recommended literature in order to understand the issues relating to design for the older people; and b) to propose a suitable design solution which would motivate older people to engage with digital technology. The cohort was divided into two groups. One group was given access to papers and two interviews from the online repository (each team had a different pair of interviews detailing older people's pastimes, lifestyles and access/or not to digital technology), while the other group did not have access to the interviews. Within each group, students worked in teams of three and four.

Discussion of the findings. Our findings are based on the analysis of 13 team reports as well as discussions with teams in seminars with a view of identifying a change in perception of older people as a result of accessing the social stories. Our findings include a summary of positive outcomes as well as lessons learnt.

1. Positive outcomes from the social stories group

- Out of six teams who had access to the audio interviews, all but one referred to interviews when discussing their design process.
- Three teams went further than simply referring to papers and interviews and talked to their grandparents with a view of getting some further insight into their lives and their interest in digital technology.
- Listening to social stories brought older people's lives closer to students, thus making them more personable and easier to relate to. Most teams referred to 'an older person from audio interviews', while discussing their needs and lifestyles.
- In two projects, design solutions were directly inspired by stories older people told - favourite pastime (library) and favourite place at home (fireplace).
- Although this group referred to literature, the interviews were mentioned more often than papers.

2. Lessons learnt from the group with no access to social stories

- The group with no access to the social stories wished they had been given access to them.
- Two teams used their own initiative and interviewed older people they knew. This was due to a perception among some students that not having access to stories will somehow adversely affect their marks. As a result, one of the teams came up with a very innovative design solution based directly on the interview they took (SEED pod project).
- The group's referencing of literature was rather mixed. Two teams seem to have referred more extensively to published papers and reports than other students in either group. Others teams' references were more sketchy. The difference seems to

have been dependent upon the academic strengths of individual teams, rather than access or not to social stories.

3.2 University of Leeds

At the University of Leeds the study was conducted with five postgraduate (MDes.) product design students in their team design project. The students were given access to six audio recorded interviews with older adults about their personal stories. The stories included daily and working lives, interests and pastimes, contact with and use of technology (at home and in public places), views on digital technology. The design methodology was based on the Systems Engineering 'V' model and the spiral iterative product design model. For a detailed account see [13]. Initially, the students listened to the interviews (archived in a virtual repository) and created their summaries highlighting issues experienced by older adults in daily lives or routines. In this way they gained insights into the needs of older adults as potential users of digital technologies. Afterwards, the students carried out review of literature. Next, the student designers proposed a number of initial design concepts in response to the stories. Low fidelity prototypes of initial design concepts were created to aid in user evaluation. The student designers carried out evaluations of the initial design concepts (through interviews and discussions) with representative older adults (at local Age Concern office) by reviewing prototypes and obtaining user feedback. Originally, it was intended to evaluate the design work with the original interviewees but practical difficulties such as the time taken to generate the designs made review with the original interviewees infeasible. From the user feedback, the student designers produced an updated and detailed definition of design requirements and technical design specifications to inform final design solutions. Final design solutions were produced to meet the needs, wants and aspirations of older adults (examples of the final design solutions are available online at: www.leeds.ac.uk/productdesign/showcase/ proddesignv3/index.htm#/118/) and high fidelity prototypes created to aid in user testing.

3.2.1 Discussion of the findings

The findings at Leeds were as follows:

- Initial feedback from student designers indicated that the interviews gave fresh perspectives on designing for older adults. The interviews, used as part of a virtual participatory design approach, provided designers with fast access to more users than would have been possible using traditional participatory design. Interviews captured as social stories in virtual repository reduces time and effort needed from the users themselves.
- In addition, the interviews (captured as social stories) inspired the students to carry out the same style of research with their own focus groups. For example, some students used their own initiative and interviewed their older relatives and their parents and grandparents to gain further insights into the needs and aspirations of older adults.
- Students' attitudes towards the older adults seemed to change through the team design project, evidenced, for example, by the language they used to refer to their users. It is not ascertained whether this change of attitudes of student designers

was as a result of listening to the individual stories (interviews) of older adults, or meeting older adults (while evaluating initial design concepts) or something else. However, it could largely be due to the former two reasons.

- At the end of the project, there was a real benefit in the students being able to evaluate their actual designs with real users. We observed that feedback from the real users made a significant improvement to the detailed definition of design requirements, technical design specifications and the final design solutions.

Lessons learnt

These experiences led to the conclusion that the personal stories of older adults enhance inspirations among young designers to better understand and gather more information about older people's needs early in a design process.

4 Conclusion

This paper has considered the findings from a prototyping exercise with undergraduate and postgraduate students which took place in stage one of the SEEDS project at the Universities of Kent and Leeds. The results from the studies indicate that access to social stories for both undergraduate and postgraduate students inspired them to carry out more research into this user group. Some students used their own initiative and interviewed their older relatives and their parents and grandparents to gain further insights into the needs and aspirations of older adults. Students' attitudes towards the older adults seemed to indicate that access to social stories has brought people's needs and lives closer to the young designers. This was evidenced, for example, by the language they used to refer to their users (Leeds), and references to people's lives, favourite objects and pastimes (Kent). Our initial findings indicate that providing young designers with access to rich lived experiences of older people may result not only in changed perceptions, but also in designs inspired directly by older people's lives.

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Evaluating the Design, Use and Learnability of Household Products for Older Individuals

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Abstract. Assessing the usability of products, interfaces and artefacts from an inclusive design perspective can widen cross-market acceptability and adoption, enhancing their potential commercial success. This paper is part of ongoing research that attempts to evaluate the design of existing products on the market, in terms of usability and learnability, with a view to improving these facets where deficiencies become apparent across user populations. Individuals were assessed according to the development of their product understanding during increased product exposure, providing concurrent protocol whilst product interaction occurred. The extent of participants' technological familiarity was also investigated to determine how prior experience may affect product interaction performance. Age related differences were evident in both approaches to problem solving and extent of technological familiarity, and this also impacted overall interactional performance.

Keywords: Inclusive Design, Prior Experience, Product Interaction Learning.

1 Introduction

Inclusive design has the potential to increase long-term profits, enhance the competitive edge of companies and can assist in the production of better products for all end users [1]. Its intention is not to develop designs for specific groups [2], but optimise design for maximum accessibility in conjunction with minimizing the user effort required for interface or artefact interaction [3]. The approach of this research was to examine how humans learn and interact with interfaces and designs, and by understanding more about how learning occurs, use this knowledge to influence future design in terms of ease of learning, use and access to all.

In the United Kingdom, those aged over 60 recently overtook the number of those under 18 years of age [4]. Therefore, a product design catering inclusively for all potential user age groups, has the potential to appeal to an ever-increasing commercial market. The importance of maintaining independence for older persons within communities and within the home has been widely reported in terms of sustaining both physical and mental well-being [5, 6]. As the everyday lives of older individuals are heavily affected by the social and physical interactions they experience [7], this work

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focuses upon the design and manufacture of household products, and contributes toward maintaining independence in the home, on a global scale.

1.1 Background

Previous work in the area has identified that distinct differences can be made between user groups, purely on the basis of age. A study by Langdon [8] reported how symbols identifying features of an interface across product families were recognised by different generations, and how older individuals failed to recognise modern symbols. According to Docampo-Rama [9] this is a factor of exposure to technology at a particular stage in life – modern symbols and layered computer interfaces being more familiar and suited to the interactional processes of those 25 years and younger.

It has also been argued designers have preferred to design products and artefacts from their own knowledge-base, under the presumption that product users will possess similar cognitive and physical abilities to the designers themselves [10]. Failing to connect with users and their requirements may risk alienating or excluding a significant proportion of the population which makes poor and short-sighted commercial business sense [11]. Catering for diversity within the target market should be prerequisite for all design and a natural component within requirements specification. Design should consider users as individuals, possessing unique aptitudes, experiences and other human characteristics [12].

2 Features of the Current Research

Participants were allocated to one of three groups according to age: 16-25, 26-59 and 60-80. By the age of 16, the most significant human physical and psychological development has taken place and this largely stabilises until somewhere in the region of sexagenariansim or late adulthood. Further significant cognitive change occurs in older adults, often as a symptom of natural atrophy, within the 60-80 age range [13, 14]. Thus, although the age groups used in the study appear unbalanced, they are capable of elucidating differences according to age group membership, both in terms of task and interaction performance, and in extent and form of prior knowledge.

This research utilises novel products throughout, as this is a key element used to highlight the intuitive nature of product design. The findings go some way in identifying how product features, both functional and aesthetic, can contribute toward successful product interaction. There has also been an attempt to highlight and identify specific product features used that may cause interactional problems, either in terms of physical manipulation or in terms of facilitating learning and the development of correct and appropriate mental models. These findings have been borne out of observation and verified through interview material, questionnaire data and experimental investigation.

2.1 Research Approach

The Black & Decker Laserplus laser-level (Figure 1) is a multifunctional device contained within a unique and bespoke aesthetical design and is used to detect wooden and metallic studs or pipes and electricity cables obscured behind walls or fascias. It is also capable of emitting a laser beam to provide a straight level line. Whilst the devices functionality may arguably be limited, the level of conceptual development required to understand and operate it would appear significant. Its novel nature affords more direct study of understanding-development as the likelihood of prior specific product experience is minimal. Literature suggests the familiarity of features within a products design, interactional style or its conforming metaphor, are key features for intuitive interaction [15]. Thus, prior experience and technological familiarity are important features of this work; to determine if experience with other products affects interaction with new products.

Fig. 1. Black & Decker 'Laserplus' laser-level

3 Methodology

3.1 Experimental Design

Between-subjects design, assigning a total of 30 participants to one of three groups according to age: 16-25 (10), 26-59 (10) and 60-80 (10)
Independent Variable: Age: 3 levels: 16-25, 26-59, 60-80
Dependent Variables: Cantabeclipse cognitive assessment performance, warning icon pre/post exposure recognition, task performance, initial/post exposure product feature recognition, and technological familiarity questionnaire performance.

3.2 Experimental Procedure

- Administer pre-test assessment using Cantabeclipse Cognitive Assessment Tool
- Assessment of warning icon recognition
- Record initial exposure to the product and participant understanding
- (including initial product exposure feature recognition)
- Record participants performing randomised tasks with the product whilst verbalizing actions: 1: Fit Battery, 2: Find Wooden Stud, 3: Find Metal Pipe, 4: Find Electric Cable, 5: Fit Hanging Tool, 6: Hang and operate laser level

- Reassess participant understanding of product and interaction.
- Reassess warning icon recognition.
- Assess post exposure product feature recognition.
- Administer technological familiarity questionnaire.

3.3 Research Materials

Cantabeclipse Cognitive Assessment Tool. The Cantabeclipse software program [16] was used as both a screening mechanism as it assesses for a range of cognitive disorders, and to verify that age differences in performance were not limited to the experiment alone. Two programs were utilised. The Motor Screening (MOT) test introduces participants to the bespoke interface (a touch-screen entry system) whilst assessing vision, movement and comprehension ability. The Spatial Span (SSP) test is a computerised version of the Corsi Block Task [17] and assesses short-term memory and screens for neuropsychological impairment.

Icon Assessment Sheet. An icon assessment sheet was developed to test participants recognition or understanding of warning icons appearing either upon the packaging of the device or upon the device itself (Figure 2). This was presented before and after product exposure to both verify participants' levels of prior experience and determine knowledge and understanding acquired during interaction.

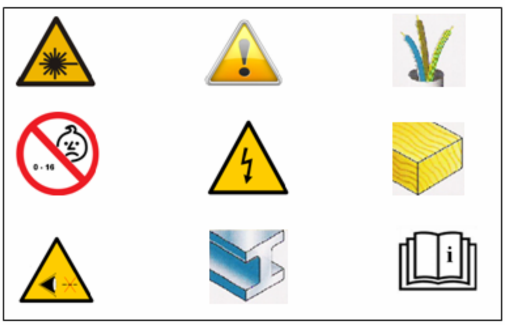

Fig. 2. Icon Assessment Sheet

Product Feature Assessment Sheet. This tool was developed to assess the quantity of product features each participant recognised, post exposure (Figure 3). Study of the video-data would allow assessment of feature recognition during initial exposure, and thus post exposure completion of the product feature assessment sheet allowed determination of features, usage and understanding development over the course of exposure.

Technological Familiarity Questionnaire. The Technological Familiarity Questionnaire (TFQ) was a modified version of that used in a previous study [18], which itself has origins within the work of Blackler [19]. The modified Technological Familiarity Questionnaire posed the same two questions: "How often do you use the following products?" and "When using the products, how many features of the product are you familiar with and do you use?" but detailed a larger range of both contemporary and less-contemporary products than before. Again, rating the answers provided produced an overall participant TFQ score.

Fig. 3. Product Feature Assessment Sheet

3.4 Data Analysis

The recorded video-data verified how the concurrent protocol corresponded to the users' actions, assessment of task completion times, and understanding of the products design and function before, during, and after product exposure. Interview material gleaned qualitative and quantitative data upon user perception of interaction to confirm overall level of product understanding, and how this influenced interaction. Other data recorded included: MOT and SSP scores, Warning Icon Recognition initial and subsequent scores, Product Feature Recognition initial and subsequent scores, overall two-stage TFQ scores, and the quantity of products recalled during interaction.

3.5 Hypotheses

Based on previous experimental findings, we propose the following three hypotheses:

- Knowledge is enhanced through interaction and increased exposure.
- There will be a correlation between age and technological familiarity/experience.
- There will be a correlation between age and performance.

4 Results

The methodology was successful in yielding useful qualitative and quantitative data and these are presented in tablature and graphical form below.

MOT assessment was completed quickest by the 26-59 age group, followed by the 16-25 and 60-80 age groups. Memory Span Length correlates uniformly with age with the 16-25 group recording 7 items, the 26-59 age group recording 6 and the older age group recording 5. Overall, understanding and recognition of warning icons increased over the course of exposure, and the number of products recalled, prompted by product exposure also correlated to age, with the older age group recalling the least, and the younger age group recording the most, number of products. Figure 4 indicates time taken to complete tasks 1 to 6 (1: Fit Battery, 2: Find Wooden Stud, 3: Find Metal Pipe, 4: Find Electric Cable, 5: Fit Hanging Tool, 6: Hang and operate level).

Table 1. Means per age group (n = 30)

Means per age group	16-25	26-59	60-80
Cantab MOT Completion time (s)	49.2	45.7	50.9
Cantab SSP Memory Span Length (number of items)	7	6	5
Warning Icon Recognition (pre-exposure)	4.6	5.5	4.1
Warning Icon Recognition (post-exposure)	8.4	8.3	6.2
Product Feature Recognition (pre-exposure)	8.7	10.8	6.4
Product Feature Recognition (post-exposure)	16.4	15.7	11.7
Prompted Product Recall	3.0	2.7	1.1

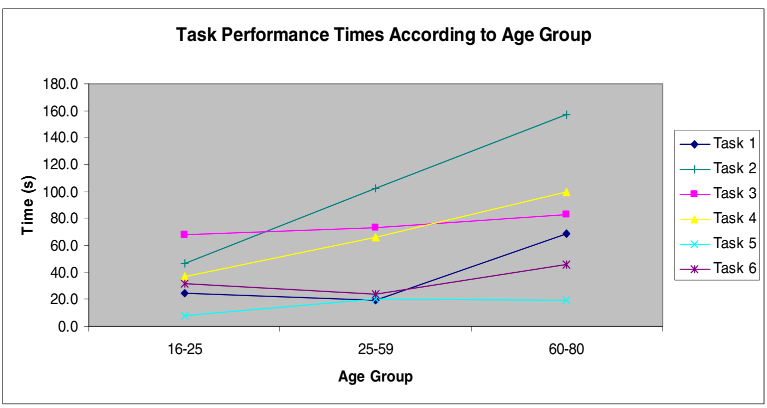

Fig. 4. Task Performance Times according to Age Group Membership

Statistically, a significant effect of Age on Task Performance can only be reported regarding Task 1 Performance [F(2, 27) = 5.418, p = 0.011] and Task 4 Performance [F(2, 27) = 6.251, p = 0.006]. However, for 4 out of 6 of the tasks, there was a significant correlation between Age and Task Performance:

Task 1; r = .552, n = 30, p = 0.02   Task 2; r = .425, n = 30, p = 0.019
Task 4; r = .503, n = 30, p = 0.05   Task 6; r = .458, n = 30, p = 0.011

The remaining tasks also showed correlations, although they were only marginally significant. The TFQ results represented below (Figure 5) indicate that differences are observable between groups, the 16-25 age group possessing the highest overall TFQ Scores and the older age group the lowest. The effect of Age on TFQ Score are also significant $F(2, 27) = 3.470$, $p = 0.046$].

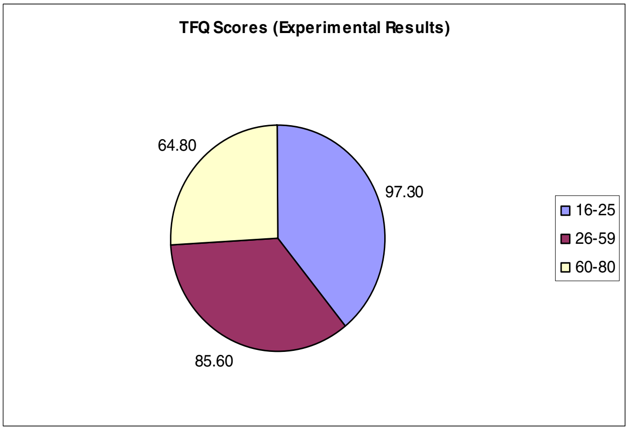

Fig. 5. Technological Familiarity Questionnaire Scores according to Age

5 Discussion

Regarding the means table (Table 1) the expected trend of the younger age group performing the quickest is not in evidence within the Cantabeclipse MOT results. In this instance, the middle age range (26-59) performed the quickest, with the younger age group closely followed by the 60-80 group. The older age groups performing the slowest of all groups does however, conform to literary expectation. Likewise, the Memory Span Length results also conform to expectation with the older age groups have the shortest span and the younger age group, the largest. In all instances, the results for waning icon recognition or accurate inference showed knowledge acquisition and increased understanding through product exposure. It was noted that all age groups were not fully aware from the beginning, or able to initially make completely accurate inferences regarding warning icon meaning and design. This in itself has significant ramifications for designers attempting to convey important (in this case potentially safety-critical) information to users.

A similar trend is observable regarding product feature awareness during the course of exposure, and this again, is considered evidence for knowledge acquisition and increased understanding regarding product functionality and intent. These are all elements that have inclusively contributed to the formulation of overall product concepts or mental models. Likewise, the number of recalled products varies uniformly with age – older participants recalling less than the other age groups, and the younger age group recalling the most. This is considered a factor of prior experience – younger individuals appearing more familiar and aware of a greater number of products whilst interacting with the novel device and this might be beneficial if not in learning to interact with a novel product, certainly in understanding more about its functionality. This is further supported by the TFQ data (Figure 5).

Task performance times are more varied and whilst trends can be seen according to task, it is not evident in all tasks. Battery fitment (Task 1) was completed most efficiently by the 26-59 age group, and not the 16-25 group as might be expected. Interacting successfully with the product and locating the wooden stud (Task 2) did conform to expectation with the younger age groups completing the task significantly quicker than older age groups. Locating the metal pipe is also inline with literary expectation (albeit to a lesser extent), as is Task 4 – locating the electric cable. The 16-25 age group took the least time to successfully secure the products 'hanging tool' and the 26-59 age group the least time to operate the laser level function.

5.1 Hypotheses Acceptance

Knowledge was enhanced through interaction and exposure, and the elements that contributed to this have been increases in iconic knowledge and awareness and appropriate inference in combination with increases in product feature recognition.

Hypothesis 1. Increases in age were correlated with decreases in amounts of knowledge acquired during product exposure/interaction; $r = -.443$, $n = 30$, $p = 0.14$ and the effect of age on differences in amounts of pre and post exposure knowledge or awareness of icon design was significant [$F(2, 27) = 3.425$, $p = 0.047$]. The mean number of increases in warning icon recognition/understanding over the course of exposure was 2.97 items. The overall average number of increases in features identified over the course of exposure was 5.97 items – although these differences were not significant.

Hypothesis 2. There is a correlation between age and technological familiarity/experience supported by the TFQ data. Increases in age were significantly correlated with decreases in TFQ score or experience; $r = -.446$, $n = 30$, $p = 0.013$.

Hypothesis 3. There is support for the hypothesis that there will be correlations between age and task performance, evidenced by the results presented; task performance correlated with age in 4 out of 6 instances, the remaining two still being marginally significant.

6 Conclusion

The data presented backs up participants' verbal reports of product understanding increasing over the course of product interaction. These product features and understanding of warning icons/images are elements that contribute to users mental models of product purpose and interaction. As in previous studies, it was clear that participants recognised consistent elements of the overall product concept, comprising of individual components, and outward aesthetic elements (figure 6).

Fig. 6. Individual Element Perception

6.1 Improving Usability through Inclusive Design

A number of design issues were voiced during the course of participant interaction. These included the LCD display timing out too quickly for individuals to fully comprehend the information available on screen, and it was felt this contributed toward participants finding it difficult to realise intuitively the functionality and purpose of the different modes in searching for wood and metal objects.

The requirement to continually press the detector button was demanding and fatiguing particularly for older people. The provision of visual and audible feedback was considered beneficial in highlighting object detection, but the audio frequency raised issues for older people with deteriorating hearing. More comprehensive and coherent icon understanding could have been facilitated with the use of clearer design upon the product and packaging, and it was thought this would yield greater accuracy and detail in product understanding and interaction. During battery fitment, a large amount of conscious attention was observable in the process of inserting the battery correctly. This could be intuitively improved by contrasting the colour of the battery insertion diagram molded within the battery compartment to its background. Although the diagram is embossed, it remains the same colour as its surrounding.

The design of the device and particularly its side-grips caused the LCD display to often be occluded by the users' hand. Equally, due to this issue, it would be easy to overlook the illumination of the LED that indicates the detection of an electrical cable. Ambiguity was also cited over the multi-functionality of the LED, as it illuminated both during calibration and when detecting a live electrical cable. Misinterpretation could lead to the misdiagnosis of a safety critical situation by the user, with the potential to result in electrocution.

The intention has been to understand how facilitating learning in interactional processes may be achieved. Not only can this have the net result of making products more usable and user-friendly, it can also make them more intuitive and accessible to a wider proportion of the population.

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Part III

Designing for Users Diversity

Disable Workstation Development: A Multicompetence Approach to Human Behaviour Analysis

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Abstract. The aim of this paper is to report the analysis process adopted by an interdisciplinary team to understand human-product physical interaction in order to develop a PC workstation to be used by physically impaired people for their professional reintegration. In previous experiences [1] simple biomechanical measurements and electromyographic analysis were used to evaluate the physical stress connected to different workplace situations. In the present context we have chosen to apply to occupational ergonomics both a biomechanical and ethnographic approach and then correlate them in an integrated approach. The idea of merging qualitative and quantitative methods has become increasingly appealing in areas of applied research. As Human Machine Interfaces (HMI) and ergonomics are multifaceted issues it is important to approach them from different perspectives and to combine data coming from different methods. Multicompetence approach integrates different research methods into a research strategy [2] increasing the quality of final results and providing a more comprehensive understanding of the analyzed phenomena..

Keywords: ethnography, biomechanics, user centered design, disabled worker.

1 Introduction

Ergonomic evaluation and physical disabled people's workplace development are very difficult issues because standard methods are not applicable: risk analysis is not reliable because tasks are often performed in an unusual way and functional anthropometrical data are difficult to retrieve.

Interesting studies [3] are in progress to develop specific virtual reality approaches for supporting the Design for All approach since occupational ergonomic analysis on virtual mock-up is today not possible due to the fact that the human models within existing applications do not include impaired persons.

Generally disabled workers reintegration is usually faced through ad hoc adaptation of workstation and work environment for each subject [4]. This approach allows to obtain high customized solutions that are very efficient but involve a great effort and cannot be applied on a large scale. For this reason we decided to focus our

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research on the development of a standardized adjustable solution as adaptable as possible to different users pathologies and office activities.

Learning from adaptation experiences and virtual reality approaches we based our research on participatory observation [5] and combined it with the development of a proprietary virtual model and its validation through laboratory test.

A participatory phase was planned to directly involve users in product development and evaluation [6].

2 Process Description

The methodological process consists in 3 main steps (Fig.1.).

a. At the beginning we performed ethnographic investigations on subjects affected by spinal cord lesion at different levels to detect their user habits [7] and self made solutions and strategies. Observations accompanied by contextual interview were carried out in the real user environment and involved paraplegic and quadriplegic subjects. Evaluating the collected data we also defined a test setting and a series of motor tasks to be investigated from the biomechanical point of view.

b. The biomechanical analysis was divided in a virtual study and a laboratory test. The first one was based on a biomechanical model which includes six degrees of freedom (dof) for the upper trunk, three dof for each shoulder, two dof for the elbows, two dof for the wrist was implemented in order to compute the joint moments required to perform the different tasks.

The second one comprehending real movement acquisition and evaluation was performed on healthy subjects in a first stage to define the strength associated to reaching objects in different positions in the extracorporeal space. A stereophotogrammetric system with eight infrared TVcameras was used to detect the movement of the upper limbs in relation to the trunk, and the movement of the trunk in relation to an absolute reference system fixed within the laboratory. Retro-reflective markers were attached to the head, shoulders (acromions), elbows, wrists, and metacarpal area and dorsal surface of the trunk.

c. The outputs regarding user behavior and movement strategies were used to define the first design proposals which are the basis for an active involvement of expert users in virtual and real prototypes development. [8].

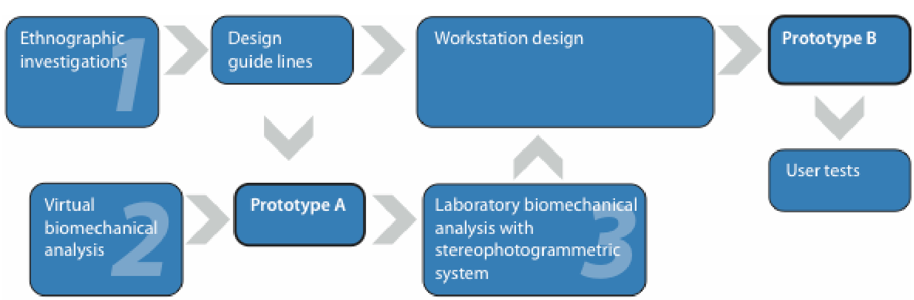

Fig. 1. General research process with 3 main steps and integration

The subsequent evolution of the project will include the tests to be performed with the involvement of disabled people and an inquiry about the level of acceptance of the proposed solutions.

3 Method

3.1 On-Site User Analysis and Target Group Definition

The ethnographic investigation has been structured in four steps: warm-up, general questions, static analysis of the work environment, user observation during their work activity. 16 workstations placed in home and office environment has been evaluated regarding qualitative issues.

The acquired data have been compared and the real situations have been grouped in 3 different categories:

- user with high spinal cord lesion, working with an assistant, without moving from their workstation, at home;
- user with middle-high spinal cord lesion, working without moving from their workstation, at home or in the office;
- user with middle-low spinal cord lesion, working moving from a workstation to another, in the office in team with colleagues or with patients.

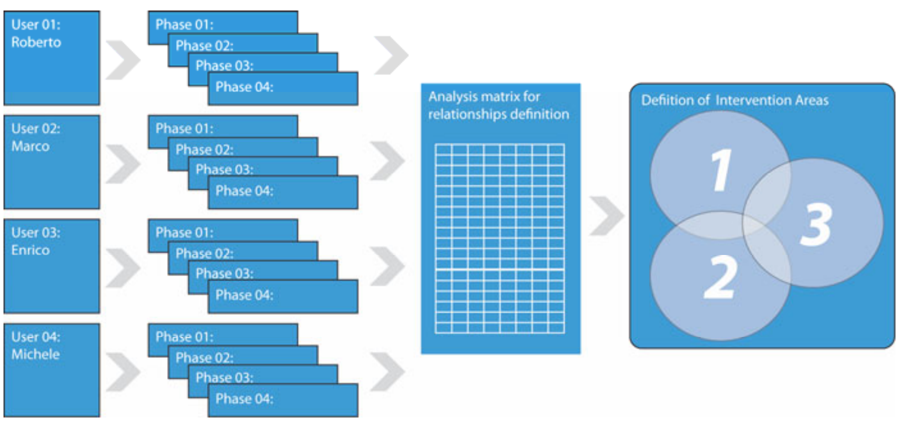

Fig. 2. Ethnographic investigation process (on the figure are represented only 4 users has example)

On field analysis revealed interesting differences between home and office workstations regarding for example self adaptation solutions, like the placement of the printer under the table at a 40cm high, which are more frequent in home workplaces. A careful study of those adaptations could suggest useful solutions to be transferred also in office environment.

A great number of object are dislocated in both situations on or around the workplaces including obvious and less obvious ones ranging from PC, paper, pencils to mobile phone, pictures and medicaments. A new workstation has to face the problem of organizing all this object according to user habits.

Table dimensions vary from 100cm to 300cm length, 70cm to 90cm depth, 67cm to 85cm high. Their configuration appears to be affected by working modalities: the desks are predominantly rectangular if interaction with colleagues or patient is needed and "L" formed in several cases were people work alone and place is available.

The three identified categories were evaluated and we choose the one regarding people with middle/high spinal cord lesion working alone at home or in office for further development since it is the more statistically frequent situation and it permits the development of a solution suitable also for tele-work.

The most important needs detected through on site user analysis regarding the selected category concern:

- avoiding the necessity to shift from wheelchair to operating chair;
- maintaining distances and adjustments in relation with the working area;
- increasing trunk mobility and stretching possibilities;
- increasing trunk balance and facilitating the achievement of an upright posture when it happens to lose it;
- reducing the falling of objects or facilitating their recovery;
- positioning of an easy to reach case for personal items;
- reaching all devices and commands;
- avoiding cable hindrance.

Deeper analysis of this users group and their needs has been performed through a questionnaire to the users and interviews to experts like occupational ergonomists and disabled worker's reintegration specialists.

3.2 Virtual Human Model and Workspace Definition

In order to identify the portion of the workplace space that can be reached with a certain level of muscular effort, a dynamical model was developed which allowed to quantify, by simulating several load conditions, the force necessary for completing the task. The model (Figure 3) is composed of a number of rigid bodies corresponding to head, trunk, pelvis and lower limbs, upper arm, forearm, and hand for both sides. The parameters like segments' length and mass, were obtained from anthropometric tables [9]. Location of centers of mass and moments of inertia derived directly from the geometry of the rigid bodies. The focus here was the upper limb movement, and so the following constrains were designed among the segments: three rotational axes at the shoulder representing adduction/abduction, flexion/extension, internal/external rotation, one rotational axis at the elbow, representing flexion/extension, one rotational axis at the wrist, representing pronation/supination of the hand. The trunk was fixed to the backrest of the wheelchair, and the pelvis to the seat. Both inclination of backrest and seat height can be adjusted to test different relative positions between subject and table. The table itself can be risen or lowered and rotated around a horizontal transversal axis to reproduce different slopes. Each point of the extracorporeal space can be reached by changing the angles of the different joints. A limit however was defined by the total limb length. Additional space can be added by changing the inclination of the trunk. For each position in space of the hand, the corresponding joint angles and joint moments are computed, so that the whole reachable space can be mapped.

In the example presented here, the right hand movement was analyzed (but the procedures here described are also valid for a left-hander) and a unimanual task

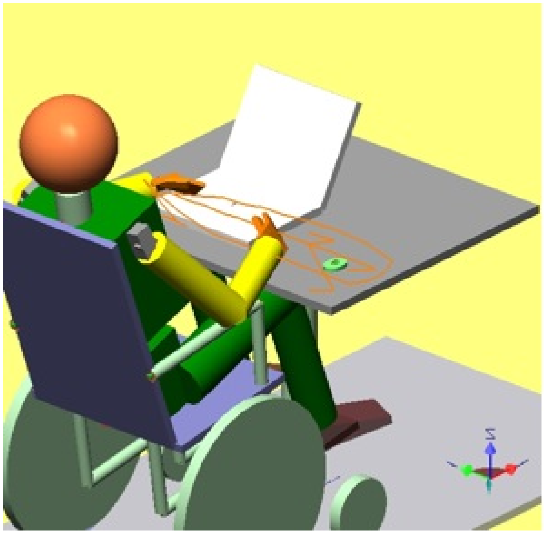

Fig. 3a. The anthropomorphic dynamic model represented in one specific position (see text). The track of the hand centre of mass during systematic analysis of the reaching is reported on the table by a orange line.

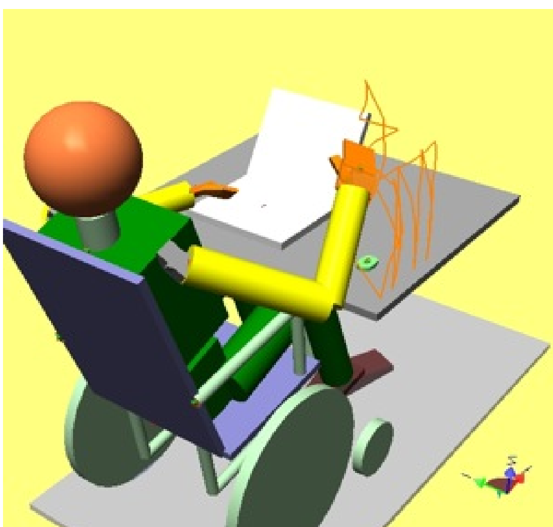

Fig. 3b. The same model while scanning the right-hand space on a vertical plane (see the hand track)

(i.e. without using the contralateral arm) was simulated in which the hand was positioned in different point of the deskwork plane. The seat height was 0.466 m (forward edge with respect to the ground); the table height was 0.7 m from the ground and the surface was horizontal. The backrest was inclined by 20° on rear, and the relative position between subject and table was such that the lower edge of the trunk (corresponding approximately to the extremity of the rib cage) was at 0.19 m from the edge of the table. A grid of points was defined on the table surface sufficiently close each other as to have a good spatial resolution, within the reaching-area border (namely the limits of the full area where an object can be placed that can be reached by only extending the arm, without moving the trunk).

Since the same point of the space could be reached in different manners, each representing a diverse combination of rotations about the different axis of the joints, a particular condition was imposed that was a fixed orientation of the hand palm in relation to the horizontal plane. The wrist angle also was kept at a fixed degree. In this way the hand, which originally had six degrees of freedom, is constrained so that only four degrees of freedom are active. These, in our choice, are the three shoulder rotations and the elbow rotation. The goal was thus to associate to each position of the hand, the joint angle and the joint moment obtained from the dynamical simulations, for each of the following movements: shoulder ab-/adduction, flexion/extension, internal/external rotation of arm, elbow flexion/extension.

The results are shown in Figure 4. Here the joint angles and moments associated to each position of the hand in the reachable plane are reported with reference to the

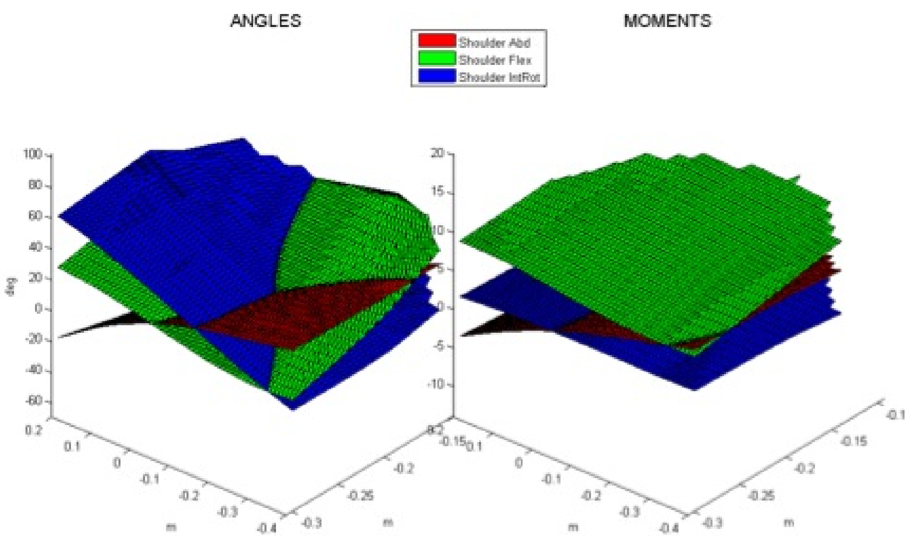

Fig. 4. Systematic analysis of the shoulder angles and moments associated to maintaining a given position of the hand on the work plane, supposed horizontal, 5 cm above the table surface. The three intersecting surfaces refer to shoulder flexion (green), abduction (red), internal rotation (blue). The point (-0.4, -0.35) corresponds to the right-rearmost corner of the table surface.

shoulder joint. They are represented by three surfaces corresponding respectively to the flexion/extension, abduction/adduction, internal/external rotation degrees of freedom. It appears that the whole positioning of the arm segments has a direct influence on the increase or decrease of any considered moment necessary for reaching a particular point in the space. If a particular joint moment or joint angle cannot be overcome because of limitations in the strength or mobility of the hypothetical subject, different portions of the original space could be identified, which can be reached by applying a moment contribution which is less than the maximum moment the subject can develop. A similar result was obtained for the angular rotations.

In this way, alterations due to pathology, which impose limitations in both the range of movement and the moments produced, may be considered in order to identify these parts of the space that can be easily reached than others and, consequently, in order to consider these limitations during the design process.

4 Discussion of Results

In previous researches [10] we faced some problems with the analysis of data acquired from natural users movements because of the excessive variability in behaviors that made inter-subject comparison very difficult. On the other hand a to strictly definition of movements risks to make them unnatural. In this experience we consequently decided to consider different conditions: the relative positions of wheelchair and table were changed as well as the location and orientation of different objects like: monitor of the computer, keyboards, mouses, joysticks, electrical plugs, electrical switches, other communication devices (switches activated by head, blow, eyes).

From methodological point of view, we found a positive conciliation to integrate ethnographic qualitative data and physical modeling movement quantitative data to support product development defining a proactive approach to ergonomics based on data related to physical interaction between the human and new or existing products.

The method was applied to disabled worker PC station analysis while its extension to the design phase and to other application fields is under development.

Further developments should also take into account the integration of functional supports needed by persons with spinal cord lesions who sometimes make use of assistive devices and functional electrical stimulation to perform basic functions [11].

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Making Visual Maps Accessible to the Blind

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Abstract. Visual maps deliver content in a simple and effective way. They can be useful for various purposes in areas such as street guidance, surrounding information, and education. However, sightless persons are unable to explore visual maps and risk being cut off from several multimedia Web applications. In this paper, starting from accessibility issues of map-based applications, we discuss possible interaction modalities and devices to use for truly achieving usage perspectives desired by blind people. New ways to interact with a mobile device (such as gestures or touch commands) and possible solutions for making a map truly effective are investigated. In order to better explain the issues and needs of blind users accessing visual maps, an example of an interaction is presented.

Keywords: Accessibility, blind, visual maps, mouse, touch screen.

1 Introduction

Today's Web is increasingly rich in multimedia and dynamic content. Anybody with a computer or a smart phone can produce content, access social networks or explore dynamic content. Visual maps are especially useful for traveling and locating places rapidly and effectively. Google Maps (http://maps.google.com/) is one of the most popular tools showing street maps, satellite and 3D images. It is often linked by organizations (hotels, museums, conference sites, shops, public offices, service providers, etc.) to offer their customers or visitors simple-to-use directions with the "Get directions" function for tracing routes (by car, bus, walking, or bike) between one's starting point and one or more destinations. Likewise, several online services such as booking websites (e.g., hotel reservations) use visual maps to locate the place or to explore its surroundings. Exploring maps could also be useful for blind children, as a tool for effectively studying geography as well as geometry.

Unfortunately, these visual-based contents do not fully benefit a blind person interacting with the computer via screen reader, voice synthesizer and keyboard, since the graphic part of the information is lost.

Map exploration has three main application fields: 1) for orientation and movement, 2) for exploration and localization of points of interest, and 3) for educational purposes. A previous study showed that tactile sense in a blind child develops links between neurons in the brain area that in a sighted person is dedicated to sight. This

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suggests that the function of touch may replace (in the sense of being equivalent, performing the same function) the perception acquired by experiencing sight [1].

The problem of delivering an equivalent description for any non-text content is one of the main guidelines of the WCAG 2.0 [2]. Satisfying this requirement ensures the same content or function will be delivered to individuals with reduced perception. The real issue is how to enable visually-impaired users to obtain the same information provided by a visual map. Indeed, it is important not only to provide alternative descriptions to the graphical elements, but also to find a solution aimed at putting the user in the same conditions as a sighted person. However, achieving this equivalence is a big challenge and new approaches are needed to enhance interaction and reduce the integration gap between normally- and differently-abled persons. Visual maps offer various opportunities. All modalities must be exploited to provide the same information and functionalities to visually-impaired users, and make maps accessible to and truly usable by all.

In this paper we discuss issues related to potential applications based on accessible maps as well as possible techniques and devices for achieving our goal. A common case is how to access maps via screen reader, or through assistive technologies on a mobile device. Particular consideration will be given to possible new ways to interact with a mobile device, such as gestures or touch commands. The discussion in this paper could be a valuable analysis for identifying user requirements for visual map accessibility. In addition, possible solutions for making a map really effective will be suggested. In order to better explain the issues and needs of blind users accessing visual maps, an example of interaction will be presented. Touch screens, advanced mobile devices or well-structured online maps can greatly increase opportunities for people with impaired vision.

2 Related Works

Most maps today have legal or technical restrictions on their use, preventing people from using them in creative, productive, or unexpected ways. The OpenStreetMap project was created to fulfill this requirement: it provides free geographic data such as street maps to anyone who wants them [3]. Related to this project, blind.accessiblemaps.org is trying to develop an alternative system that provides geographic data, also keeping in mind accessibility for blind persons. The project, still in a beta version, proposes the use of special tags of interest on visual maps, for visually impaired users (i.e.: "Traffic Signals with sound for walk").

Images are used everywhere for many purposes such as logos and branding, signage, adverts, photos and illustrations. Some images are designed to be purely aesthetically pleasing, many are designed to convey information of some type, but all are potentially interesting to individuals with sight loss. For these reasons it is important to make graphic information accessible for all. There are a few ways to make this graphical information accessible, and the most appropriate depend on the requirements of the individual or user group concerned. Image descriptions are intended to replace a given image by conveying the core message in descriptive text or audio. Large print images are intended to be used by sighted or partially sighted people, and can be as simple as very clear versions of the print original. Tactile graphics are images which are specially created to be touched rather than looked at. There are a number of ways to produce tactile graphics. However, converting a visual graphic to an appropriate tactile graphic is not simply a matter of taking a visual image and making some kind of "tactile photocopy". The tactile sense is considerably less sensitive than the visual sense, and touch works in a more serial manner than vision. Therefore the visual graphic needs to be re-designed to make sense in a tactile form for blind and partially sighted readers.

In the museum environment, tactile exploration of reproductions of famous paintings in three dimensions (bas reliefs made of special material) might be an alternative technique for conveying visual information to visually impaired people (e.g. http://www.cavazza.it/museoanteros/). This is an interesting approach but it is costly and difficult to scale. New solutions that are cheaper and easy to implement are still needed. A recent approach by Miao et al. uses tactile paper prototyping to bridge the visual and haptic modality while ensuring multimodality when a screen reader user accesses graphical user interfaces [4].

Tactile maps can support blind people's mobility but to enjoy full independence they need to generate tactile maps by themselves, to easily check their walking route anytime as needed. [5]. To improve the accessibility of geographic data, Zeng et al. developed an audio-haptic map browser to access GIS data through a large-scale Braille display. The haptic map system supports interactive multimodal interaction by combining audio and haptic feedback. Furthermore, gesture recognition of fingers establishes a natural interaction for navigation of tactile maps [6].

In 1985, in a short unpublished paper, Loomis [7] had proposed the idea of developing a system of digital maps as part of a navigation system for the visually impaired, with audio information indicating the user's position, possible interesting places and the best route to follow to reach them. Today many interests focus on multimodal devices with audio, visual and tactile output. In the context of haptic devices, the HyperBraille project (http://www.hyperbraille.de/) has been founded by the German Federal Ministry of Economics and Technology, with the aim of developing a touch-sensitive tablet display for blind and partially sighted users. Spindler et al. [8] proposed re-designing existing non-visual approaches and the development of appropriate haptic interaction techniques for tactile widgets. Specifically, they describe a complex user interaction with tactile widgets and how to adapt a screen explorer developed on the HyperBraille project to requirements of third party applications (such as plug-ins).

In the framework of the EU project HaptiMap, Magnusson et al. [9] carried out a study on how to make geospatial information more usable and accessible by the use of a haptic display in combination with audio feedback, suggesting a roadmap for dealing with these challenges (http://www.haptimap.org/). The HaptiMap project is aimed at making maps and location-based services more accessible by using several senses like touch, hearing and vision, with the goal of increasing the number of persons who are able to use mainstream map services. Within the same project, McGookin et al. [10] presented the initial design and development of Virtual Navigator, a 3D virtual haptic (used as a virtual white cane) and audio training simulator for route navigation, designed to improve the support provided by mobility trainers to blind and visually impaired cane users in the U.K.

Habel et al. [11] proposed a verbally assisting virtual-environment tactile map (VAVETaM) that utilizes a haptic force-feedback device. The generation of verbal instructions and descriptions are extracted from the user's tactile explorations of the virtual-environment tactile map. The goal of the VAVETaM project is to generate verbal assistance for virtual-environment tactile map exploration, both to communicate labeling information like street and building names and to assist the user's exploration.

To explore digital maps and display them in tactile way, Schmitz et al. [12] developed a system that uses a Braille display or a text-to-speech engine, and a standard rumble gamepad, used to take requests from the user and to give him tactile output. Sánchez [13] presented a set of applications studied for PocketPC devices to assist the navigation of blind users in a real environment; he developed the applications for four different contexts (neighborhood, bus transportation, Metro network and indoor environments such as schools), carrying out a usability evaluation for each of them.

Addressing blind or severely visually impaired travelers' needs, the Tactile Maps Automated Production (TMAP) project [14] combined existing tools such as the World Wide Web, geographic information systems, Braille embossers and touch tablet technology.

Marsto et al. [15] manipulated values of attributes in digital map files produced by TMAP (in the Scalable Vector Graphics - SVG - format) to have visual maps that can present these data in a format usable by people with varying degrees of visual impairment. Kulyukin et al. [16] presented an algorithm for placing street names on street maps produced by TMAP software; the algorithm takes as input the user preferences configured on a XML file and generates a SVG file.

Wagner [17] investigated the use of audio-tactile maps in an educational context with visually impaired users, and proposed the speech- and audio-enhanced tactile map as a possible solution. Wang et al. [18] proposed a solution to automatically convert visual digital maps into interactive tactile-audio maps. The result is a tactile map and an SVG file containing text and graphical information used with a touchpad.

Moreover, gesture interfaces were also investigated in association with handheld devices that offer touch screens. Brock et al. [19] investigated the use of multi-touch displays for multimodal interactive maps to use gestural interaction; they proposed a solution to improve accessibility of geographical information for blind users, with multimodal interactive maps obtained by placing a tactile map on a touch device. Paladugu et al. [20] proposed and evaluated a set of patterns with different shapes and textures, to use for adaptive map rendering via a legend; they suggested putting a start information button on the top right corner of the map to help blind users to find the route start/end points by touch.

Making geo-referenced information accessible using multimodal interfaces (e.g. audio and haptic), the project Atlas.txt [21] investigated how geo-referenced information (often conveyed via shaded thematic choropleth maps) can be communicated to blind users; the project developed a prototype data-to-text Natural Language Generation (NLG) system that produces textual summaries of UK 2001 Census data.

Concerning accessibility of touchscreens, McGookin et al. [22] carried out a study that illustrates accessibility problems on touchscreen use for visually impaired users, comparing two different methods for confronting this problem: to overlay a raised paper control panel that incorporated tactile buttons on the screen and to use a touchscreen gesture-based player. Some guidelines are provided to design more accessible interfaces for future touchscreens.

Crossan et al. [23] proposed a non-visual browsing mechanism where users can run their fingers over a touchscreen to feel a vibrotactile texture depending on the functionality of that area of the touchscreen, with the use of a vibration motor on the back of the mobile device. Lastly, not strictly addressed to visually impaired people, McGookin et al. [24] describe two interaction techniques to display off-screen points of interest in maps shown on mobile visual displays [25].

3 Discussion

As mentioned in the Introduction, maps can be used for various purposes, such as finding a target or exploring the surroundings, or for educational aims, such as understanding shapes and distances. Usually tactile maps are used to show and explain educational content such as geographic maps, geometric figures, schemes and so on. According to the desired aims, the maps could be designed and developed in different ways. In some cases a Web-based map accessed via screen reader could be enough, if alternative contents are provided. For other goals, a more specific map accessed via new user interaction might be more suitable (e.g., by using a touch screen).

3.1 Important Map Features

The main basic abilities required to a user when exploring a map are:

1. Recognition of map borders and pinpointing one's own position within or outside the map. Orientation on the map respects the cardinal points (N, S, E, W).

   This requires knowledge of the measurement system.
2. Identifying a point on the map (target). Identifying a destination. Identifying the path between source and destination.

   These functions can be carried out automatically using a search function that returns textual information. For instance, Google Maps provides a text box for search and getting directions; retrieved information appears in graphic form on the map as numbered drops (A, B, C) and related text info appears on the left side, to be explored visually or auditorily.
3. Exploration of additional related info, such as hotels, restaurants or other points of interest close to the destination.

Touching a map may advance user orientation and improve his/her experience. Smart phones and the latest models of laptops offer integrated touch screens that facilitate physical exploration of the maps. Our idea is to design a multimodal UI to make visual maps accessible to blind users, by both auditory and tactile means. However, the system must be designed to have little or no impact on sighted users, i.e. keeping the visual user interface unchanged.

Touch is the equivalent to exploration via mouse, so a mechanism is needed to activate the corresponding audio description (or clue) when a finger-press event is caught by the system. Furthermore, identification of the target should be driven by the system with relative measurements from the map borders. Encoding of gestures and touches are necessary to deliver different amounts of content according to user ability.

3.2 User Interaction

In order to achieve the abovementioned goals, a multimodal interaction should be considered when designing a Web-based map. When a developer plans a Web map, they should keep in mind the potential modalities by which a user will explore the map. Many studies have investigated in different contexts how gestures and audio channels can be used to make mobile devices more accessible ([26], [27]). Recently, applications by Apple [26] offer a high accessibility level by using touch and audio channel via the screen reader voice-over; thus, multi-approaches for interaction need to be investigated.

The main aspects to consider regarding user interaction can be summarized as follows:

– Textual content read by an assistive technology (i.e. via screen reader) or at least via voice synthesizer or audio labels.
– Audio icons and aural symbols to provide additional brief information. For example when exploring a map, short sounds could be used to inform the user about a specific category of an item (e.g. whether a touched point is a restaurant, hotel, or a city, etc.).
– Touch. To explore the map item by item or to perceive different areas, using tactile material and special pellicles can offer new multimodal modalities of interaction.
– Vibration feedback. Different kinds and intensities of vibration could be used to inform the user about a specific area, such as borders, mountains, etc.
– Gestures. To better explore and interact with a mobile device (e.g. to explore a map), gestures could represent a valuable way for the users to use.

To apply all those features, recent smart phones, tablets or large touch screens can all effectively achieve the desired results. Web-based maps should be designed and developed taking all these means into account.

3.3 Designing a Web-Based Map

In this section we consider some aspects of designing a Web-based map for various purposes. In the Introduction we mentioned that a map can be used for three kinds of applications:

1. Orientation and movement: usually this type of information is provided visually. To make this functionality accessible, the user is provided with an alternative description (e.g. in textual format). Additional information or elements could improve the overview of the map in order to give an idea of the path or map structure. This means, when providing alternative descriptions additional information that is usually perceived visually should be considered in order to add useful content (e.g. by adding short sounds, labels, general description of the map, etc.).
2. Exploration and location of points of interest: providing a way to explore the map point by point (by adding a sound and /or label for each point), by movements through gestures, and so on can provide new ways to explore a map. In this way

the user can obtain more information when "touching" a point. Specific materials such as special pellicles could make certain elements or details more accessible.
3. Educational purposes: especially useful for learning shapes, geographic maps, and geometric figures. Vibration and special pellicles could offer specific features to make certain parts more usable. Certain elements, such as borders, important items, and particular areas could be made accessible thanks to new materials and technologies.

4 A Web-Based Map: A Case Study

We present a case study to illustrate how a specific map-based function could be made accessible. A map is often used for exploring around one point as occurs when searching for a hotel. A booking hotel service very popular in Italy is http://www.venere.com (Fig. 1).

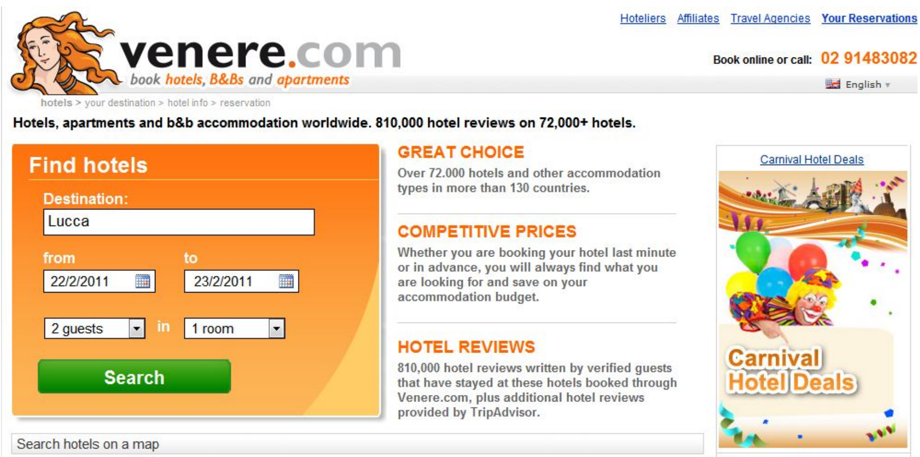

Fig. 1. Venere.com home page

Let us suppose that a person is interested in looking for a hotel in Lucca. After selecting the destination, dates, and room details the query is performed pressing the Search button. Results are available in different ways: on the map, sorted by city areas, budget, stars or accommodation types.

On the visual map, hotels are shown as "a house in a blue drop". Two functions are available when using the mouse (Fig. 3):

1. The "on mouse over" function reveals the name of the hotel pointed
2. A left mouse click activates a small frame showing the hotel's details: name (which is a link), stars, price and rating (hotel reviews). Clicking the hotel name the full details (photos, information, location) are shown to encourage the user's booking.

Those two functions can be very useful for quickly locating a hotel that is in the surroundings of a specific point (e.g. a conference venue, a railway station, a airport, a given hotel, etc.). Similar opportunities could be provided through alternative descriptions or textual formats, but they do not provide the same 'semantic' access. For instance, the system could provide a list of the nearby hotels with additional details such as distance, stars and others. That kind of information might not be as usable as exploring a map, since it requires additional effort.

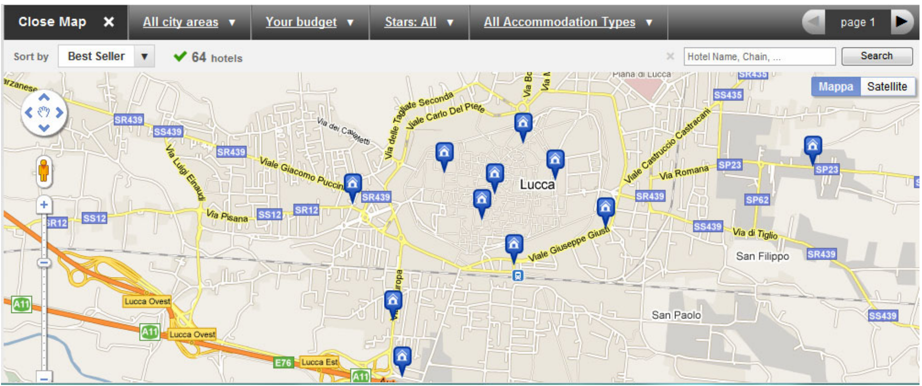

Fig. 2. Query results shown in the map format

Fig. 3. Results shown in the map format: on the left on mouse over, on the right the mouse click

For making these maps accessible for blind users, those functions should be available even without using a mouse. Touchscreens and other channels (auditory, vibrotactil or Braille) could be valid solutions.

For instance the “on mouse over” function might be mapped on a single touchscreen click (just one touch) and the mouse single click might be mapped on a double touchscreen clicks (or a double touch). Also, a longer touch might load the page with full hotel details.

In addition, short sounds and audio icons might be a way to rapidly communicate information such as hotel stars or reviews (guests evaluation). Thus, by a single touch the system could communicate the type of the point, i.e. a hotel with a certain number of stars (e.g. through different short sounds) and the name of the item via a label. Other solutions could also be offered by technology (e.g. vibration feedback).

5 Conclusions

We discuss possible strategies for making visual maps usable by blind users, exploiting new technologies such as touchscreens and vibration feedback. Maps can be used for various purposes and in different application areas.

In addition, visual maps are increasingly used in websites or for other online services. This field should be investigated by taking into account the potential opportunities offered by new technologies. In this sense, the discussion addressed in this paper could be a starting point for considering issues related to visual maps.

Touchscreens and new ways of providing feedback can create opportunities for interaction modalities for blind users. In the future, there will be increasing use of touchscreens, tablets and smartphones, and this research area should be investigated more thoroughly.

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Untapped Markets in Cloud Computing: Perspectives and Profiles of Individuals with Intellectual and Developmental Disabilities and Their Families

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Abstract. People with intellectual and developmental disabilities (I/DD) and their families represent an untapped market for the cloud computing industry. There is a great need to develop alternative cloud-based care supports as traditional methods of care become more difficult to obtain. Contrary to some perspectives, many people with I/DD are capable of using cloud computing technology; they and their families are a viable consumer market. Advances in civil rights and self-determination principles regarding people with I/DD have secured their acknowledged position as a natural constituency of society; however, too often they are left out of consideration of social design. Excluding the needs of people with I/DD in cloud computing consideration, design and structure may put them at risk for further marginalization in human society. This paper discusses the profile of the global I/DD population, self-determination principles, and family perspectives of technology.

Keywords: disabilities, intellectual, universal access, family perspectives, underserved populations, developmental disabilities.

1 Introduction

The population of people with intellectual and developmental disabilities (I/DD) and their families represent an important untapped market resource for the cloud computing industry. Families of individuals with I/DD are receptive to acquiring and using new technology-based support alternatives to improve their quality of life and self-determination outcomes for their loved ones [1]. There is a need to invest in technological personal support options for individuals with I/DD and their families that augment expensive traditional and human labor-intensive personal supports. Cloud computing represents one such alternative. Contrary to some perceptions, many individuals with I/DD are fully capable of using technology with training. Individuals with I/DD can provide critical insights into the needs of this particular consumer

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market. Without mindful attention to their inclusion into the design of cloud computing as the global communication network, there is a real risk that this population will not gain equitable access to the network, and as a result may become perpetual peripheral spectators to the rest of the world in the infrastructure ofweb-based social communications. Yet few cloud technology developers, people with I/DD, or their families are fully aware of cloud computing and its potential for providing much needed supports and connection to society

2 Population Definition and Demographics

Generally, people with intellectual and developmental disabilities are included in and are a subset of the broader population of "people with disabilities." They are also considered a subset of the population of people with "cognitive disabilities," which include disabilities stemming from brain injury, Alzheimer's Disease and other dementias, severe and persistent mental illness, and, in some cases, stroke [2]. In the United States, intellectual disability is defined as a disability characterized by significant limitations both in intellectual functioning (reasoning, learning, problem solving) and in adaptive behavior, which covers a range of everyday social and practical skills [3]. I/DD occurs in all ethnicities and social classes. Developmental disability is an umbrella term that includes intellectual disability but also includes physical disabilities which manifest themselves before the age of 22 years and are likely to continue indefinitely. It should be noted that in 2010, the former term of "mental retardation" was officially retired in the United States federal government, replaced with "intellectual disabilities" by Congress and signed into law by President Obama in response to advocacy efforts by self-advocates who found the former term offensive [4].

Across the globe, there are millions of individuals with intellectual and developmental disabilities. Estimating the number of people with I/DD that exist globally is challenging. Prevalence estimates of I/DD derived from epidemiological studies in developed nations range consistently from three to five per 1000 of the general population [5]. Published prevalence studies of I/DD in developing nations within the past decade report rates ranging from 5.3 to 20 per 1000 persons [6] with even higher levels in the poorest countries [7] due to effects related to higher levels of developmental risks that influence the rate of intellectual disability [8,9,10]. This information suggests that the full measure of disability lies beyond the current capabilities of structured statistical surveillance methods, and that the nuances of disability identity and identification are impossible to capture in a singular numerical index [11].

Fujiura et al., 2005 captures this point most eloquently:

"There is no single correct answer (to how many people there are with intellectual disabilities in the world) just as there is no singular best definition of disability. Rather we must accept the existence of multiple conventions, each more or less suited to a particular purpose. The lesson for intellectual disability is the importance of clarity in how we employ numbers in our policymaking and advocacy… However, numbers can also serve as a means to an end, used to elevate awareness of the relationship between societies and their citizens with intellectual disabilities. 'Simple' statistics hold the potential for galvanizing policy and advocacy in the developing nations of the world."

3 Disability Construct

It may be of interest to discuss briefly the construct of disability. Among prevalent disability theories include the medical model of disability, which locates the disablement within the individual; the moral model of disability, which asserts that disabilities are a result of moral failings and are therefore a punishment from divine sources; and the social model of disability, which asserts that disability is a socially-derived construct that occurs when the environment is not equipped to reduce or eliminate barriers to full social participation [12]. There is also the family model of disability, which holds that families connected to disability also have a disability identity that is unique and separate from families not connected to disability [13]. The social model of disability is the one most widely held among disability advocates; who acknowledge the presence of biological diversity within the body yet firmly assign responsibility to social, cultural, political, and environmental settings to provide an equal playing field for those with biological diversities or impairments. If society responds and eliminates social and environmental barriers to full participation for those with impairments, then disability ceases to exist; if it does not, then society has in effect constructed the disability. For individuals with intellectual and developmental disabilities, the social model resonates. They hold that their impairments do not deny their status as full members of society and that impairments can be mitigated by the proper supports, albeit taking on a different form that supports such as wheelchairs, guide dogs, or hearing aids. Supports may need to be in the form of a human being – or alternative innovative support - to help them negotiate intellectual territory, assist with decision-making, help with personal travel and manage daily personal decisions. Therefore, an individual's impairment only imperfectly defines disability status; the experience of disablement occurs within a social, cultural and political context, and those contexts can be vastly different within and across national borders [14] as well as across time and circumstance for individuals and families.

4 Profiles of Individuals with I/DD

There is no "norm" of typical profiles or personal supports needed by individuals with intellectual and developmental disabilities. In many cases, an individual may have functioning skills sets in one area of behavior, yet demonstrate a need for support in others. In other cases, significant needs exist in every area of adaptive behavior. Sometimes, training can help the individual to learn how to do things and they will retain that knowledge; in other cases, issues relating to memory, cognitive, or physical impairments may limit an individual's ability to accomplish a long-term mastery of a skill. Expressive and receptive language may be affected by I/DD, some individuals may be non-verbal and avoid making eye contact with others. Some individuals with I/DD are highly social; others may be more withdrawn. Individuals with I/DD may have speech impairments; many use sign language to communicate. Many learn how to read at an early age; others may take years to acquire reading skills, and still others read word icons. Some can make extraordinary calculations in an instant or may know in-depth histories and statistics of a topic such as a sports team, but have difficulty with remembering a name or how to tie shoes. Many people with I/DD appreciate and benefit from accessible language; that is to say, language that simply conveys concepts or messages, and information that can be provided at a slower speaking rate. People with I/DD often have vibrant personalities, friends, like sports or have hobbies, read books or play video games. Many can and do use cell telephones and computers as a natural part of their communication skills. Some individuals with I/DD are able to function independently without significant oversight; others have significant behavioral issues that are difficult for caregivers to manage in public and private spaces. These individuals often require the most intensive amount of personal care. Mobility impairments, visual and hearing impairments, manual dexterity, and chronic health issues may be experienced by some individuals with I/DD. Often, the individual may demonstrate different levels of skill mastery at different points along a continuum, including surges of progression and regression of acquired skills.

5 Systems of Support

Close to 90% of individuals with I/DD rely upon their families as the primary caregivers [15]. With longer life expectancies and growing governmental fiscal constraints, reliance on family caregivers for adults with disabilities will likely grow [16]. Families caring for adults with developmental disabilities have reported high unmet needs for respite services, case coordination, transportation, recreational services, and information regarding housing, financial plans, and guardianship [17,18]. Formal and informal supports to these families, including assistive technologies, can substantially affect their overall quality of life. Adults with disabilities who live in their own homes, apartments, or small group homes may contract to receive outside supports. The most prevalent service model for supporting consumers with disabilities is through a standard care model with the use of onsite support staff [19]. In addition to living with family or in ones' own home, the array of community living options for individuals with developmental disabilities includes congregate care, host family, and supported living [20].

Depending on social attitudes, family supports and services, and other resources for education, residential, employment, and aging care needs, people with I/DD may or may not live with their families. Many countries including the United States are still struggling with the concepts of self-determination and acknowledging that individuals with I/DD can and should have personal choice in where they live, who cares for them, where they work and what they do, and the myriad of personal choices made in course of a typical day. In developing countries, options are few. There are high frequencies of family abandonment which is sometimes forced, extreme poverty often leading to homelessness, abuse, institutionalization, poor health and high mortality rates, lack of education and employment options, and social disinterest in their welfare.

6 Self-determination Principles and Policy Frameworks

The principle of self-determination shifted the trajectory for individuals with intellectual and developmental disabilities from one of social exclusion and marginalization to one aimed for full participation in all aspects of society. This is an important construct to know for those unfamiliar with the civil rights perspectives that are gaining in popularity among this population and their families, as self-determination often drives the goals, objectives, and strategies for individuals with I/DD in their daily lives. From the earliest calls in the disability literature for self-determination [21] to today, the use of the construct has been contextualized within a disability rights and empowerment emphasis [22]. Wehmeyer defined self-determination as “the outcome that people with intellectual and developmental disabilities and other disabilities have opportunities to exert control in their lives and are provided supports than enable them to take advantage of such opportunities in ways that respect their values, beliefs, and customs and those of their family and culture [23].”

Self-determination as a social movement powers the need to design access to and provide options for cloud computing for people with I/DD. Cloud computing technologies and other assistive technologies provide people with I/DD with more choice and more opportunities to engage in and with their world in which they live. Shifting the environment and the choice options within that environment has a positive effect on self-determination outcomes [24].

6.1 United Nations Supports Full Inclusion of People with Disabilities

According to the United Nations [25], the equalization of opportunity concept, which emerged from the UN World Programme of Action, reframed the disability agenda from a medical or rehabilitative perspective to one of basic human rights. The Convention on the Rights of Persons with Disabilities and its Optional Protocol was adopted in 2006 and entered into force in 2008. The Convention marks a "paradigm shift" in attitudes and approaches to persons with disabilities. It confirms the abandonment of viewing persons with disabilities as "objects" of charity, medical treatment and social protection towards viewing persons with disabilities as "subjects" with rights, who are capable of claiming those rights and making decisions for their lives based on their free and informed consent as well as being active members of society. The Convention is intended as a human rights instrument with an explicit, social development dimension. It adopts a broad categorization of persons with disabilities and reaffirms that all persons with all types of disabilities must enjoy all human rights and fundamental freedoms. It clarifies and qualifies how all categories of rights apply to persons with disabilities and identifies areas where adaptations have to be made for persons with disabilities to effectively exercise their rights and areas where their rights have been violated, and where protection of rights must be reinforced.

7 Technology for People with I/DD

Many individuals with I/DD use assistive technology devices at some point in their lifetime. An assistive technology device is defined as "any item, piece of equipment, or product system, whether acquired commercially, modified or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities"[26].

It is through the lens of assistive technology that the intersection between cloud computing and people with intellectual and developmental disabilities may be viewed as aligned yet unlooked for allies. While many in the disability field tend to think of technology for people with I/DD as devices, such as augmentative and alternative communication or a switch to control the environment [27], product engineering is evolving from stand-alone devices and applications to distributed, connected, integrated, and multi-technology systems [28, 29, 30]. State-of-the-art technological advances in computer science, engineering, communications, rehabilitative science, and microelectronics have rarely been adapted for people with cognitive disabilities, although this population may derive deep benefit from responsive design. Braddock et al. surmised several areas of technology that has significant potential for both the technology industry and the population of those with cognitive disabilities [31], and which may also have potential implications on the developing cloud computing technologies. They are within personal support areas, including personal digital assistants, computer assisted learning and communication, universal design, assisted care systems technology, Smart Houses, smart transportation and tracking, personal robots, and virtual technologies. These kinds of technologies – and those that perhaps have not yet been created - have enormous potential to help those with I/DD and other cognitive disabilities to achieve greater independence, productivity, and quality of life [32].

8 Family Perspectives

The Arc of the United States launched a national data collection effort in 2010 to identify issues of strength and concern among adult individuals with I/DD and their family or professional caregivers, called The Family and Individual Needs for Disability Supports (FINDS) Survey. Areas covered in the on-line survey included education, home and living, college, work, transportation, health, emergency preparedness, social, technology, support needs, and caregiver needs. Limitations of these results include that data was generated by an on-line survey that required participants in the United States to speak English and have access to an internet-connected computer. This effort was not successful in engaging a representative sample of those from other minorities, ethnicities, or other countries, and may not have engaged those living at or near poverty or in rural environments where internet was not available. The design of this data collection effort may also have limited participation by respondents who do not use a computer.

9 Results

There were 5,845 individuals that responded to the survey from every State in the United States, plus the District of Columbia and Puerto Rico, with approximately 90% identifying as caregivers. Of the caregivers, slightly more than 70% lived in a household with three to five members; of those that answered, 29% reported a family income before taxes in 2009 of between $60,000 and $99,000 with another 23% reported family incomes of between $100,000 and $200,000. Sixty percent of the respondents reported having four year college degrees or graduate degrees. Almost 90% of the caregiver respondents reported being White. Out of 3,391 respondents, 52% stated that they wished to receive more information about new technologies that could make their lives easier. We present highlights of early data findings (see Table 1) from the caregiver perspective specific to the area of assistive technology, which includes technologies that support cloud applications. Data was stratified according to disability identity: intellectual disability (I/DD), Autism Spectrum Disorder (ASD), and Other developmental disabilities (Other.)

10 Discussion

The data suggests that 76% of caregiver respondents reports that their family members with I/DD, autism, or other developmental disabilities either use or need to use technology or assistive devices. In this sample, roughly one out of two individuals with

Table 1. Questions for Parents/Caregivers about technology and assistive devices

Table 1: Questions for Parents/Caregivers about technology and assistive devices						
		Disability Type				
Technology & Assistive Device Needs	%	IDD	ASD	Other	F/X2	Sig.
Special equipment, technology or other assistive devices needed by not currently available	3753					
Yes, our family member with I/DD uses AT	29%	32%	37%	49%	20.00	***
No, our family member with I/DD does not use AT	53%	68%	63%	51%		
I use this now:	1872					
Smart home technology	3%	3%	2%	2%	0.40	
Portable GPS guides	4%	3%	6%	3%	3.14	*
Cell phone	47%	45%	52%	39%	5.73	**
Video communications	6%	5%	7%	4%	1.15	
Wheelchair, cart, scooter	28%	27%	5%	61%	147.72	***
Home modifications for accessibility	14%	13%	3%	30%	55.84	***
Computer/software	32%	30%	40%	28%	8.42	***
Picture communication software (reading and writing for non-readers)	11%	11%	15%	7%	5.62	*
Audio books	11%	11%	9%	13%	1.38	
Communication board device	13%	11%	17%	15%	6.24	**
Exercise equipment	16%	17%	14%	14%	1.02	
I need this but don't have it now:	1755					
Smart home technology	33%	31%	33%	37%	2.01	
Portable GPS guides	19%	17%	27%	12%	14.80	***
Cell phone	16%	15%	18%	16%	1.09	
Video communications	15%	14%	17%	14%	0.96	
Home modifications for accessibility	21%	22%	8%	40%	55.29	***
Computer/software	40%	39%	45%	34%	4.34	*
Picture communication software (reading and writing for non-readers)	35%	38%	37%	24%	10.39	***
Audio books	27%	28%	27%	26%	0.14	
Communication board device	25%	26%	27%	18%	5.09	**
Vision assistance	9%	10%	4%	11%	6.80	**
Exercise equipment	38%	37%	39%	43%	1.82	
If at least one item was checked, non-responses were coded as unchecked.						
Significance *** p < .001, ** p < .01, * p < .05						
# - No variance within groups						

I/DD, ASD, or other developmental disability use a cell phone, and one out of three report using computers, suggesting that many in this population are already connected to cloud platforms. The results also suggest that families connected to I/DD that are not currently using technology are receptive to acquiring and using technologies. The findings indicate that families are interested in knowing more about innovative technologies that could have a positive effect on the personal support needs of their family members with I/DD. Families report that they need but don't have technologies in the areas of smart home technology, portable GPS guides, computers/software, picture communications for non readers, audio books, communication board devices, and exercise equipment. In the category of smart home technology, there is a wide gap between current use of the technology by individuals with I/DD (3%) and the reported need for the technology (33%). This gap in use and desired used needs further exploration to determine why smart home technology is not being used with high frequencies by individuals with intellectual and developmental disabilities. There is also an indication that families are concerned with health and physical activity supports for their family members with I/DD as almost 40% reported a need for exercise equipment. These numbers reflect an untapped consumer market for technology developers, including those in cloud development. In terms of difference found between disability groups in both current and desired use, the results indicate that there were significant differences found among the disability groups of those with I/DD, those with ASD, and other developmental disabilities. Overall, those caregivers connected to individuals with ASD reported the highest frequency of use of assistive technologies as well as the highest rates of need for assistive technologies, but families in all categories. While more research is needed to fully understand this phenomenon, this data suggests that families connected to individuals with ASD are more likely to have provided their family members with assistive technology, and are more likely to have identified a need for additional assistive technology.

11 Conclusion

In conclusion, this brief discussion has presented an overview of the profiles of individuals with intellectual and developmental disabilities and their needs as a potential consumer market for the cloud computing industry. The data presents a clear opportunity for those in the technology industry to consider the unique though not insurmountable needs of this population, and lead efforts to include them in cloud solutions. However, the issue has much larger implications; indeed, there is a much greater human rights issue at stake. These opportunities may well represent the last unchaining of social restrictions for people with I/DD if solutions are developed deliberately to bring them into the mainstream of society and alleviate restrictive environmental barriers. Without the deliberate engagement of people with I/DD and their families by the cloud computer technology industry, without infusing their needs in the development and use of cloud technology and designing effective solutions, and without an industry-wide assumption that people with I/DD must be, should be considered as a key consumer audience from development to market, there is a potentially tragic outcome. This outcome could foster the creation of a permanent, insurmountable chasm between people with I/DD and the rest of the cloud-connected society, erasing many gains made in civil rights and self-determination arenas that have advanced if not secured their rightful place as valued members of society. By not including them, the effect will diminish the right of individuals with developmental disabilities to live independently, to exert control and choice over their own lives, and to fully participate in and contribute to their communities through full integration and inclusion in the economic, political, social, cultural, and educational mainstream of a global society. There is a sense of urgency for the cloud computing industry to recognize this audience, their potential as consumers in the market, or have a sense of urgency to engage people with intellectual and developmental disabilities in developing needed technologies. There is great risk before us. Presume competence.

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Patient-Centered Design: Interface Personalization for Individuals with Brain Injury

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Abstract: This paper explores patient-centered design (PCD) as a methodology for personalization of software used in rehabilitation of cognitive disabilities. This methodology serves scenarios where clinical priorities, expertise, and services can be factored into socio-technical software design decisions and clinicians explicitly included in the process. The clinical context anticipates the patient's progress toward at least partial recovery and justifies clinical services. PCD builds on and integrates user-centered design (UCD) and participatory design (PD). Case studies come from work in traumatic brain injury rehabilitation.

Keywords: user interface, user-centered design, participatory design, patient-centered design, cognitive disabilities, cognitive assistive technology, assistive technology.

1 Introduction

Patient-centered design (PCD) is a methodology for personalizing software used to help individuals with cognitive disabilities. There is evidence that, for individuals with traumatic brain injury (TBI), specially designed computer software can partially restore cognitive abilities [10,11,12,25,case study 2 below], as well as serve as cognitive assistive technology (CAT). This methodology serves scenarios where clinical priorities, expertise, and services can be explicitly factored into socio-technical software design decisions. PCD places the user in a clinical context, with its focus on the individual, nuances of the condition, and prospects for treatment and recovery. PCD builds on and integrates user-centered design (UCD) and participatory design (PD). PCD is significant in that it can focus attention on clinical goals in addressing application functionality while achieving significant gains in both cognitive abilities and cognitive functioning. PD is a key element because of the key role of the user interface (UI) coupled with the user's ability to fine-tune the UI. Studies of individuals with TBI show the UI to be particularly sensitive, with small changes having a disproportionate impact on UI performance, suggesting that the UI is the principal design issue [cf. 10]. Furthermore, users, even those with profound cognitive disabilities, can guide UI design to produce highly efficient interfaces for their software. This methodology also promotes user engagement, which can have substantial clinical impact. This methodology comes out of our work with CAT and with therapists'

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treatment tools known as computer-based cognitive prosthetics (CBCP) and telerehabilitation delivery system [10].

1.2 Background

This line of research began as the design of CAT for individuals with cognitive disabilities arising from TBI. These individuals had completed cognitive rehabilitation, were dependent on caregivers, and evoked no medical expectation of a gain in cognitive abilities. There are an estimated 3.1 million people in the United States with cognitive disabilities from TBI [3]. The CDC reports that 1.7 million TBIs (including concussions) per year receive some attention, with 275,000 hospitalizations [9]. TBI cognitive rehabilitation typically has poor outcomes [4]. CAT can increase cognitive functioning by addressing an individual's actual activities in the setting where they are performed. CAT uses a computer placed in the individual's home for frequent use in performing everyday activities. The ability to highly customize software led therapists to try to treat patients with these techniques.

Personal productivity tools [13] have long been known to increase the cognitive productivity of individual users, particularly knowledge workers. These tools work at the level of subtasks and activities, which are contextual artifacts of cognitive functioning, not of cognitive dimensions themselves. In the 1980s, in pioneering what would become CAT, our research questions were: Can this software have similar results with an individual who has suffered a decrease in cognitive functioning, such as from TBI? Can software be designed that will partially restore that individual's level of cognitive productivity? Could assistive technology (AT), which increases personal productivity and level of functioning without expectation of providing a cure, be designed for individuals with cognitive disabilities?

TBI cognitive rehabilitation is an attractive vehicle for approaching these questions. Within TBI cognitive rehab, functional rehabilitation can focus on helping the individual perform everyday activities [25], providing a direct fit with personal productivity software tools. Also, the WHO definition of disability is the inability to perform everyday *activities*, due to pathology and other factors [22].

TBI produces diffuse damage across the brain, which leaves each individual with a unique pattern of damage across cognitive dimensions. Individuals who share a diagnosis have very different presentations of injury – activity tasks and subtasks that are affected – especially at finer granularity. These individuals are a heterogeneous population with unique disabilities from a shared diagnosis [4,25].

Diagnosing a TBI is done at a coarse level of granularity [4,25]. The basic question is whether there is evidence of brain injury pathology, along with suggestions of which *global* areas of cognitive functioning may be affected. Cognitive rehabilitation is largely an outpatient service, with patients coming to the clinic to see therapists at the clinic. Therapy activities themselves are based on generic everyday activities. Unfortunately, TBI patients typically have difficulty applying abstract lessons from exemplar activities (e.g., baking brownies to learn planning and organization) to their own activities; they do much better with the concrete situations of their everyday life. Seeing a patient in the clinic makes it extremely difficult for therapists to use the patient's actual activities as the context of therapy.

Rehabilitation tools have continued to be based on manual tools like 3-ring binders, Post-its, generic flashcards, and forms. While computers are widely available in rehab clinics, computer software is rarely designed to be a therapist's tool. Computation appears ideally suited to addressing the cognitively disabled individual's everyday activities, and supporting Functional Rehabilitation. As CAT, computation lets the patient deal with concrete instances of activities. Its applications can be highly customized to each individual's needs. TBI presents an opportunity and challenge for a computational approach to support rehabilitation. The opportunity arises from decades of experience in supporting cognitive activities of users. The challenge is that the cognitive deficits that produce disabilities in everyday activities can also impair the ability to use computer software. Also, a software solution must not be so burdensome as to require substantial therapy time.

An early model of interface performance may be helpful in understanding the challenge presented by disability, adapted from Card, Moran, and Newell [7]. See figure 1. There are 3 clusters of independent variables: (1) user characteristics, which include cognitive functioning and disabilities, (2) task characteristics, and (3) system characteristics, which include UI design and functionality. These clusters then predict (1) state-to-state transition time, (2) work time per unit, (3) length of productive working time, (4) number of errors, (5) ease of error recovery, (6) training time per feature, and (7) training information remembered.

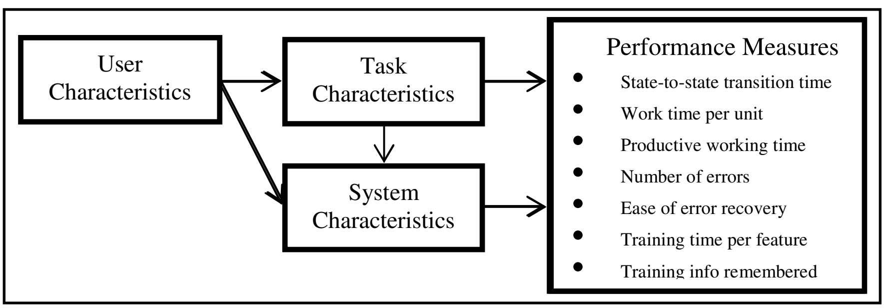

Fig. 1. Performance measures and predictor variables used in evaluating interface designs

Performance is a function of user, system, and task characteristics. Systems are designed for people with a certain level of assumed abilities. If the individual's characteristics are lower (U↓) and performance levels are to be maintained, then the system design needs to fit the user better (S↑), e.g., through a better-fitting UI. This means that for individuals with U↓, a higher quality UI is required and more emphasis needs to be placed on UI design. As we will see below, for individuals with cognitive disabilities, i.e., U↓, the UI is extremely sensitive to even small changes in UI design. In the case of an individual with a unique set of deficits and abilities, a better-fit system design requires personalization. The task component suggests that different tasks may require different designs for functionality or interface or both. The model doesn't provide guidance on *how* to achieve a better fit, but the model does provide a means of *evaluating* an interface design and comparing designs.

2 The Patient-Centered Design Model in the Brain Injury Context

PCD derives from our work on TBI rehabilitation treatment of cognitive disabilities where one-of-a-kind software systems have provided substantial independence to the individual [see 10]. PCD incorporates some features of UCD and of PD and also addresses clinical issues. In PCD, the focus is on the individual patient, on rehabilitation treatment plan objectives, on the skills of the therapist in treating the patient, and on using the patient's abilities.

There are 3 types of actors who participate in PCD: clinicians, individuals with cognitive disabilities, and software designers. In our implementation of PCD, clinicians apply functional rehabilitation, which uses everyday activities as the context of therapy. Patients are treated in their homes via computer workstations with a TBI telerehab delivery system combining CBCP software and videoconferencing.

The first step in the design process involves UCD in the selection of patient priority activities, which become the context for cognitive rehabilitation therapy. These are activities that have required caregiver support since the injury. A therapist elicits a set of priority activities and upcoming events from the patient. The clinician evaluates the activities for their therapeutic appropriateness, including their relationship to upcoming events, and selects one for the initial intervention. A criterion for the initial intervention is that the patient be able to achieve success within a week or 2, unusually fast for rehabilitation. The Initial Intervention centers on a particular concrete activity that can be well specified, and simplified, in contrast to a generic activity that involves many contingencies. UCD uses patient participation and engagement in therapy sessions and in the setting of target activities as major motivators and elements of rehabilitation.

Both UCD and PD involve observation of the present system to establish user requirements. This is done in the user's setting because few users can communicate with the necessary accuracy and level of detail. In addition, the analyst will notice artifacts that provide useful information. In the case of PCD, observing the current system helps identify tasks and subtasks that the individual cannot – and *can* – perform, giving clinicians an inventory of contextualized abilities. When a computer is used to help perform an activity, the analyst will observe the individual's use of the software and identify failures. From this data will come user requirements, consisting of required functional features and insights into interface design. The individual generally feels successful when able to perform subtasks, and for that reason, PCD excludes those subtasks from the user requirements.

There is a 2-pronged strategy for collapsing the time needed to train the patient in use of the software. The first strategy is to strip down functionality to what is needed this therapy session only and was inspired by Carroll's training wheels concept [8]; Leung et al. [16] use multilayer interfaces to reduce learning time. Fewer features mean (1) fewer commands necessary and (2) reduced application and interface complexity. Also, with unnecessary functionality removed, the individual is freed from learning how to use features that will not be needed until later. The second strategy is to make the interface intuitive to that individual user, by using PD to allow the user to design the interface, especially the details. In this strategy, the user's mental model is factored into the UI, making it intuitive to that individual.

Usability testing is a key component of PCD and comes from PD. Our studies – and clinical work – have shown that the UI is the key design component of the application. Small changes in a UI, seemingly innocuous, can make the difference between what can be successfully used and what cannot.

Usability testing procedures are modified for the individual cognitively impaired user rather than a panel of users [10]. There is a structured testing session to obtain quantitative data and then an unstructured testing session, which provides the most valuable information. Here the user can make design suggestions at both a gross and fine level of detail. The individual shapes the UI to overcome specific cognitive disabilities. The need to refine the UI was found across the range of deficits, from profound to high-functioning, and frankly was surprising. What was equally surprising was the ability of *profoundly* impaired individuals to make key suggestions for the design of their UI [11]. They seem to have excelled at fine-tuning the UI. The resulting designs exceeded the capabilities of highly trained designers. As one observes a patient making suggestions for the UI, it is not always clear exactly what the patient is optimizing, and the patient may not be able to articulate it. What is clear is that something is being optimized. Results of the usability testing are cycled into the next iteration, which undergoes usability testing again.

This process greatly increases the design effort in the UI. The *rationale* for this effort is the degree of users' cognitive impairment, typically several standard deviations from the mean of several cognitive dimensions ordinarily involved in UI use. The *justification* for the effort rests in the outcome of the intervention.

Roll-out involves installing the system in the patient's home, on the patient's desk. The therapist and the patient (and perhaps a family member) will have selected a clinically appropriate place in the home for the patient's desk and workstation.

After the patient begins using the application, it is likely that some additional changes will be necessary or desirable. Although the software underwent usability testing, the testing was not performed under real operational and workflow conditions.

PCD requires enhancements. CBCPs have stripped-down functionality. The patient, realizing that additional features could be valuable, asks the therapist to have the features added. The CBCP software suite offers extensive functionality, so in all likelihood the functionality for any given feature merely needs to be activated, although case study 2 below involves new applications. However, the feature's interface must be designed. The patient and therapist develop the UI for the feature, and how it fits into the existing interface, perhaps in consultation with a UI designer.

2.1 Case Study 1: Essence of Text Editor

The patient was high functioning, competitively employed, and looking for another job. He continued to have deficits in memory, attention, concentration, reasoning, and problem solving; cognitive rigidity; and reduced frustration tolerance that sometimes led to outbursts. He also had handwriting problems. He was trying to write a short cover letter for his resume in response to a help wanted ad. He would write out a draft and start editing it, and the paper would tear as he tried to erase a word; an outburst would ensue. College-educated, he had been a professional in a government agency before his accident, and he knew how to touch-type.

User requirement. The immediate task was to compose, edit, and print a single cover letter. The functionality needed was default font and line spacing, and a print command. The user needed to be able to insert and delete words, both of which would rely on cursor control. Inserting words could be accomplished by keeping the keyboard in insert mode. Deleting words could be accomplished by backspacing.

User interface design. Because of the user's cognitive rigidity, a decision was made to mimic typewriter mode: Courier font, 12 point, single space. It was also proposed to implement the print command ("Print this page") with a color-coded function key. The print command would give feedback to the user in a text box that would appear on the screen. The user would design the function-key print command and the confirmation text box in the unstructured phase of usability testing. The results of the design session would be added to the application and undergo another cycle of usability testing.

Results. User training took about 10 minutes and mainly involved use of the cursor. This intervention succeeded in the first hour of use. The therapist worked with the patient in creating and revising the letter. The patient was able to make inserts and deletions as he wanted, and he was able to print the product. He kept a hard copy of the letter for his files. He went on to write additional letters, using the previous letter as a template and printing out hard copies. Shortly afterward, he asked to have a multiple-document text editor; save and retrieve features and interface were added.

This application served clinically important goals and was a major success despite its limited functionality. It served the patient's initial and important goal and is thus an excellent example of PCD. Note that the patient solved the problem of how to write additional letters by deleting and inserting. From a software design perspective this approach would be considered inadequate by most standards, but as a therapy tool for that patient, it was exactly what was needed.

This application also made the patient active in the rehabilitation process. It addressed what he saw as a priority activity, he helped to design the UI, and he made requests for added functionality. His comments revealed pride and ownership in the application and system. That application served as a gateway to other applications and increased the individual's self-sufficiency.

2.2 Case Study 2: Patient and Therapist Contributions to Design

This case study focuses on several aspects of patient involvement in design and novel use of software. This case study is also important for its outcome, which was considered extraordinary by the rehabilitation professionals who had treated the patient in the rehabilitation hospital.

This college senior suffered a traumatic brain injury when struck by an automobile. Serious medical complications further reduced her cognitive abilities. She had cognitive rehabilitation as an inpatient and outpatient. It was expected that she would need daily caregiver support, and work in a sheltered workshop was anticipated. Return to college seemed impossible despite her supportive family.

Early on, the patient needed scheduling software to remind her of daily activities, but she tended to forget an event even if she had looked at the calendar earlier and had a reminder displayed on the monitor. Therapist and patient asked if a reminder could be sent to her. This involved a major modification of the scheduling application, including a store-and-forward message system because none was available from pager carriers.

User requirement. The initial user requirement was to have a feature added to each calendar entry whereby a message composed by the patient would be transmitted at a specific time to an alphanumeric pager that she would carry. In discussions with the patient, it was decided that the messaging would be part of the appointment-scheduling form. A widget would activate several fields for the message, including the text of the message and the time for delivering the message.

User interface design. Operationalizing the notification time involved several options, including a specific time and a time offset (minutes before the event) from the appointment time; the patient chose the offset time. The UI testing let the patient specify the field labels and field placement; she chose a check-box to activate the function.

Several alphanumeric pagers were obtained for testing.

Results. The patient quickly became proficient in clicking the check-box and in composing the message with considerable care, often editing it several times. Unfortunately, the approach failed for 2 main reasons. First, the paging service was not sufficiently reliable, and messages could take minutes to an hour for transmission. More important, the pager was multimodal with soft keys, which meant that the function of a specific key changed depending on the active mode of the device at the time. None of the pagers would allow modification of the user interface. The patient had difficulty reading multipage messages and also had difficulty finding the message list. Basically, the interface failed because of both the number of errors and the inability of the user to recover from the error condition.

User requirement – redesign. The message-sending concept seemed sound, but the equipment was clearly inadequate. Cell phones could provide an immediate connection and so seemed more promising. A cell phone message could be transmitted either as text-to-speech or as a sound file recorded in the patient's voice. The patient found the idea of sending herself a reminder in her own voice very attractive and engaging.

None of the communication carriers had a store-and-forward audio file capability. Fortunately, our application designed for pagers could be easily adapted for delivering sound files via cell phone. An added feature would be recording the message composed in the text box. In design/testing sessions, the functionality would involve recording, reviewing, rerecording, and saving the audio file.

User interface design. The UI was dual: the user's interaction with the on-screen form and with the cell phone. The user phrased the labels for commands. On testing, we were able to incorporate the commands easily. She was also able to record, revise, and save the sound files. However, the sound files often had a pause at the beginning and end of the recording, which the user disliked. Rather than placing the burden on the user to coordinate speaking and recording, it was decided to automatically edit the recording, removing the silences at the beginning and end of the file. The patient approved of this solution. As for the cell phone component, the patient decided that it was satisfactory to answer the phone and press a key to begin playing the recording.

Results. Use of the cell phone feature allowed the patient to remind herself, rather than having a family member remind her, with 2 important results. First, the family could see that she no longer needed their reminders. Second, the patient appreciated hearing the reminder in her own voice.

Epilogue. The cognitive rehabilitation therapy provided with this technology increased both the patient's cognitive abilities and her level of cognitive functioning with the supportive technology. It was decided that a return to college was a reasonable goal to attempt but would require passing several academic-achievement exams. The therapist and patient proposed a multimodal concept-learning application that would combine tactile, visual, and audio components. The application was built, and refined both before and after rollout. It proved successful in helping her relearn academic material. She was readmitted for her senior year, which she successfully completed in a year, and graduated. Her therapist provided cognitive rehabilitation in the form of academic support during both periods. The therapist was certain that the recovery would have been impossible without the use of the software and its design.

3 Discussion

Cognitive technologies as catalysts of clinical gains in cognitive abilities. Cognitive technologies for individuals with disabilities seem to have 2 modes of action. The first is like a power wheelchair, bridging deficits so that the individual can use existing abilities to increase level of function. The second increases cognitive abilities, producing actual clinical gain. Merzenich et al. exploited brain plasticity in developing software to treat an auditory processing disorder [18]; repetition and patient engagement were both factors in patient success. In case study 2, a former college student headed for a sheltered workshop was able to graduate from college with a combination of intensive therapy and cognitive technology. Similar results were achieved in physical and cognitive dimensions in a young stroke patient [12] and to a lesser extent before brain plasticity had entered the neurorehabilitation clinical literature [11]. The ability to produce clinical gains suggests that some cognitive technologies would benefit from clinical expertise, both with therapy and with involvement in the personalization of software. Case study 1 shows how the most limited functionality was able to advance therapy goals. PCD can promote clinical gains. This focuses attention on clinical goals and expertise.

Contributions of TBI patients to the design of their UIs. The UI seems to be *the* key design issue for individuals with TBI, predicted by the diffuse cognitive damage caused by TBI, and the cognitive load of learning new interfaces. PD has been widely used for developing CAT functionality and contributes to UI design with older populations [1,16,23,24], developmental disabilities [5], aphasia [cf, 19], and autism [cf, 17]. To be useful, UI design for TBI requires personalization. Clinicians and UI designers lacked fine-granularity cognitive-performance data to inform UI design. Fortunately, TBI patients were particularly adept in identifying problems in a proposed UI design, and especially at fine-tuning their own UIs. In our implementation of PCD, the individual with a brain injury could best inform UI design, and was given that responsibility.

Promoting user engagement. Cognitive rehabilitation aims to increase and restore cognitive activity. User engagement aims at increasing cognitive activity as well. The implementation of PCD discussed in this paper is designed to promote patient engagement in several ways. Patients become engaged because their priority activities are the context of cognitive rehabilitation. Patients become engaged because their software contains ideas they individually have proposed, especially the UI, the most visible part of an application. Users are encouraged to suggest additional functionality to help deal with an activity in their near future. The engaged user also often develops personal new uses for applications, evidence of expanding cognitive activity. These uses of the software that haven't been taught constitute invention on a personal scale. This personal invention helps increase the individual's level of cognitive functioning and activity. Both help reduce the level of disability – especially in priority areas – and help the individuals get back into their lives. Madsen et al. [17] encouraged autistic adolescents to develop new uses of a technology tool, and Morris et al. [20] cleverly used interface design to engage autistic children by incorporating objects of their obsession into software with therapeutic goals.

The abilities of individuals with severe and profound disabilities. PCD can be a powerful tool, providing the opportunity to see a range of behaviors. Often PCD will provide a view of behavior opposite from conventional wisdom. Disabilities are typically easy to see, but abilities may not show themselves very often. Too frequently a disabled individual lives down to the level of people's expectations. PCD provides the opportunity for individuals with disabilities to be themselves, and for people who work with them to understand that many dimensions are uncorrelated or poorly correlated with each other. Our initial (and first computer science) study in cognitive disabilities [11] reports an individual with several profound deficits, coupled with substantial abilities. Case Study 2 reports on a person with some severe and moderate cognitive deficits. Both were involved in developing the UI, as well as developing new uses for her software. An individual with profound disabilities is limited, as were our expectations of ability to do PD. However, we were surprised at the ability to provide instructions that made the UI virtually intuitive. We were also surprised at her ability to develop new uses for the application, e.g., to check the accuracy of information stored in her new computer because the information in her previous computer was corrupted.

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An Information Theoretic Mouse Trajectory Measure

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Abstract. In this paper, we propose the Relative Trajectory Information (RTI) measure, an information theoretic measure to evaluate mouse pointer trajectories. The measure is used to score the level of smoothness of mouse pointer trajectories. We show that, by leveraging Gaussian processes and information theory, RTI accounts for relative differences in timestamps of the mouse pointer trajectories. RTI also does not require explicit descriptions of targets, in either their location or size. Our experimental analysis shows how RTI can capture the motion signature of a user with severe motion disabilities and distinguish it from the motion signature of smooth trajectories obtained in a control experiment.

1 Introduction

People with motion impairments are often not able to control a traditional mouse [2]. There are many mouse replacement solutions for people with movement disabilities. One approach is to allow people to control the mouse pointer using head motions captured with a web camera. One such system, the Camera Mouse [3, 7], tracks a small feature on a user's face, such as a nostril or eyebrow corner. The location of such a feature in the web camera frame is transformed into the position of the mouse pointer. In this paper, we analyze the tracked trajectories of a user with cerebral palsy. As the subject moved his head, mouse pointer positions were saved and sent to a centralized database. Numerous translation settings between the tracked feature and the position of the mouse pointer were tried.

Many trajectory evaluation measures use Fitts' law [8]. Fitts' law says that for pointing devices, the average time it takes a user to use a device to point to a target is linearly related to the level of difficulty of the task. It can be stated succinctly as $MT=c_1+c_2\times ID$, where MT represents the (mean) time to reach a target, ID is the index of difficulty of reaching the target, and c_1 and c_2 are constants dependent on the device and the user. There are many variants of the index of difficulty. One popular information theoretic formulation is ID=log(D/W+1), where D is the distance to the target and W is the diameter of the target. The Index of Performance (IP) for a particular user and device is IP = $1/c_2$, with units of bits per second, [13, 14]. Bootsma et al. developed a measure based on Fitts' law and kinematics [5]. Using Fitts' law,

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Accot and Zhai were able to derive a performance measure for more specialized tasks, such as moving the pointer in a narrow corridor of space [1].

Mackenzie et al. [15] described seven performance evaluation measures of pointing devices. These measures describe the strengths and weaknesses of devices like mice, trackballs, joysticks and touchpads. These seven measures are target-based measures, in that they evaluate the mouse trajectory from a starting pointing to a definite target in the screen. The measures are Task Axis Crossing (TAC), Movement Direction Change (MDC), Orthogonal Direction Change (ODC), Movement Variability (MV), Movement Error (ME), Movement Offset (MO). All these measures are derived from a collection of mouse position points, where the target bounding area is known. These measures were used to describe mouse motion control for motion-impaired computer users [10]. Hwang et al. [9] developed their own performance measure for motion-impaired users, with the evaluation of submotions.

In this paper we analyze the trajectories and develop an information theoretic measure of user comfort, called the Relative Trajectory Information (RTI). RTI is a measure over timed mouse trajectories, in that it is sensitive to different distributions of timestamps. RTI represents a universal measure, in that it can used to compare trajectories with variable timestamps of different scales. Since RTI leverages the semi-parametric modeling method of Gaussian processes, RTI does not require an explicit representation of targets, with either their location or their boundary area.

2 Relative Trajectory Information

In this section, we define Relative Trajectory Information (RTI), an information theoretic measure to analyze mouse motion trajectories. The measure is useful as a representation of the level of smoothness of a mouse pointer trajectory, K. The measure is defined as a function RTI(K) that returns a low number if K is a smooth trajectory and a high number if K is a non-smooth, jerky trajectory with unexpected changes in movement timing and direction. A benefit to RTI is that it is can be used to compare different trajectories K and K' with vastly different timestamp profiles. We will show that RTI is a measure that accounts for relative differences of timestamps.

A normalized mouse pointer motion trajectory is defined by a sequence $K=\{(t_i,z_i)\}_{i=1..n}$ of n mouse pointer observations. Each observation contains a timestamp t_i and a 2D velocity vector $z_i=(u_i,v_i)$. The velocity u_i represents the change in horizontal pixel positions over the change in time; and the velocity v_i represents the change in vertical pixel positions over the change in time. We denote the sequence of timestamps as a matrix $T=\{t_i\}_{i=1..n}$ and the sequences of the velocities by matrices $Z=\{z_i\}_{i=1..n}$, $U=\{u_i\}_{i=1..n}$, and $V=\{v_i\}_{i=1..n}$. Furthermore, we normalize the velocities with $U^TU=V^TV=1$. We also normalize the timestamps to range between 0 and 1. We define a series of random variables $\{\mathcal{Z}_i\}_{i=1..n}$ over the velocities Z with a joint density function of the form $f(Z)$. The random series representing the horizontal and vertical velocities are denoted by $\{\mathcal{U}_i\}_{i=1..n}$ and $\{\mathcal{V}_i\}_{i=1..n}$, respectively. The density function f

is designed to allocate more probability mass to smoother trajectories. We define the Relative Trajectory Information by

$$\mathrm{RTI}(Z) = -\ln f(Z) - h(f), \tag{1}$$

where the term $-\ln f(Z)$ represents the self-information (in the unit *nats*, not *bits*) of the velocities Z given the probability f and $h(f)$ represents the differential entropy of f. Both concepts, self-information and differential entropy [6], will be defined and discussed in detail below for our context of trajectory analysis.

A trajectory Z that contains unexpected jerky motions has a small probability of occurring and so its encoding $-\ln f(Z)$ will be high. Smoother trajectories correspond to smaller self-information values $-\ln f(Z)$. The RTI measure defined in Equation (1) is a signed variant of the "typical set" notation used in differential information theory [6]. Using a Gaussian process to model the density function f, as described below, we achieve the simplified notation for RIT with

$$\text{RTI-GP}(Z|T) = U^T C_T^{-1} U + V^T C_T^{-1} V, \tag{2}$$

with U and V defined as matrices who entries are velocity components of the trajectory, as described above, and with C_T^{-1} defined as an inverse covariance matrices of U and V, parameterized by the timestamps, as described below.

2.1 Creation of Mouse Motion Trajectories

Given a mouse trajectory $S=\{(t'_i,x_i,y_i)\}_{i=0..n+1}$ consisting of mouse positions and timestamps, we can create a mouse pointer motion trajectory, $K=\{(t_i,z_i)\}_{i=1..n}$ consisting of pointer velocity vectors and timestamps. We first compute the velocities with a computed average as follows:

$$u'_i := \frac{1}{2}\left(\frac{x_i - x_{i-1}}{t'_i - t'_{i-1}} + \frac{x_{i+1} - x_i}{t'_{i+1} - t'_i}\right), v'_i := \frac{1}{2}\left(\frac{y_i - y_{i-1}}{t'_i - t'_{i-1}} + \frac{y_{i+1} - y_i}{t'_{i+1} - t'_i}\right). \tag{3}$$

We then compute the normalized velocity components of matrices U and V, which are of the form

$$u_i := u'_i \Bigg/ \left(\sum_{j=1}^{n} u'^2_j\right)^{1/2}, v_i := v'_i \Bigg/ \left(\sum_{j=1}^{n} v'^2_j\right)^{1/2}. \tag{4}$$

The timestamps are also normalized to be between zero and one, with $t_i := (t'_i - t'_1) / (t'_n - t'_1)$.

2.2 Self Information

A useful way to interpret the properties of the self-information $-\ln f(Z)$ of a trajectory is by decomposing it into conditional probabilities with

$$-\ln f(Z) = -\sum_{j=1}^{n} \ln f(z_j | \{z_i\}_{i=1..j-1}). \tag{5}$$

The self-information of Z is small if the density function f predicts each velocity z_j given the past history $\{z_i\}_{i=1..j-1}$. This can be seen with Fig. 1.

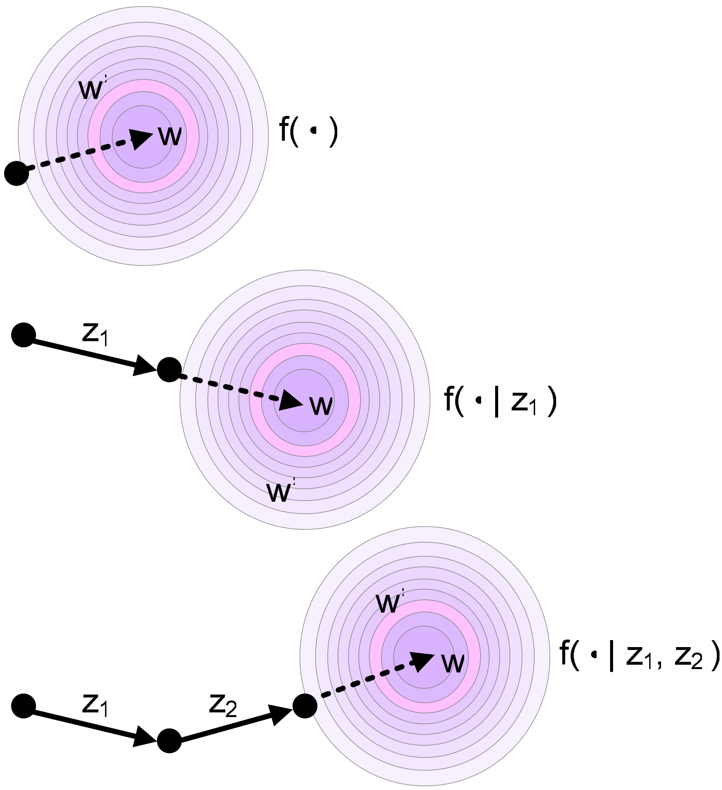

Fig. 1. Examples of the probability of $f(z_1,z_2,z_3)$, separated into conditional probabilities $f(z_1)$, $f(z_2|z_1)$, and $f(z_3|z_1,z_2)$, which are represented by contour lines describing the probability of velocity w. In each example, the velocity w is more probable than the velocity w'. The self-information $-\ln f(Z)$ is smaller for trajectories where each velocity z_j is consistent with the previous history $\{z_j\}_{i=1..j-1}$.

2.3 Differential Entropy

Our model leverages the assumption that the difference between the two timestamps t_i and t_j is correlated to the difference between the two velocities z_i and z_j. As shown in the next subsection, the probability f is parameterized with the timestamps and thus is of the form $f(Z|T)$. Generally speaking, f has a larger second moment if the timestamps are spaced further apart, as shown in Fig. 2.However, to use RTI to compare trajectories that have different average spacing between timestamps, we include a normalization term $h(f(\cdot|T))$, which represents the differential entropy of the density function $f(\cdot|T)$, with

$$h(f)=-\int_S f(x)\ln f(x)dx, \tag{6}$$

where S is the support set of the random variable. This entropy $h(f)$ represents a normalization term, which is a measure of the level of uncertainty of a given probability f. If distribution f is represents a Gaussian distribution (which we assume in the next section), then its entropy is correlated to its variance.

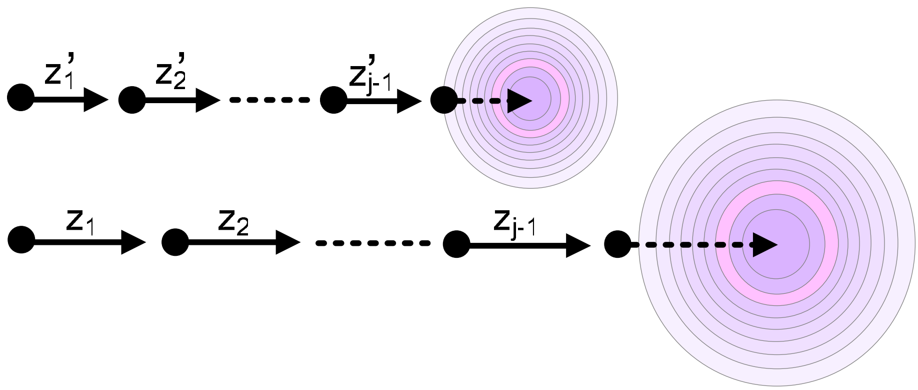

Fig. 2. An example of two trajectories: $K=(Z,T)$ and $K=(Z',T')$ The timestamps in T are spaced farther apart than in T', and thus the probability distribution f(·|T) has a smaller variance than probability distribution f(·|T '). Thus the differential entropy of h(f|T) is smaller than that of h(f|T '). As the differential entropy represents a corrective term for the Relative Trajectory Information, the two trajectories will have the same RTI values.

2.4 Gaussian Processes

Our goal is to define the density function f to give more probability mass to motion trajectories that are smoother. We can achieve this property by defining $\{z_i\}_{i=1..n}$ as two independent Gaussian processes [4], parameterized with time, T, with $f(Z|T)=g(U|T)g(V|T)$. Thus the density function for both $\{\mathcal{U}_i\}_{i=1..n}$ and $\{\mathcal{V}_i\}_{i=1..n}$ is $g(\cdot|T)$. A Gaussian process is a collection of random variables, where each random variable has a Gaussian distribution and every finite collection of those random variables has a multivariate Gaussian distribution. The covariance of the distribution is parameterized by the timestamps, T. In accordance to the standard Gaussian process definition, the covariance of any two random variables $\mathcal{U}$ and $\mathcal{U}'$ is equal to the kernel function of their timestamp t and t', with

$$k(t,t') \quad = \theta_0 \exp\left\{ -\theta_1 |t-t'| \right\}, \tag{7}$$

and similarly for $\mathcal{V}$ and $\mathcal{V}'$. The parameters θ_0 and θ_1 of the kernel are manually defined by the researchers using RTI. This definition implies that if time t_i is close to t_j then velocity z_i should be close to velocity z_j. The covariance matrix C_T for both $\{\mathcal{U}_i\}_{i=1..n}$ and $\{\mathcal{V}_i\}_{i=1..n}$, is an $n\times n$ matrix whose (i,j)th element is equal to $k(t_i,t_j)$.The matrix C_T is also known as a Gram matrix, with respect to kernel function k. Thus the joint distribution of $\{\mathcal{U}_i\}_{i=1..n}$ and $\{\mathcal{V}_i\}_{i=1..n}$ is a multivariate Gaussian distribution with zero mean and covariance equal to C_T, with

$$\begin{aligned} g(U) &= \mathcal{N}(U|\mathbf{0},C_T) \\ g(V) &= \mathcal{N}(V|\mathbf{0},C_T). \end{aligned} \tag{8}$$

The density function is of the form,

$$f(U,V) = g(U)g(V) = \frac{1}{(2\pi)^n |C_T|} \exp\left\{ -\frac{1}{2}\left(U^T C_T^{-1} U + V^T C_T^{-1} V \right) \right\}, \tag{9}$$

With $|C_T|$ being the determinant of C_T. Furthermore, the differential entropy of this density function is

$$h(f) = \ln\{(2\pi e)^n |C_T|\}. \tag{9}$$

The Relative Trajectory Information of a mouse pointer trajectory using Gaussian processes is $RTI\text{–}GP(Z|T) = -\ln f(Z) - h(f) = \frac{1}{2}\left(U^T C_T^{-1} U + V^T C_T^{-1} V \right) - 1$. Removing unnecessary constants, the final form of the RTI for Gaussian processes is

$$RTI\text{–}GP(Z|T) = U^T C_T^{-1} U + V^T C_T^{-1} V. \tag{10}$$

3 Experiments

We conducted several human-subject experiments to test the proposed relative trajectory information measure. The participant of our experiments was a young man with severe motor impairments. Due to cerebral palsy, he is quadriplegic and non-verbal. He is an experienced computer user and has worked with the Camera Mouse as a mouse-replacement interface for several years [2, 3]. Our subject was seated in front of a computer with a Logitech Quickcam Pro 4000. This web camera captures images at a frame rate of 30 Hz. The images of the web camera were sent to the Camera Mouse. The Camera Mouse tracks a small feature of the subjects face using a web camera. The feature is a 10×10-pixel square sub-image that is tracked using

Fig. 3. Images of user interacting with system. The user can control the position of the mouse pointer with head motion. The green square indicates the tracked region, whose center is converted to a mouse pointer position on the screen.

optical flow. The optical flow algorithm we used [7] was the Lucas Kanade variant [12]. The participant could control the mouse pointer using solely head motions (Fig. 3). By stopping the pointer in a small region on the screen for a period of time, the user could initiate a click event.

The user was asked to play a mouse movement game [7], which involved moving the mouse pointer to a target designated on the screen. After the user reached the target or a timeout occurred, another target was presented to the user. The interface for manipulating pictures consisted of various buttons that the user would click to activate tools such as image cropping, image rotation, a pencil tool, etc. [11]. After choosing such a tool, the user selected points on the image and manipulated the image. The game and image manipulation program enabled us to collect thousands of trajectory points while the user performed typical tasks and interacted naturally with the computer using the Camera Mouse. The collected mouse trajectories were created under various configurations that mapped tracked head motion into mouse pointer motion. In particular, we tried various settings for the horizontal and vertical gain parameters of the pointer mapping. Larger gain values resulted in larger mouse motions given the same motions of the user's heads. We tried combinations of three settings for the vertical and horizontal gains with the participant of our experiments: High, Very High, and Extreme.

Table 1. The RTI measure computed over mouse trajectories of the control motions, produced with the traditional mouse, and the mouse motions created by the user with motion impairments, produced with the Camera Mouse

Trajectory Group	Horizontal Gains	Vertical Gains	Number of Trajectories	Average RTI	Std RTI
Control Linear	N/A	N/A	84	0.089	0.032
Control Circular	N/A	N/A	118	0.085	0.025
Subject	High	High	167	0.16	0.044
Subject	High	Very High	18	0.17	0.031
Subject	High	Extreme	391	0.16	0.056
Subject	Extreme	Extreme	311	0.17	0.058

To create the control mouse trajectories, we collected the pointer positions of two smooth motions: linear mouse motions and circular mouse motions. We created an application that presented a series of small red target circles to the user. A subject without disabilities was instructed to use the traditional mouse to move the mouse pointer to each successive target. We stored the pointer positions of the mouse target application with a frequency of twice per second. For the first control group, the targets were presented in smooth linear positions. For the second control group, the targets were presented in smooth circular positions. Each mouse trajectory is represented by a sequence of 20 velocity vectors. The RTI values for the trajectories are shown in Table 1.

The results show that the RTI is resistant to changes in vertical and horizontal gain values of the subject's motions (rows 3-6). Furthermore, both sets of smooth control movements produced similar average RTI values (row 1-2). The RTI values computed for the control trajectories were on average lower than the RTI values computed from the movement trajectories created by the user with motion impairments (rows 1-2 vs. 3-6). This verifies the capability of the RTI measure to produce characteristic signatures that distinguish the movements of a subject with motion disabilities from smooth control motions.

4 Discussion

In this paper, we presented a measure to characterize mouse pointer trajectories, the Relative trajectory Information (RTI). Our derivation of the measure was based on Gaussian processes and information theory. RTI does not require the specific identification of targets and can be used to compare trajectories with a different variance of timestamps. The measure is defined as the relative self-information of the trajectory using a probability parameterized by the timestamps. In future work, we will use the RTI measure to evaluate the performance of mouse-replacement interfaces for users on a variety of tasks. We also plan to modify the definition so that it will become invariant to trajectories containing different number of mouse positions.

Acknowledgements

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Comparative Study between AZERTY-Type and K-Hermes Virtual Keyboards Dedicated to Users with Cerebral Palsy

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Abstract. The aim of this paper is to compare two virtual keyboards for people with cerebral palsy; many of these users have difficulty performing actions using their upper limbs due to large numbers of unwanted movements. The first is a classical QWERTY type keyboard, called Clavicom NG. The second is the K-Hermes proposed in this paper. K-Hermes is a reduced and monotape keyboard; its entry principles are inspired by the T9 keyboard. The aim of the experiment is to demonstrate the reduced effort and increased speed of typing with the keyboard suggested for people with Cerebral Palsy.

Keywords: Virtual keyboard, text entry, effort reduction, cerebral palsy.

1 Introduction

Much research has been done on virtual keyboards and the tiny keyboards of mobile devices. Indeed, they are increasingly used in mobile devices such as mobile phones or tablet PCs. In this paper, we focus specifically on virtual keyboards for people with disabilities. It is not possible to deal with all the existing handicaps due to their large number [18]. Therefore, this article focuses on users with Cerebral Palsy. These people have suffered neurological damage. For many of these users, their movements lack precision [13], which is why they are likely to use a virtual keyboard for text entry. In this case, a joystick is often used for mouse manipulation (other devices are also possible, such as eye-controlled devices), the clicking is done with a pushbutton. For example, the device used by the first author is shown in Fig. 1. In this paper, we begin with a state of the art on keyboards adapted for users with motor impairments. Then we propose the K-Hermes virtual keyboard. An experiment, the goal of which is to compare it with the Clavicom NG keyboard [3] used by many disabled users, is the subject of the next part. The results obtained are described and discussed.

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Fig. 1. Pointing device using the K-Hermes virtual keyboard

2 State of the Art on Keyboards for People with Motor Impairments (Cerebral Palsy)

Many studies have been conducted in the field of text entry for people with motor impairments [14] [17]. Representative examples of virtual keyboards with the goals of reducing mouse movements and increasing the speed of text input are presented below.

Dvorak [4] is an alternative to the standard physical keyboard. On the Dvorak keyboard, consonants and vowels are most likely placed in the midline of the keyboard. This layout makes it possible to perform less complex finger movements and thus offers more comfortable input while reducing physical fatigue. XPeRT [21] has a similar layout to the qwerty Keyboard. Its principle is to group the most frequent diagrams (groups of 2 letters) in order to reduce the distance traveled by the mouse pointer while typing text. OPTI and FITALI [9] offer the most probable letters in the center of the keyboard. They have both multiple space bars on the sides and a large shift bar on the bottom that make input easier and faster. This result is in accordance with Fitts's Law [8] that shows that the closer the letters, the faster and the less tiring the input. Métropolis [22] is based on the eponymous global optimization algorithm. The letters are grouped according to the attraction between them, while taking into account Fitts's law to shorten the travel distance of the mouse. Sibylle [20] is a predictive keyboard that helps the user to type faster by predicting both the most probable letters and words during text input. It should be noted that most keyboards for users with disabilities possess a word prediction system. Dasher [6] allows an input exclusively based on mouse movement by always pointing to the next character in the list of probable letters presented on the right close to the current pointer position. KeyGlass [19] provides, after each letter input, around the key, four semi-transparent buttons representing the most probable following letters.

Chewing Word [5] presents a dynamic keyboard with two rows of letter keys. After each character input, the prediction system rearranges the letter keys according to their probability of occurrence. UKO-II [9] is a keyboard designed for people affected by cerebral palsy. It uses the same principle as T9. There are only four buttons for all the characters. To input a letter, the user must enter the number of the key (from 1 to 4) associated to the letter. Then, a disambiguation algorithm proposes the most probable words according to the sequence of keystrokes. K-Thôt [1] offers a virtual keyboard for people with motor disabilities, which aims at minimizing movements and user fatigue and to maximize the input speed. The input of special characters, such as spaces, backspaces and capital letters is made particularly easy.

CLAVICOM NG [2] is an azerty layout keyboard. It has been chosen as a reference for the evaluation of the K-Hermes keyboard for the following reasons:

1. it is often used in specialized centers for people with disabilities,
2. it uses a prediction system like the K-Hermes keyboard,
3. the keyboard layout is adaptable by the user.

With Clavicom NG, the user enters its desired text by directly clicking on letter keys like a standard azerty keyboard. Word proposals appear inside white buttons located on top of the keyboard (Figure 2). Just click on one of these buttons to automatically complete the current input word and add a space. With this method, the user does not have to input a space before beginning the next word.

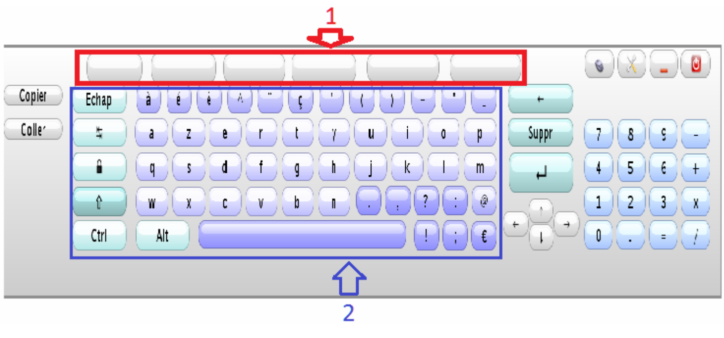

Fig. 2. CLAVICOM NG: (1) propositions of words, (2) AZERTY keyboard

3 K-Hermes

The K-Hermes keyboard has been proposed in [9]. K-Hermes is named K for "keyboard" and Hermes was the Greek god in charge of sending messages. K-Hermes is based on the layout of a T9-type keyboard. It has the advantage of enabling entry with only 9 keys. This reduces movement between the joystick and the pushbutton, and therefore reduces the fatigue of the user (which is essential for Neurological Injury) (Fig. 3). To enter the nth letter of a labeled button, the user must click on the button n times. Thus, to enter "b", he/she must double click on the button labeled "abc." In the figure, the left buttons containing the word "proposition" corresponds to the area of lexical prediction. The keys are arranged in alphabetical order so that the user memorizes the location of the letters easily, which helps reduce eyestrain.

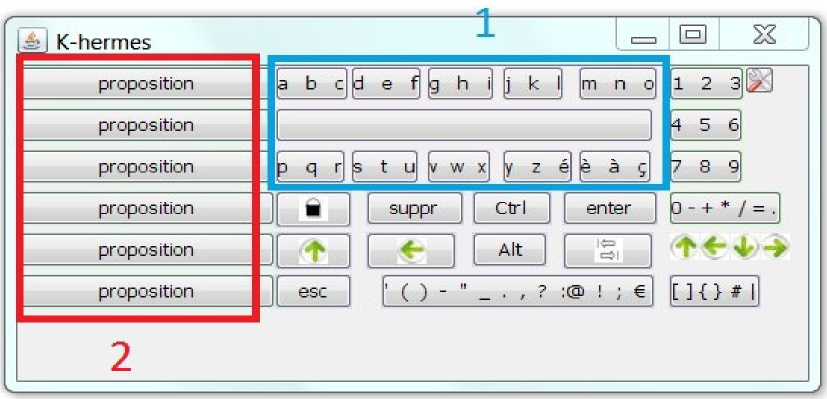

Fig. 3. K-Hermes: (1) Word proposals, (2) T9-style keyboard (3 letters per key)

The buttons with the word “proposition” (“proposal” in English), which are located on the left side of K-Hermes, are used to display a set of words in the dictionary. In the current version of K-Hermes, if the user types the letter “a”, the keypad will display the first six words in its dictionary that start with “a”. Note that further information on the word prediction will be provided later in the subsection “Word Prediction”.

For users with cerebral palsy, it is important to clarify in this article that all of these movements if repeated several hundred times a day, can cause muscle pain.

The comparative experiment involving the proposed keyboard and Clavicom NG is the subject of the next part.

4 Experimentation

The hypothesis is as follows: K-Hermes with a word prediction system allows for less movement (return of the hand between the joystick and push button, visible in Figure 1 for entering text. This consequently leads to a decrease in fatigue. To prove the hypothesis, we conducted a series of tests with three different types of people:

- A person with cerebral palsy is the subject of reference for the experiments.
- A group of able-bodied people simulating a disability to use the device seen in Figure 1 for handling the pointer on the screen. They use their favored hand during testing.
- A group of able-bodied people using a mouse.

People simulating a disability had an additional constraint thus bringing them closer to the extent of physical capacity of a person with cerebral palsy: they had to manipulate the joystick with one hand and a clenched fist. Under these conditions, testers make about the same movements as users with cerebral palsy.

The left joystick is used to direct the mouse pointer. The first four buttons (top two in each row) are used to simulate a left click. The following four (the last two of each line) are used to simulate a right click. This device was designed based on an old joystick which was amended and connected to a box used to translate the electrical impulses emitted by the joystick and buttons into digital data. Click lock is accomplished by holding down the top button of the first line (see Figure 1).

The test was conducted in two sessions for the following reason: Cerebral palsy causes its victims to be plagued with a lot of unwanted movements. Therefore, we decided to conduct only a few sessions. Indeed, when able-bodied people manipulate the joystick for the first time with their fists, they too must undergo a large number of additional movements. Thus making the input conditions close to those of a person with cerebral palsy. Carrying out many of these sessions makes it harder to reach the reality of those conditions, as able-bodied people become used to the constraints, which greatly reduces the involuntary movement.

The time between test sessions was 24 hours. The testers used the following four methods alternately: (1) K-Hermes with word prediction, (2) K-Hermes without word prediction, (3) Clavicom NG with word prediction, (4) NG Clavicom without prediction words. The tests were conducted as follows: (1) the testers filled out a questionnaire about their habits with computers. (2) An explanation was given about the keyboard to use. (3) During a period of 5 minutes, they input a series of 5-letter words. (4) These actions were repeated for the four keyboards over two sessions. (5) A final questionnaire was filled for their thoughts on each keyboard.

Some information has been recorded for the purpose of analysis by more: the distance traveled by the pointer, the average distance between two keys, the number of comings and goings of the hand between the joystick and push button, the number of words per minute (WPM: *Words Per Minute*), the number of characters per second (CPS: *Characters Per Second*).

5 Data Analysis

Preference: to evaluate the preference of testers for different keyboards, we asked testers to draw a line on an axis of ten centimeters. 0 symbolizes the most negative response (difficult to use or exhausting) and 10 the most positive (easy to use or no fatigue felt). We can see that the Clavicom NG left a better impression with testers, because of their practice with an AZERTY physical keyboard type. In addition, 90% (calculated from the questionnaire) of the participants send their messages from their mobile phones with an AZERTY keyboard (mono-tap).

Word Prediction: K-Hermes is more efficient than Clavicom NG. Indeed, the former predicted 1.82 words per session and the second predicted 0.89 word per session over all the sessions with all the users. These results were calculated by summing the

Table 1. Results of the questionnaire completed by the testers at the end of each test session

Category of questions	Average (on 10)
Difficulties in K-Hermes without word prediction	4.92
Difficulties in K-Hermes with word prediction	5.08
Difficulties in CLAVICOM NG without word prediction	3.02
Difficulties in CLAVICOM NG with word prediction	3.42
Fatigue level for K-Hermes without word prediction	4.69
Fatigue level for K-Hermes with word prediction	4.23
Fatigue level for CLAVICOM NG without word prediction	2.88
Fatigue level for CLAVICOM NG with word prediction	2.88

number of words predicted by the keyboards, and dividing by the number of participants, based on the extension of the dictionary [7] of 60 000 to 336 531 words. K-Hermes has an additional advantage in this domain: when the user uses the backspace key, the previously suggested words are proposed again. Consider the following example (see Fig.4).

- the user types on the 'M' key;
- the word prediction proposes the words “Matter”,”Middle”,”Mistake”.
- the user types on the 'O' key;
- The new list of words proposed: “Mother”,”Motor”,”Monster”.
- By deleting the letter "o", the words: “Matter”,”Middle”,”Mistake” are proposed again.

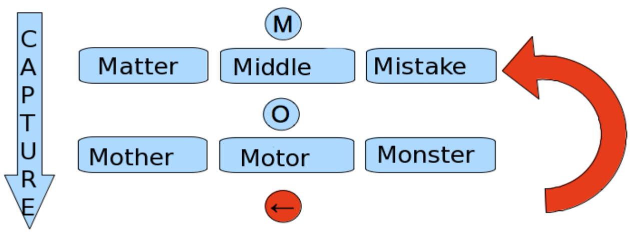

Fig. 4. Relationship between backspace and word prediction system in K-Hermes

This system is not implemented in the Clavicom NG software. When the user removes a letter, all proposals are deleted. This means that the tester must complete the entry word and generates additional movements. The selection of proposals will automatically add a space as a word separator, the user does not need to enter it. This last principle is implemented in K-Hermes and Clavicom NG.

Number of words per minute: There is a very important difference between the results obtained for the group simulating a disabled person (see Figure 5) and able-bodied people for Clavicom NG. The cause is the manipulation of the pointer: performing an action with the mouse requires a little more time, just one second (the average mouse pointing time is estimated to be 1.1 seconds according to the Keystrole Level Model(KLM) [2]), whereas with the joystick the same action may take only a few seconds. However, it was also noted that some of those who used a traditional mouse were much more precise with the pointer. First, we thought it was normal fault (handling a pointer with a joystick is not easy), but we later learned that some of the testers were used to playing video games with a joystick. The gamers had just as much difficulty manipulating the mouse pointer. This is due to the sensitivity of the joystick and the effect of reducing the precision of the pointer.

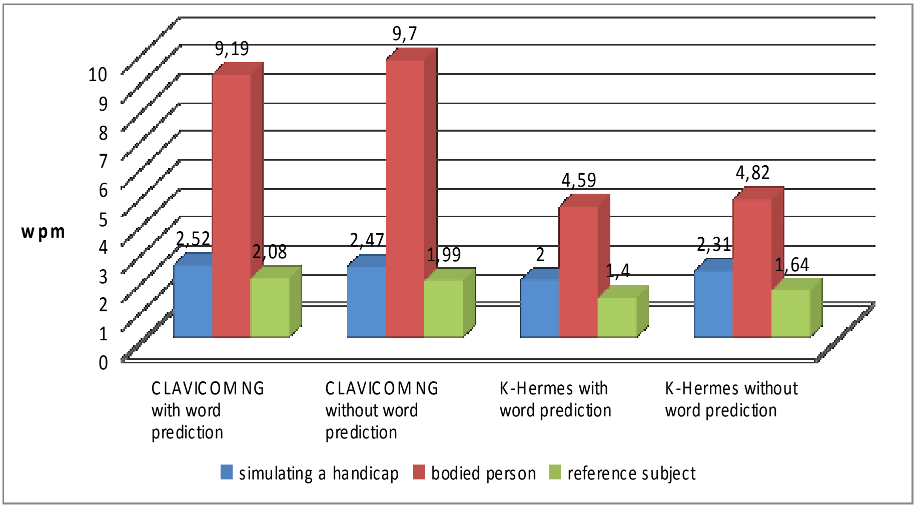

Fig. 5. WPM for all configuration to 2 sessions

With K-Hermes, the difference between the three groups of testers is reduced. All of the able-bodied people were slower in their entries because of the disambiguation system, the testers had to make an extra effort to select the desired letter on the buttons contrary to Clavicom NG with which the characters are accessible with one click. For the group who simulated a disability, the typing speed difference between the two keyboards with word prediction for the second session was 0.16 words per minute. The reference subject obtained a lower entry speed than the other two groups. This suggests that the simulation of disability is imperfect. The reference subject made more moves because of his disability during the tests, which reduced the number of words he was able to type.

Error rate per word: for all the groups, the two keyboards are approximately the same (Clavicom NG: 0.003 errors per word; K-Hermes: 0.002 errors per word). The Multitap system in K-Hermes to choose the desired letter did not disturb the users. The fact of having to count the number of clicks to get a letter requires additional concentration and prevents the user from choosing the wrong letter.

Number of comings and goings of the hand between the joystick and button validation: for a specific period of time, assuming that users of K-Hermes and Clavicom NG input as many words as they can, the average difference between both keyboards with word prediction is 15 movements, with fewer movements for K-Hermes. If the prediction system is disabled, the number decreases to 10. Table 2 shows the number projections for a complete day. Indeed, the test lasted 5 minutes. Thus, based on the questionnaire, which was completed by all of the testers, they use a computer for an average of 7 hours per day (including breaks). Consequently, in theory, the number would reach 1260 movements within one day (without considering the break time, for example). Such a number of movements has a significant effect on the user's fatigue level. The length between the joystick and the button used during testing is 8 cm; thus the total length over a day (on such a device) could reach up to more than 20,000 cm (20,160 cm in theory).

Table 2. Average number of movements (Number of comings and goings of the hand between joystick and validation button) during the two sets of tests

Keyboards	Average number of moves
K-Hermes without word prediction	99
K-Hermes with word prediction	93
CLAVICOM NG without word prediction	109
CLAVICOM NG with word prediction	108

Table 3 includes the average distance traveled by the mouse pointer over all the tests carried out.

Table 3. Average distance traveled by the mouse between two keys in the 2 sessions (G1: A group of people simulating a disability G2: group of able-bodied people)

Keyboards	Average distance G1 (to pixel)	Average distance G2 (to pixel)
K-Hermes without word prediction	108	116
K-Hermes a with word prediction	107	114
CLAVICOM NG without word prediction	164	178
CLAVICOM NG with word prediction	159	180

The difference between the two keyboards for the group simulating a disability with word prediction is 52 pixels. We can come to two conclusions: the user manipulates the joystick less time with K-Hermes, this reduces the movement of the arm. The second observation is on pointing precision. On K-Hermes, the keys are larger because they represent three letters. According to Fitts' law [8], the tester needs less precision and he/she performs pointing gestures faster. The testers tend to move beyond the appropriate button with Clavicom NG; the consequence is the necessity of additional operations to correct their actions. With K-Hermes, the consecutive letters in a word and finding the consecutive letters on the same key do not require moving the mouse pointer. This is a very important result for users with cerebral palsy.

In the light of the different results obtained, we can conclude that our hypothesis has been verified.

6 Conclusion

In this paper, the K-Hermes virtual keyboard has been proposed and described. The purpose of this paper was also to compare the reduction in effort with this T9-style keyboard compared to a QWERTY style keyboard for users with cerebral palsy. Such users greatly benefit from a reduced keyboard to limit their movements during text entry and thus reduce their physical strain. The results obtained during the experiments show a significant decrease in the number of movements. Note that other experiments have reached the following conclusion: a valid user may reach 10.4 words per minute after 10 hours of training with a T9-type keyboard [10]. We are far from this performance, because we chose to do a limited number of tests to remain as close to reality as possible due to operations performed by users with cerebral palsy. However, through our work it was possible to increase the text entry speed while decreasing the physical effort for people with cerebral palsy, which is very promising. Our perspectives focus on improving the prediction system. We are also thinking about different layouts for the keys.

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New Trends in Non-visual Interaction - Sonification of Maps

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Abstract. An inexpensive sonification system of maps and charts for visually impaired is described. A digitiser (tablet) is used as system's input device, which helps to investigate the map. The maps are presented using xml technology – mainly svg language tags. Then the maps from svg are converted to RGB bitmap. A system software is based on Microsoft .NET technology. Free Microsoft development systems as Visual C# 2008 Express Edition and Direct Sound are used to implement sonification system.

Keywords: Blind, sonification, map, svg language.

1 Introduction

With the increasing usage of multimedia systems, there is a real need for developing tools able to offer aids for visually impaired or blind people in accessing graphical information. This technological development opened new prospects in the realization of man-machine interfaces for blind users. Many efforts have been devoted to the development of sensory substitution systems that may help visually impaired and blind users in accessing visual information such as text, graphics, or images.

Creating, manipulating, accessing, and sharing information such as pictures, maps, charts and other visualisations as well as mathematical data and tables are fundamental skills needed for life. Visualisation is commonly used within almost every scientific field. For teaching blind children or students other information presentation ways must be found, which replace visual information. Solution is to transform visual information to stimulus which could be perceived by others human sensor systems, which are functioning normally. We selected approach that transformation to auditive signals must be preferred.

One of the first approaches to use sonification signals in human computer interaction is called earcons [1]. Sounds used for earcons should be constructed in such a way that they are easy to remember, understand and recognise. It can be a digitised sound, a sound created by a synthesiser, a single note, a motive, or even a single pitch.

A method for line graph sonification invented in the mid 1980s was called Sound-Graphs [2]. Movement along the x-axis in time causes notes of different pitches to be played, where the frequency of each note is determined by the value of the graph at that time. It was established by experiments with fourteen subjects that after a

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small amount of training, test subjects were able to identify the overall qualities of the data, such as linearity, monotonicity, and symmetry. The flexibility, speed, cost-effectiveness, and greater measure of independence provided for the blind or sight-impaired using SoundGraphs was demonstrated.

In the late 1980s a system called Soundtrack was developed [3]. It is a word processor for visually impaired people. The interface consists of auditory objects. An auditory object is defined by its spatial location, a name, an action, and a tone.

Invention of haptic devices leaded to design of multi-modal interfaces to access graphical information. This technique was used in the GUIB system in which graphics were communicated using sound and text using synthesised voice or Braille [4].

Some of them are based on transformation of visual information to auditive signal. These approaches assume a sufficient knowledge of both visual and auditory systems. At present time, we can consider that the various solutions suggested for text access are acceptable. However, the information presented in the form of graphics or images presents a major obstacle in the daily life of blind users.

2 Method

Our aim was to develop widely available graphical information presentation system for blind user[5]. We tried to use most common and cheapest hardware and open source or free software components.

Nowadays vector graphics format is widely used to store digitized maps. Often rich interactive maps are published in web using SVG file format which is an XML markup language for describing two-dimensional vector graphics. It is an open standard created by the World Wide Web Consortium. The available fill and stroke options, symbols and markers enable higher quality map graphics.

As a XML based language, SVG supports foreign namespaces. It is possible to define new elements or add new attributes. Elements and attributes in a foreign namespace have a prefix and a colon before the element or attribute name. Elements and attributes in foreign namespaces that the SVG viewer does not know, are ignored. However, they can be read and written by script. Foreign namespaces are used to introduce new elements (e.g. GUI elements, scalebars) and for the attachment of non-graphical attributes to SVG graphic elements.

Most suitable software for browsing interactive SVG maps some years ago was plugin Adobe SVG Viewer, available for all major platforms and browsers (Linux, MacOSX, Solaris, Windows) which earlier could be downloaded free from the Adobe SVG homepage.

Mapping represents a perfect application of SVG because maps are, by nature, vector layered representations of the earth. The SVG grammar allows the same layering concepts that are so crucial to Geographic Information Systems (GIS). Since maps are graphics that depict our environment, there is a great need for maps to be informative and interactive. SVG provides this interaction with very high quality output capability, directly on the web. Because of the complexity of geographic data (projection, coordinate systems, complex objects, etc.), the current SVG specification does not contain all the particularities of a GIS particularities. However, the current specification is sufficient to help the mapping community produce open source interactive maps in SVG format.

Text field with information about the map is information for presentation to user by speech synthesis. Other elements represent regions of maps. Actually, region is graphical tag of SVG, which describes contour of region. This tag has attributes related to sound, text and similar. Sound attribute allows to indicate sound file, which is played when cursor is over region. Text attribute is devoted to information about selected region.

In our application we need devices which give absolute coordinates. There are two choices: tablet and touchscreen. For graphical input on desktop or laptop computer we selected digitiser (tablet) as cheaper and more accurate device. PC computer have sound system and installed Microsoft Windows XP (Service Pack2) operation system. Created sonification software without executable file has resources (collections of WAV and XML format files) and configuration file.

Software must implement these actions:

- loading default system configuration;
- selection of XML file;
- parsing of XML file;
- handling of mouse move events or menu options.

Moving of pen on tablet invokes mouse movement event in computer OS. Mouse events must initiate the generation of non speech sound. Mouse coordinates are defined and by them it is determined, over which region the mouse is present. If the mouse is on the same region as previously, now changes are done to played wav file. If the mouse goes to the new region, correspondingly, the old sound file is stopped and new file is started to play. Additionally, the distance of cursor point to the region boundary is measured to give alert signal if cursor is approaching the boundary of region.

The algorithm for determination of distance is next. The initial direction angle and the step for angle increase are selected. By default angle is equal to 0 degrees and step is equal to 5 degrees. We go from cursor point by the given angle while we reach boundary. Boundary is reached when pixel colour changes. Then we calculate Euclidean distance from cursor point to point on the boundary. The obtained value is stored in the array. Next direction is selected by adding angle step to current direction angle. And again point on boundary and distances is found (Figure 1)). From the array of distances, which is plotted in Figure 2, minimal distance is defined.

A warning sound signal about boundary of two regions is issued, when pen of digitiser is close to the boundary. Because it is easy to jump through boundary without stop on it the signal is started to generate at some distance from boundary when the pen is approaching to it. Also it is necessary to indicate when the pen goes toward to boundary or is departing from boundary. So volume of sound is selected according to the distance from exact intersection of two regions. If the pen moves parallel to the boundary then the volume remains at constant level. When the pen is points on boundary detection in all directions approaching to boundary the volume of warning sound is increased. The maximal volume is reached on exact boundary. The volume is decreased when pen crosses the boundary and recedes from it.

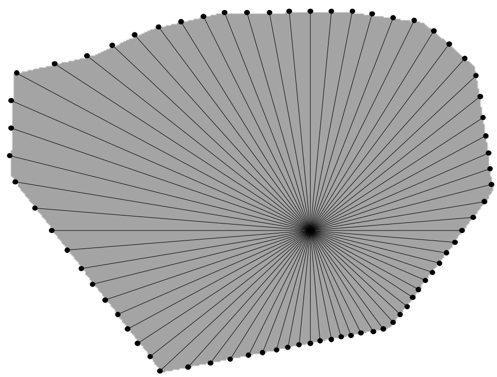

Fig. 1. Map with contour of Finland and example of contour description (points on boundary detection in all directions)

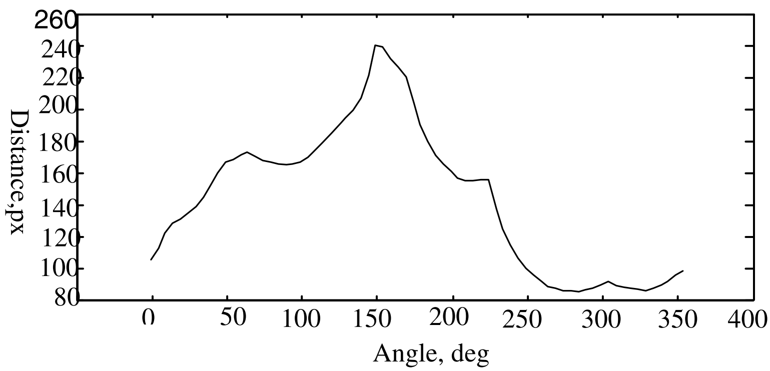

Fig. 2. Map with contour of Finland and example of contour description (plot of distances between cursor point and boundary points)

3 Implementation

In this section we will discuss implementation issues of the sonification system. For coding we selected C# language. We used the free Microsoft Visual C# 2008 Express Edition. The Windows application is based on ***System.Windows.Forms*** assembly.

The developed software must be very stable because it will be impossible for a disabled to solve a software crash and respond to unpredicted dialog boxes. Best guarantee for stability should be found in widely used technologies. In recent years the .NET Framework by Microsoft has brought the ability to write much more robust and secure code on the Windows platform.

.NET Framework promises good options for interoperability. It is easy to combine code written in different .NET languages because all code is first translated into CIL (Common Intermediate Language). CTS (Common Type System) also exists and ensures compatibility of parameter types in functions calls. It is simpler to invoke methods on COM objects. There are also some choices for cross-machine communication between managed modules.

The parsing of SVG document was implemented using XLINQ library functions, other called as LINQ to XML library. LINQ defines a set of general purpose standard query operators that allow traversal, filter, and projection operations to be expressed in any .NET-based programming language. XLINQ provides both DOM and XQuery/XPath like functionality in a consistent programming experience across the different LINQ-enabled data access technologies.

We used object-oriented programming technology. XLINQ allows parse data from XML file directly to classes of graphical objects.

Graphical rendering was implemented with Windows GDI+ functions. PictureBox control allows draw stable pictures. Included bitmap in it allows organise navigation plane.

For speech synthesis we used Speech library from NET. Framework version 3.0. It allows not only synthesize English speech but also some effects as emphasis of words or speech rate changes by 5 levels.

Only one software component was used outside .NET Framework. It was DirectSound library from Microsoft DirectX version 9c. Attractive features of DirectSound are advanced sound playing control: some files in the same time with independent parameters control.

4 Discussion

The differences of visual and auditory systems are pointed by Brewster [6]. Our visual system gives us detailed information about a small area of focus whereas our auditory system provides general information from all around, alerting us to things outside. Visual system has a good spatial resolution, while auditory system has preference in time resolution. So it is impossible to convey the same information by these two information channels.

In the sonification report [7] it is stated that progress in sonification will require specific research directed at developing predictive design principles. There is also indicated about the need of research by interdisciplinary teams with funding that is intended to advance the field of sonification directly, rather than relying on progress through a related but peripheral agenda.

Analysis shows that there many different sonification efforts including solutions for visually impaired but they are more as project results and are not widely available. The described sonification system can be easily implemented and easily integrated to bigger projects. The improvements mostly can concern selection of sounds.

5 Conclusions

XML format files were successfully used for preparing information for sonification. The developed model of sonification was successfully implemented using free software development tools: Microsoft Visual C# 2008 Express Edition and Microsoft DirectSound library.

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Opportunities in Cloud Computing for People with Cognitive Disabilities: Designer and User Perspective

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Abstract. The ability to manage information and programs in the cloud, that is, on networked computers that users need not manage, offers potential opportunities for improved services for people with cognitive disabilities. Author Ward is a self advocate with experience in creating a Web site designed for people with disabilities, and in using the Web. Her experiences suggest what some of these opportunities are, and how they can be realized.

Keywords: inclusive design, loud computing, cognitive disabilities.

1 Introduction

The Web is an increasingly important channel, not only for access to information, but also for services, and social and civic participation. Because of the flexibility with which computer-readable information can be transformed, the Web potentially offers improved access to people with a range of disabilities. Increasingly, the Web is used not just to present information, but also to store it, share it, and perform computational operations on it, all using computers to which users connect via the Web but which they do not have to manage or maintain: this is *cloud computing*. (The cloud image is a generalization of an earlier use of cloud to refer to communication via the Internet. The term meant a means of sending messages whose workings need not be understood: messages enter the cloud and simply reappear where they should go. The term cloud has now been extended to include computers that are accessed via the cloud.)

Author Ward is a self advocate, that is, a person with a disability who works as an advocate for persons in a similar situation. She works as a member of the team that has created the Medicaid Reference Desk (theDesk.info), an informational site about Medicaid services relevant to people with cognitive disabilities. This site illustrates some of the features of services that can make them useful for people with cognitive disabilities, which we summarize here.

Currently the Medicaid Reference Desk does not exploit all of the potentially valuable features of cloud computing. Also, it does not address all of the needs that cloud

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computing can potentially address. We describe what this additional potential is, and how it might be realized.

2 Web Features That Enhance Cognitive Access

Simple Navigation with Progress Indicators. The process of finding information on the Medicaid Reference Desk is structured into a series of steps, starting with selecting a state (Medicaid programs differ among states), and continuing to select a category of service. As the user makes these selections, progress indicators show what stage of the process they have reached, and what step comes next. This helps users keep track of their progress, and to choose their next action (Small et al. [1]).

Content Edited to Be Easy to Understand. The information presented on the site is based on government program descriptions that are written as policy definitions for specialists, not for consumers. An editorial team, of which Ward is a member, works to rewrite these descriptions to make them easier for consumers to understand.

Access to Definitions of Unfamiliar Words. Even when descriptions have been rewritten, they sometimes use terms that aren't in common use. For example, the term "waiver" is used to mean "A Medicaid program that provides services and support so people can live in the community." Unfortunately, although this term familiar to consumers at first, it is so widely used among service professionals that avoiding it would create more barriers to communication than it would eliminate. The solution is to use the term, but to provide ready access to the definition, just given. This is done by rendering all terms for which definitions are available as links; clicking on one of these links brings up the associated definition.

Audio Presentation. Many people with cognitive disabilities can't read well. Important text on the Medicaid Reference Desk is accompanied by recorded speech that can be played by selecting a control next to the text. An additional control allows the user to see a video recording of someone reading the associated text. This is helpful to users whose understanding may be enhanced by seeing the words spoken. Also, because the reader is a self advocate, the video helps to reinforce the idea that the content on the site, unlike most material on the Web, really is intended for people with cognitive disabilities to use.

Making a Record of Choices. Services described on the Medicaid Reference Desk address a wide variety of needs, related to work, health, community, and home life. A consumer may find it difficult to keep track of what needs they have, and what preferences they have for meeting them. For example, in choosing a place to live many constraints (such as access to public transportation) and preferences (for example for noise level) have to be considered. The site includes a planning tool that uses a structured questionnaire to guide a consumer through some of these choices, giving them a chance to express and record their constraints and preferences. The consumer can then use this record in conversation with agency staff about support programs that can meet their needs.

Control of Font Size. Because many people with cognitive disabilities have some vision problems, the site includes a control that selects larger type.

3 How Cloud Computing Can Improve Web Access

Today, the helpful features found on theDesk only exist on a handful of sites. Simple navigation and understandable text are available only when site designers deliberately create them, and can't be provided by a technical fix, whether based on cloud computing or not. Other features, however, could be provided, or provided more easily, by creating and using cloud computing infrastructure.

User Preferences should be Supported by Profiles in the Cloud. A few sites, like the Medicaid Reference Desk, provide font size controls. Some users have figured out how to configure their browsers to increase font size. But these adjustments require extra work for users who consistently need large fonts (for example, font size controls on Firefox are reset when one enters a new URL.) A superior solution would allow users to create information presentation preference profiles, stored in the cloud, and accessed whenever the user accesses any site, from any device. The Global Public Inclusive Infrastructure initiative (GPII, [2]) aims to develop this infrastructure.

Cloud Services Can Make Audio Presentation Widely Available. As mentioned, the Medicaid Reference Desk includes controls that request that important text be presented in audio form. Doing this required a great deal of work by the site creators, and requires maintenance whenever content changes, since the audio form is recorded speech, not synthetic speech. Most operating systems, including those on phones, include features that provide text to speech conversion, but these features do not always work with browsers. Tools like BrowseAloud (http://www.browsealoud.com/) or WebAnywhere (Bigham et al. [3][4]);) make it possible for any text, on any Web site to be read at user request, freeing the developers of individual sites from the need to support audio presentation. These tools work by sending content from a Web page to a text to speech service running in the cloud, that is, running on a computer accessed via the Web.

These services cannot deliver all of the benefits that the Medicaid Reference Desk supplies. As mentioned earlier, the Medicaid Reference Desk can supply video of someone reading the text, something not now provided by the tools just mentioned. Nor do these tools present the material as it is read by a self advocate. Future versions of these tools, however, may come quite close. There are presentation tools that can show an animated speaker, whose mouth moves to show how the speech is formed (Cole et al. [5]). It may be possible to tune these tools, and the underlying speech generation, to approximate the speech of a self advocate.

Definitions Can be Provided from the Cloud. The definitions of terms provided by the Medicaid Reference Desk have to be created manually by the site designers, posing the same challenges of cost and maintenance as audio presentation. Here again cloud-based tools can eliminate, or at least reduce, this burden. The BrowseAloud tool system mentioned earlier includes the ability to select any term on a page and receive a definition, and there are several browser addons that offer similar support.

As the example of the definition of "waiver" shows, however, a generic solution cannot solve all of the problems. Definitions for terms with special uses will have to be provided by site designers. This also means that definition services will have to allow generic definitions to be overridden in specific contexts. The BrowseAloud tool provides this capability: a site designer can provide definitions that are accessed in particular contexts instead of a generic definition.

Consumer Choices Could be Saved in the Cloud. As mentioned earlier, the Medicaid Reference Desk helps consumers to record their preferences for matters that can affect their choice of services. After making this record, a consumer is prompted to print a copy, email it to an address they type in, or save it on their own computer. For some consumers, none of these options is workable: they may not want to keep track of a printed record, they may find it difficult to remember and type an email address, and they may not have their own computer. But because of concerns for privacy, the Medicaid Reference Desk will not itself store the record (and it does not ask consumers to identify themselves.)

Privacy concerns are also raised by the information presentation preference profiles discussed earlier. Since such a profile may suggest information that consumers may not wish to make public, such as that they cannot read well, it is necessary that people be able to specify these profiles separately from personal identity information. A related requirement is that people be able to have multiple profiles, so that they can specify a profile in a context in which they must be identified, for example in accessing a bank account that could differ from a profile they might use when their personal identity is not known.

Given that appropriate cloud-based infrastructure has to allow users to control access to their personal identity, it will be possible for information such as the Medicaid Reference Desk choice record, to be stored and retrieved safely. The infrastucture can associate the stored information with the user, for future retrieval or sharing by them, without revealing their identity to the Medicaid Reference Desk. To do this, a user would authenticate with the infrastructure, which would provide a code to the Medicaid Reference Desk that contains no personal identity information but allows the infrastructure to identify the user. The Medicaid Reference Desk would store this code with any data recorded for that user. In a future interaction the user would again authenticate to the infrastructure, which would use the same code to identify the user to the Medicaid Reference Desk, so that the Medicaid Reference Desk can retrieve and display the stored information for that user.

4 Other Applications of Cloud Infrastructure

As well as being one of the creators of the Medicaid Reference Desk, Ward is herself a user of computing services. The cloud infrastructure sketched here can provide useful support for her, and others like her, in the user role.

Automatic Configuration of a Range of Devices. Control of font sizes is important for things other than Web pages. Ward uses smartphone devices, and needs large font display on these. Today, changing to a new phone is a painful process, requiring someone to figure out how to adjust the font on the new phone. In principle, configuring a new phone, like displaying a Web page, could be governed by profile information stored in the cloud.

Providing Ready Access to Personal Information. Like many people, Ward maintains and uses an “Instruction Book”, containing information about how to do tasks that she doesn’t need often enough to have learned thoroughly, such as how to scan a document. If she is away from home, and doesn’t have the book, there is usually some one she can ask for help. But, as she says, “Why should I have to ask for help?” Her instruction book could be stored privately in the cloud, accessible wherever she is.

Remote Assistance. Ward and her co-workers use GoToMyPC [6] , a PC tool that allows another person to see the screen of Ward’s computer and control it, to help her get unstuck if can’t work out how to do something. For example, Ward uses Google Calendar (a cloud-based service), but can’t always find the control needed for a function, such as specifying a repeating event. Today, such tools work only for particular devices, for example not for Ward’s phones. Can future infrastructure provide uniform support for this common need?

5 Conclusion

Computing and communication services have gone through a number of paradigm changes over the decades (for a review of changes relevant to human-computer interaction see Grudin [7]). Some technology leaders argue that the shift of services into the cloud will be one of the most significant (Coleman [8], Ozzie [9]). We’ve used the Medicaid Reference Desk, and some personal experience, to illustrate what this shift can mean to people with cognitive disabilities.

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Adaptive Mouse-Replacement Interface Control Functions for Users with Disabilities

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Abstract. We discuss experiences employing a video-based mouse-replacement interface system, the Camera Mouse, at care facilities for individuals with severe motion impairments and propose adaptations of the system. Traditional approaches to assistive technology are often inflexible, requiring users to adapt their limited motions to the requirements of the system. Such systems may have static or difficult-to-change configurations that make it challenging for multiple users to share the same system or for users whose motion abilities slowly degenerate. As users fatigue, they may experience more limited motion ability or additional unintended motions. To address these challenges, we propose adaptive mouse-control functions to be used in our mouse-replacement system. These functions can be changed to adapt the technology to the needs of the user, rather than making the user adapt to the technology. We present observations of an individual with severe cerebral palsy using our system.

Keywords: Adaptive User Interfaces, Video-Based Interfaces, Camera Mouse.

1 Introduction

We present adaptive mouse control functions for use in video-based mouse replacement interface systems by people with severe motion disabilities. Our target user population is generally non-verbal and has some voluntary control of their head motion, but are unable to use traditional interface devices such as mice or trackballs. We track the user's head or facial feature positions to control mouse pointer movement on the screen. Head or facial feature positions may be detected by camera-based systems such as Camera Mouse [1, 4] or SINA [10], or by infrared head-trackers (e.g., [Boston University Computer Science Department Technical Report, February 2011.
1]). Motion of the head or tracked feature in the video frame is typically scaled by a constant factor and transferred to control the mouse pointer movement. This scaling factor enables configurable faster or slower mouse pointer motion.

Our experience with users showed that they were often not able to move their heads in all directions. This resulted in constricted motion of the mouse pointer when mouse pointer control functions with constant scale factors were used. With an adaptive function, the user is able to move the mouse pointer to all positions on the screen

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with head movements that are most comfortable. In this paper, we describe our experiences with various groups of individuals with motion impairments who present unique challenges to our assistive technology system. We then propose adaptive mouse control functions that address these challenges.

One way to address the problem of varying user movement abilities is to design adaptive user interfaces [5, 7]. Such interfaces can change their configuration to better suit the individual user. We previously proposed adaptive mappings [9] to solve this problem. This paper presents an extension of that work and includes a user study of the adaptive function system implemented within the Camera Mouse.

2 Interactions with Intended Users

The intended users of mouse substitution interfaces are people with severe physical disabilities. Mouse substitution interfaces are most beneficial to those who retain the ability to control their head movements, but do not have control of their extremities. We have been able to observe several distinct groups of people with such severe paralysis. Although each individual person may face their own challenges in terms of working with a computer-vision-based interaction system, some common challenges may be observed.

2.1 Adults with Degenerative Conditions

We visited a residential care facility in Dorchester, Massachusetts, called The Boston Home [3], several times in order to test and observe HCI systems such as the Camera Mouse. The residents of this facility were adults with Multiple Sclerosis (MS) and other progressive neurological diseases. The people we have met are generally adults who have spent much of their lives without disabilities. Some of them are very familiar with technology and are accustomed to working with computers. Some of these people have sufficient motor control so that they remain mobile, e.g., controlling a wheelchair, by interacting with a computer via a mouse or other input device. Residents with the ability to speak may use speech recognition software to control computer software and dictate emails. Due to the nature of degenerative diseases, the physical capabilities of the residents can change over time, presenting us with the challenge to develop and maintain assistive technology capable of adapting to changes in physical abilities of the user.

We observed several people interacting with the Camera Mouse and other HCI systems. We were particularly interested in each subject's range of motions and ability to repeat motions with their heads. Through these observations, we discovered that some of our assumptions about how people with severe motion impairments move and position their heads while interacting with video-based HCI systems did not apply to all users. For instance, one subject we observed had difficulty holding her head in an upright position. Another subject was able to turn her head further in one direction than the other direction.

Many people in The Boston Home care facility have some ability to speak, which makes speech recognition software a useful tool. This is often used in writing emails. It is notable that the software is set up so that users dictate their messages directly into the email program, thus granting them privacy (instead of dictating the message into a text-entry program that the care giver then cuts and pastes into an email program). Even when a person's speech becomes slurred, modern speech recognition software can adapt to allow this dictation to be relatively successful.

We learned from this experience that completing a task without assistance is rewarding for people with disabilities, when help is needed for so many other tasks. The small amount of privacy gained by dictating one's own email messages, even when speaking becomes difficult, is important in an environment where privacy is often not possible. Also important to note is the surprising level of usefulness of speech recognition technology even for people with limited speech abilities.

In 2008, the Camera Mouse was not used at The Boston Home due to staffing limitations. The Camera Mouse version available at the time required an assistant to be present throughout the computing session. The assistant would have to manually select the feature to be tracked on the user's face and reset the system if a loss of feature occurred during tracking. The Boston Home did not have the staff available to actively monitor users of the system and to help the system to recover if the tracking failed.

2.2 Adults with Stable Conditions

We have completed an extensive case study with an adult with Cerebral Palsy whose condition has been stable for a long period of time. This user has been especially helpful in facilitating our understanding of the challenges we face in developing human-computer interaction systems for people with severe motion impairments.

The participant of our study has developed his own method of communicating with others via subtle head movements. Because of the nature of his disability, he has some involuntary motions, specifically with his arms and head. When he uses the Camera Mouse, the involuntary head movements sometimes cause the mouse to move without his intention. This can be especially problematic when the participant tries to select a button on the screen by using the dwell time function of the mouse replacement system. We also observed that the participant has some difficulty moving his head precisely horizontally or vertically while using the Camera Mouse to control a mouse pointer.

2.3 Students and Small Children

The Boston College Campus School [2] provides education and therapy for students with multiple disabilities. The students we observed at the Campus School were familiar with various assistive technologies, including the current version of the Camera Mouse. The Camera Mouse system was originally developed for and tested with some of the students at the Campus School [1]. While the main goal at the Campus School is education, assistive technology is also being used as therapy to refine motor control as well as a tool to enable communication for nonverbal students.

The Campus School environment presents its own set of challenges and opportunities for developers of assistive technology. Some students have cognitive disabilities in addition to physical limitations. Some of the young children may be learning about their own motor control as they use the technology. When using the Camera Mouse, students may learn that their head movements correlate with the movements of the pointer on the screen. Some of the students at the school have Cerebral Palsy and their movement capabilities are unlikely to worsen over time. Some of the students have extremely limited motion abilities which severely restrict the direction and distances they are able to move the mouse pointer with the Camera Mouse.

2.4 Summary of Observations

By observing these diverse subjects, we have learned much about which assumptions about HCI systems for people with motion impairments can safely be made and which assumptions cannot. What had worked well in tests with able-bodied graduate-student subjects may not work well with people with disabilities. In one experiment, we had assumed that the users would hold their head upright while our computer-vision interface system looked at their eyes. We quickly learned that this was a reasonable assumption for able-bodied users of the interface, but not for users with severe motion disabilities. Some people with spastic cerebral palsy have involuntary movements of their head. Others, who did not have the strength to fully control movements of their head, often positioned their head at an angle.

3 Experiences with Users

In the traditional Camera Mouse, mouse motion is inferred from the apparent motion of the user's facial feature within the image plane of the camera. Specifically, the system assumes that if the user wants to move the mouse pointer directly to the left, then the tracked feature will move left in the image plane. However, our observations of users with disabilities have shown that they may not be able to comfortably hold their heads in a vertical position. This results in tilted head motion from side to side when the intended mouse control is horizontal. As a result the mouse cursor moves in a diagonal direction.

In two initial experiments, we recorded the mouse trajectories of an adult subject with cerebral palsy using the Camera Mouse. In the first experiment, circular targets appeared on the screen and the user was asked to move the mouse pointer to the highlighted target. Sometimes the user was able to position the mouse pointer near the target relatively quickly. Then he only needed to move the pointer a short distance horizontally or vertically to reach the destination. However, the recorded trajectories showed that he failed to make these short horizontal or vertical movements several times and instead moved the pointer in a diagonal direction, missing the intended target.

In a second experiment, we asked the user to move his head left and right while he was not directly controlling the mouse pointer. The aim of this experiment was to determine if his natural sideways motions, performed without the need to control the pointer, would differ from his motions when he intended to move the pointer (Fig. 1).

We observed that his natural horizontal head motion in general had a diagonal component to it. In addition, he altered this movement with an upwards motion when he neared the extremes of his left and right motions. This analysis of the user's motion trajectories suggests that the linear pointer control function of the traditional mouse-replacement interface, which uses constant scale factor, may not be best suited for this user and an adaptive approach should be tested (Fig. 2).

Fig. 1. A user conducted an experiment where he moved his head left and right. The exaggerated white line indicates the motion of his nose feature.

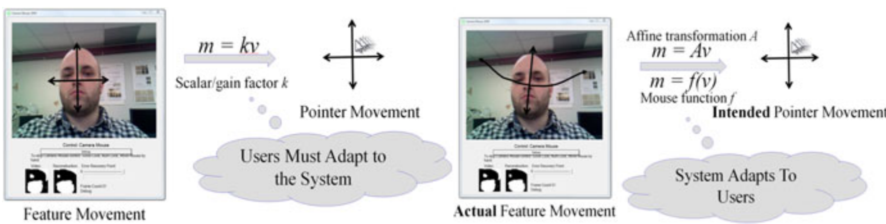

Fig. 2. Conceptual design of pointer movement functions. In a traditional mouse-replacement system, the mouse control function maps the facial feature motion linearly to the mouse pointer motion on the screen (left). In an adaptive system, the user's head motion is transformed into the intended mouse motion with a nonlinear function.

4 Mouse Mappings

We present a framework for modifying the pointer-movement control function of the traditional mouse-replacement system. In particular, we explored whether off-axis motion (i.e., motion that is not horizontal or vertical) can be compensated for. This would increase the usability of the interface for people who cannot easily move their heads in exactly horizontal or vertical directions. A seemingly straightforward solution to this problem would be to rotate the camera to the same angle as the user's head is tilted, or to provide the same functionality in software. However, our initial observations indicated that the users' motions were complex and required a more complicated analysis of the intended mouse motion. Based on our observation of users, we propose the functions shown in Figure 3 as alternatives to map facial feature movements into mouse pointer movements.

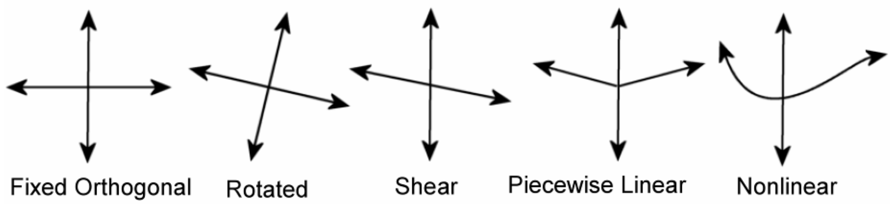

Fig. 3. Adaptive pointer-movement functions for mouse-replacement systems

In addition to alternative mappings based on movement in the image plane, we build upon work that explored a multi-camera system that analyzed motions of the user in three dimensions [8]. An experiment was conducted where users of the Camera Mouse system moved the pointer between targets while their motions were recorded with a multi-camera system. An analysis of feature trajectories shows motions in three dimensions (including towards or away from the camera) that are ignored by the traditional two-dimensional image-plane feature tracker.

The interface creates mouse motion in screen coordinates S. The two-dimensional system bases the movement on tracking a feature in image coordinates I, which is a projection of three-dimensional world coordinates W. The current approach relies on motions that are are aligned to the axes of the image coordinate system: $\delta S_x = K_x \times \delta I_x$, $\delta S_y = K_y \times \delta I_y$ for some constant gain factors K_x and K_y. The horizontal and vertical components of mouse motion in screen coordinate depend *only* on the corresponding horizontal and vertical components of feature movement in the image coordinates.

We previously proposed a generalized mapping to an affine transformation matrix A that allows both rotation and shear along with scaling [9]. Here, we propose mouse-pointer motion functions f that take into account additional information, such as both components of movement to create a tilted or rotated motion function $\delta S = f(K, \delta I)$, or the absolute coordinate of the screen pointer to create disjoint or curved response functions $\delta S = f(K, \delta I, S)$. If world coordinates can be estimated, they can be used to provide other response functions that take into account the user's motions in three-dimensions $\delta S = f(K, \delta W)$.

5 User Experiment

We invited the test subject mentioned above to participate in another experiment. Our previous analysis revealed that the user tended to tilt his head and that his motion had a diagonal component when he intended to move the mouse pointer simply horizontally. For an experiment with this user, we developed a pointer movement function that compensates for diagonal motion:

$$\delta Sx = fx(K, \delta I) = Kx \times \delta Ix \tag{1}$$

$$\delta Sy = fy(Ky, \delta I) = Ky \times (\delta Iy + D x \delta Ix) \tag{2}$$

$$D = \{-0.5, -0.25, 0, 0.25, 0.5\}, \quad (3)$$

where the diagonal factor D in the pointer control function defines how much diagonal compensation will take place. This compensation causes the mouse pointer to move up or down by a factor relative to its horizontal motion. This function can therefore be used to compensate for diagonal head motion when horizontal mouse motion was intended. When D=0, the function reduces to the linear scaling function of non-adaptive traditional mouse-replace systems. For constant values other than 0, the function defines a shear function (see Fig. 3).

Other adaptive functions can be obtained by dynamically modifying the parameter D in Eqn. 2. We can define a piecewise linear function that moves the mouse pointer differently on the left and the right side of the screen. This can be accomplished with a negative D when the mouse pointer is on the left half of the screen, and positive on the right half. The non-linear response function is similarly obtained by varying D with the horizontal distance from the center of the screen.

As part of our experiment, we asked the participant to use a paint program and to move his head left and right while the program drew colored boxes under the mouse pointer (Fig. 4). We attempted four settings of the adaptive mouse function and observed the resulting mouse trajectories. With the constant setting of D=0.5, the user was more easily able to create a horizontal mouse motion compared to the control setting of D=0.

Once we settled on a setting for the adaptive mouse control function, we experimented with two additional user programs with this subject. In the first program, called MenuController [11], large buttons along the top of the screen are used to

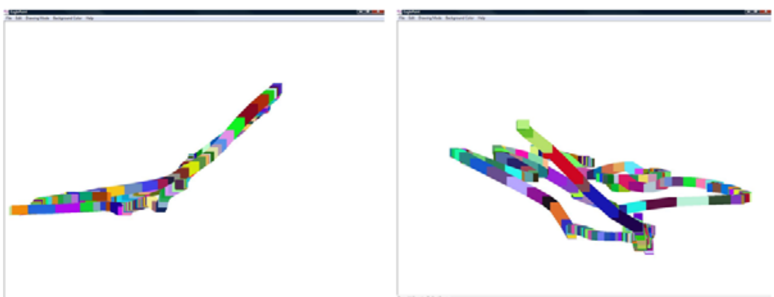

Fig. 4. Screen shots of two paintings made by the quadriplegic participant of our user experiment whose left and right head motion was interpreted by the Camera Mouse interface and controlled a paint program. Two versions of the Camera Mouse were used, a version with the traditional, non-adaptive mouse control function, i.e., D=0 (left) and a version with the adaptive mouse control function with D=0.5 (right). The non-adaptive mouse control function could not compensate for the significant diagonal motion in the mouse pointer that the user had not intended (left). The adaptive mouse control function compensated for some of the diagonal motion, producing a more horizontal mouse motion as the user had intended (right).

Fig. 5. Screen shot of the Camera Canvas photo editing program for people with motion disabilities

control window menu functions. The user had difficulty reaching these buttons at the end of this session. The user also used the Camera Canvas [6] program which has a configurable user interface with large buttons (Fig. 5). He was able to reach these buttons more easily. These last two experiments were near the end of the session and the subject was becoming fatigued.

Our experimental setup is shown in Fig.6. The user looks at a monitor while a webcam and the Camera Mouse control the mouse pointer. We also recorded his motions with a two-camera thermal infrared system and a four-camera visible light system for future analysis.

6 Discussion and Future Direction

Adaptive pointer control functions can help users with limited motor control use mouse replacement interfaces. The ability to adapt the program to the user rather than requiring the user to adapt to the program is important for users who cannot move in certain ways or who become fatigued when moving in a way that is not comfortable to them. We suggest that adaptive interface systems are beneficial for users whose condition changes between sessions or even within sessions as they experience fatigue. Additionally, adaptive interfaces would be useful when different users at a care facility need to share the same system.

We plan to continue developing adaptive pointer control functions and extend our user study to additional individuals so that we can measure the efficacy of our methods. In addition, we have captured user sessions with a stereoscopic thermal infrared system, and a four-camera visible-light system for analysis of movement trajectories (Fig. 6). We plan to use this data to help develop mouse control functions that take into account the user's motion in three dimensions so that their intended mouse pointer movement can be better inferred.

Fig. 6. Experimental setup. The user is placed in front of a computer screen with a webcam capturing his motions to enable mouse pointer control. We simultaneously recorded his motions with a two-camera thermal infrared system and a high-speed four-camera visible-light system for future analysis.

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A-Cross: An Accessible Crossword Puzzle for Visually Impaired Users

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Abstract. Crossword puzzles are a very popular word game, with high recreational and educational value, which can also be used as mental work-out tools, assisting in the prevention of age-related diseases, such as Alzheimer's disease. Despite their high value and although users with visual impairments constitute an important market share, there are only few accessible crossword puzzles. Even these, however, are limited in providing alternative input and output modalities for users with disabilities and do not support equitable use, simplicity and intuitiveness, especially for blind users. This paper presents A-Cross, an accessible crossword puzzle for visually impaired users, aiming to support word solving in a novel and usable way. The evaluation process that was followed in order to assess the usability and accessibility of a functional yet early prototype of the A-Cross puzzle is also described.

Keywords: Accessible, crossword, visually impaired, blind, puzzle, game, evaluation.

1 Introduction

Crossword puzzles are a very popular word game, dated since 1913 when they first appeared in the Sunday New York World. Ever since they have spread worldwide, to the point that almost every newspaper nowadays includes a crossword puzzle, while several dedicated books and monthly magazines are being published and purchased by an enthusiastic audience. Modern versions of crosswords include computer games, which beside their recreational character, may also act as educational tools and as mental work-outs.

Crossword puzzles have been employed for educational purposes since the 1920s [11]. Childers [3] reports the use of crosswords in an introductory sociology course as an exercise that would help students identify those areas in which they needed additional work, and as a device to help them study for the final exam. Childers also discusses the evaluation that was carried out with 99 students, regarding the use of crosswords. According to the results, 96% of the evaluation participants found

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crosswords helpful, 47% reported their usefulness in studying for the final exam and 26% stated that crosswords helped them identify areas for further study or clarified certain concepts. Franklin et. al [5] used games and puzzles as a tool for stimulating class discussion of study topics and concluded that crossword puzzles are useful aids to learning. Weisskireh [16] used crossword puzzles as exam review tools and concluded that an appropriately designed crossword puzzle can provide an easy and engaging way for students to review concepts when preparing for a test. Wise [18] discusses the use of crossword puzzles as a tool for students' self-assessment, and reports positive student attributes and their unanimous confidence that crosswords could be employed by teachers to support learning.

On the other hand, the use of crosswords as memory aids is also widely recognised and an important corpus of research has been devoted to this area. For example, a study that was carried out with 801 participants between 1994 and 2001 analysed participants' cognitive activity and Alzheimer's Disease (AD) incidents and reported that frequent participation in cognitively stimulating activities (which include crossword solving) is associated with reduced risk of AD [17]. Another study [14] carried out with 469 participants between 1980 and 2001, reported that elderly persons who did crossword puzzles four days a week had a risk of dementia that was 47 percent lower than that among subjects who did puzzles once a week.

Given the high value of crosswords as recreational, education and mental work-out tools, their accessibility is of high importance for people with disabilities, who constitute an important market share [4, 15, 19]. Crossword accessibility is an interesting issue for blind users, who need alternative access to the game content, but also to understand the relations between words and to receive appropriate feedback regarding the input that they have provided and in general about the results of their actions. Although there are some crossword puzzles aiming to be accessible for blind users, their main problem is that they only provide alternative output through audio and access through keyboard, instead of also facilitating users in understanding how words are interrelated in the crossword and assisting them to create a representative mental model of the crossword.

This paper presents A-Cross, an accessible crossword puzzle for visually impaired users, aiming to support word solving in a novel and usable way. The next sections provide a discussion of accessible crossword puzzles for blind users, present the A-Cross puzzle and describe the evaluation process that was followed in order to assess the usability and accessibility of a functional early prototype of the puzzle. The last section of the paper discusses the conclusions from the conducted work and highlights future plans.

2 Accessible Crossword Puzzles for Blind Users

Several crossword puzzles are available online on the web or as standalone applications, few of which however are accessible to blind users. The main accessibility needs of blind users typically include audio output, as well as keyboard access to the application functionality, but the mere application of these techniques is not adequate to constitute a crossword puzzle genuinely accessible to blind users. In order to illustrate the above, three accessible crossword puzzles are further studied and their main accessibility features are presented in detail.

Talking Word Puzzles [1] is a puzzle application aimed at blind and visually impaired computer users. Output to blind users is inherently provided through speech, without the need for specialised software, mainly by announcing the clue that the user has selected to solve, as well as the letters typed by the user when solving a clue. Furthermore, when a clue is announced, the number of letters composing the correct solution is also declared. Navigation is supported through keyboard, namely with the Tab key, which moves the focus to the next clue, and the Enter key, which moves the focus from a clue to the corresponding crossword field, allowing the user to type the solution. It should be noted that the standard crossword format is retained, and therefore clues are organized in two dimensions, across and down, while each clue is identified by a number. Alternatively, users may navigate in the crossword grid, using the arrow keys, while the application announces each letter the cursor crosses. If there is a number in the square to which the cursor moves, indicating the beginning of a new word, the program announces that number, too. At that time, the user can directly move the focus from the grid to corresponding clue, by pressing the Enter key. Finally, the user may retrieve information regarding the number of remaining words in order to solve the puzzle.

Tackle Reading Crossword Puzzle [6] was developed for elementary school children, providing keyboard access and screen reader support for blind students. Users can access the clues' list sequentially through the Tab key, while at any time they may easily access a clue related to the active one, using the arrow keys. Two clues are related if their answers are crossing each other on the crossword grid.

Finally, the Blind Gamers (BG) Crossword puzzle [2] provides keyboard support and speech output to users without the need for a screen reader. Players are first presented with the "across" clues list and can change to the "down" clues' list by selecting an appropriate keyboard shortcut. At any time during the game play, players may switch to the related clues intersecting the currently active word, through an appropriate keyboard combination. Overall, the game provides to players a large number of options aiming to enhance its accessibility and usability; however, this is achieved through a large number of keyboard shortcuts, which may cause frustration to beginner game users. Another important drawback that has been noted is that if there are already filled-in letters for the word that currently receives focus (e.g., if some of its intersecting clues have been solved) the existing word data are not announced to the player and as a result the solving process may advance more slowly.

Careful reviewing of the aforementioned accessible crossword puzzles indicated that, although it is possible for the target user group to interact with the game, there are several concerns that should be taken into account, in order for the game to be actually usable. A-Cross was designed with these issues in mind, aiming to be both accessible and highly usable by blind users.

3 The Design and Development of A-Cross

A-cross was designed with the aim to cater for blind users' needs, having in mind not only to provide an accessible interface, but also to adhere to the "Design for All" principles [13]. Particular attention was therefore paid in order to create a crossword that would ensure equitable use, simplicity and intuitiveness for the specified target group.

In this context, the crosswords concept as well as issues regarding their representation on a grid were revisited and assessed in relation to the blind users' needs. In more detail, the simple spatial representation of words in the two dimensions, which is a concept tightly related to crosswords, turned out to be ineffective for blind users. As a result, a challenge during the design of A-cross was to provide blind users with information equivalent to all the visual hints conveyed to sighted users by the actual crossing of words on the grid. Furthermore, additional cues obtained by sighted users, such as which letters have been already filled in for a word, or the number of letters constituting a word, should also be effectively communicated to blind users of A-cross, allowing them to develop an efficient strategy for crossword solving.

In order to address the aforementioned issues, A-cross does not only provide clues classified in two dimensions (across / down), clues are instead presented according to their relevance to the currently solved clue. The term relevance is used here to denote all the words that actually cross the current word the user is solving in a typical crossword grid. Therefore, an algorithm for the automatic suggestion of the next clue to be announced is applied, allowing blind users to efficiently solve the puzzle. As illustrated in the algorithm flowchart in Fig. 1, if the current clue has been solved, then the next related unvisited clue with the fewest missing letters is automatically suggested. Unvisited clues are considered those which the user has never listened to before. If the user wishes to move to the next clue without solving the currently suggested one, then the same decision making process is followed. When there are no related clues available, then the next sequential clue in the clue list is suggested.

Additional features of A-cross aiming to improve its usability and accessibility include:

- Automatic announcement of the number of letters constituting the corresponding answer, when a clue is announced
- Automatic announcement of the letters that have been already completed for a clue, by solving other related clues
- Audio feedback for the correct answer to a clue
- Audio feedback for correctly typed letters when answering a clue. This feature can be activated or not, according to each individual user's preferences
- Elimination of the already solved clues from the clues list. This is an important feature, aiming to speed up the crossword solving process, by discarding all the unnecessary information. The reasoning behind this feature is to simulate the mental model of a sighted user, who would not revisit a correctly answered clue. This feature is initially automatically enabled, however users may disable it.
- Enlarged interface for low vision users and high color contrast interface for color blind users.

It should be mentioned that A-cross was designed and implemented as a dual user interface [9], allowing access to both sighted and blind users at the same time. Currently, a fully interactive prototype of the game has been implemented, in order to allow its evaluation. The implementation was carried out in C# with Microsoft Visual

Studio 2010, while the text to speech facilities required for the narrator are available through the Microsoft Speech API 5.3[1]. Keyboard navigation is supported for blind users through the TAB and arrow keys (for lists).

Once the game is installed, the default settings have the narrator enabled, ensuring first-time access for blind users. Players may disable the narrator and adjust the visual layout according to their preferences when creating or editing their player profile (Fig. 2a). Additional profile options include high color contrast and interface enlargement, in order to make the game accessible for color-blind and low vision users. Furthermore, every time the game is initiated, it considers as active the last

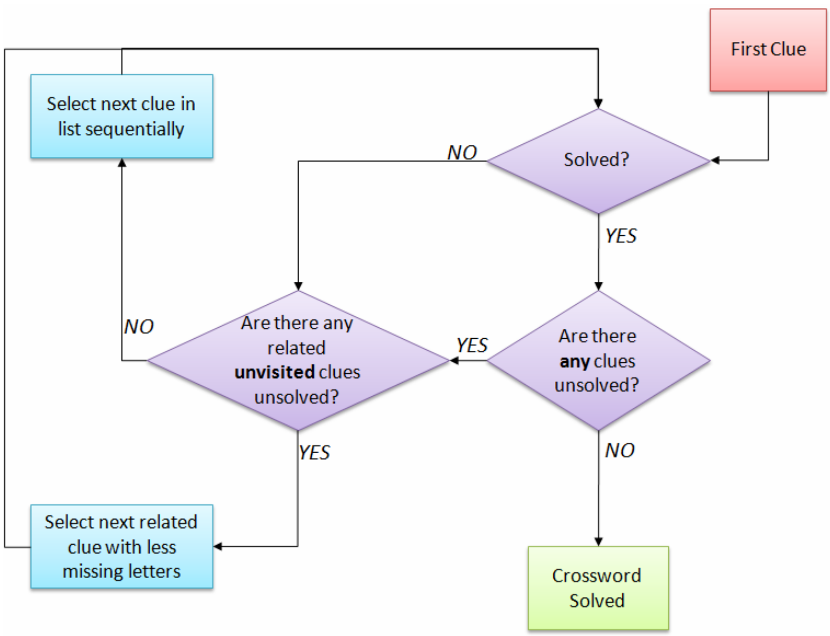

Fig. 1. Flowchart presenting the algorithm for the automatic suggestion of the next clue to be solved

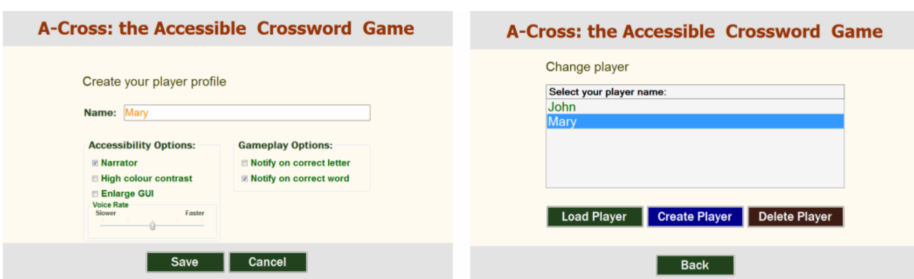

Fig. 2. (a) Creation of new player profile **(b)** Player selection

[1] http://msdn.microsoft.com/en-us/library/ms723627%28v=VS.85%29.aspx

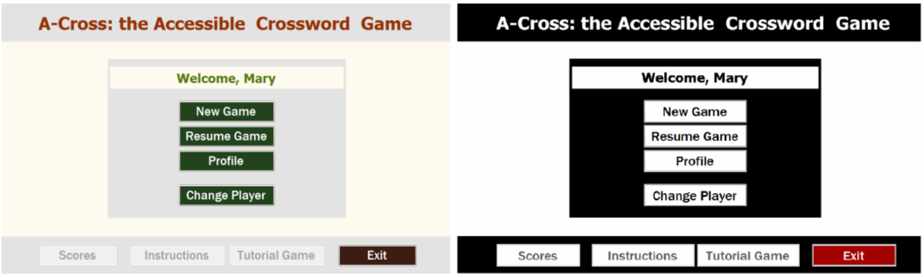

Fig. 3. Main menu **(a)** standard **(b)** high color contrast

player's profile. Users are however allowed to change (Fig. 2b) the current player profile through an option in the main menu (Fig. 3).

Players are able to select the game they wish to play through a list of available crosswords. In the main game screen (Fig. 4) a horizontal menu allows users to pause the game, solve the game, get letter or word hint, change their profile settings (e.g., enable / disable the narrator), change volume settings and return to main menu.

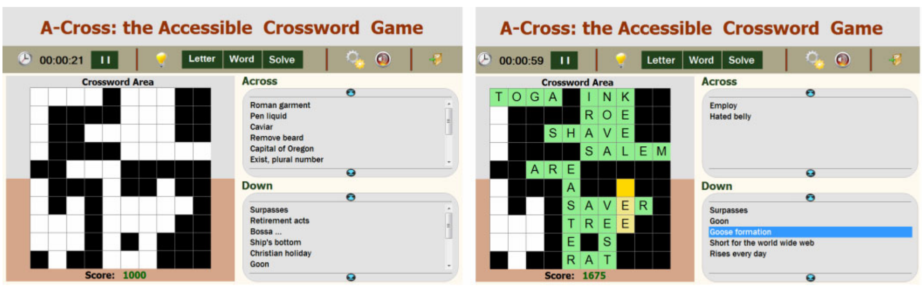

Fig. 4. Crossword screen **(a)** no clues solved **(b)** the word clue lists get smaller as the user solves the puzzle

The A-cross prototype is deployed with four crosswords embedded. However, an important feature of A-cross is that the supported crosswords are not hard-coded; instead, they are available through external .xml files, allowing thus updating A-cross with an infinite number of new crosswords.

4 Usability and Accessibility Evaluation of the A-Cross game

Once the first working crossword puzzle prototype was developed, an expert based evaluation was conducted in order to test the game application against usability and accessibility standards. Expert and cognitive walkthroughs are two of the methods of expert based evaluation which involve having one or more accessibility/usability experts interact with the application looking for accessibility and usability problems and areas that may potentially cause confusion and trouble to the user [10]. Expert based evaluations are very valuable for identifying most usability and accessibility issues before conducting real user based evaluations. They also serve as a good alternative when it is difficult to find actual or potential users for evaluation [12]. The A-cross crossword puzzle was designed primarily for use by users with blindness, partial blindness, and other vision impairments. Considering the fact that finding local users who are blind, have some computer experience, and speak English is not an easy task, when such testers are found, it is imperative to make the most out of their testing experience and not waste their time with obvious inefficiencies that could have been caught by an accessibility expert. Thus, at this preliminary stage of the application life cycle, expert based evaluation was chosen as the method of testing and user based testing with blind users was reserved for a later stage after the first improvements and adjustments are made on the game.

4.1 Expert / Cognitive Walkthrough

The evaluation was conducted by three usability and accessibility experts. Each one of them carried out a thorough inspection of the game functionality and overall design and wrote their findings in a report. The discovered problems were then aggregated on a single report, and each item was rated individually by each expert using a scoring scale from 0 (not a usability problem) to 4 (usability catastrophe) [8]. An average score was given for each item on the list. The most severe issues found by the experts are discussed in more details below.

Expert Evaluation Results. The evaluators found a total of thirteen issues that a blind user might encounter. Of those thirteen issues, three of them were rated pretty high (received an average score of greater than 3.5) on the scoring scale and their resolution was thus deemed of critical importance. These issues are described below:

- *Issue 1. Severity score= 4:* There are no clear instructions for the blind user on how to proceed with solving the puzzle once it is loaded. In particular, when the puzzle gets loaded the narrator says "The game started. This crossword puzzle has 21 word clues that you need to solve. Happy Gaming". Since proceeding to the crossword area and interacting with the clues is carried out with the arrow keys and not the TAB key which is reserved for the menu options (pause, hints, settings), the blind users may be confused and not able to proceed. The experts recommended that the problem would be easily solved by including brief instructions on how to proceed to the game after the initial message.
- *Issue 2. Severity score=3.83:* Another point that received very high marks by all experts is that there is no easy or obvious way for the user to have the word clue repeated to them on command after it is read by the narrator the first time. Considering the fact that the spoken output by the narrator is not always clear, such a function becomes imperative. The experts noted that the omission of this functionality will frustrate the blind users who want to be able to go back and forth in a sentence if they don't understand it the first time. A shortcut key (Ctrl + R) that would repeat the last word clue was suggested as a remedy.
- *Issue 3. Severity score= 3.63.* As shown in Fig. 4, A-Cross provides the users with two help options, namely to reveal a letter and to reveal a word. Although the hint is provided to the user, the system does not provide appropriate feedback regarding the letter or the word that was solved, creating confusion to blind users. Besides,

announcing the requested letter or word after it is filled out by the system, experts also suggested not having the system automatically move to the next word clue, but allow the user to do so at his/her own time.

- *Issue 4. Severity score = 3.16.* Experts noted that although the A-Cross layout resembles a regular crossword, there are no numbers marked either on the crossword area, or next to the word clues.

Other suggestions included minor graphical user interface improvements, the addition of keyboard shortcuts for instant access to game options during crossword solving (e.g., voice volume, speed of speech) and elimination of a few functional errors that occurred.

Features of A-Cross that were positively commented by the experts include the simplicity of the graphical interface, the simplicity of keyboard alternatives, as well as the expected learnability and ease of use even by beginners (once the identified problems will be eliminated).

Finally, one question raised by the experts was if the A-Cross model matches the mental model of players, since for example the next word to be solved is automatically suggested by the game or since once a word clue is solved correctly it disappears from the clues' list. However, the mental model of blind players could not be adequately estimated by the experts and a user testing was deemed necessary in this respect. An additional issue that user testing is expected to reveal involves the effectiveness and efficiency of the narrator, in order to provide appropriate guidance and feedback to blind players.

As already mentioned, plans for user-based testing on A-cross are in the near future and after the first round of improvements on the design of the game has finished, given that usability testing is the most fundamental evaluation method, because it provides direct input on how the user perceives and interacts with the application or interface that is being tested [7]. However, one user based test with a blind user that fit perfectly the profile of a game user was conducted after the expert evaluation was completed. Even though testing with one user is not enough to draw any final conclusions, it does help in confirming the experts' findings. The findings of that test are discussed in the next section.

4.2 Preliminary User Testing with Blind User

The user was a female in the age range of 25-30, very familiar with using assistive technologies on a computer and fluent in English. The evaluation was carried out in a usability evaluation lab and the session was recorded by a camera, after a signed permission was acquired by the participant.

Initially the participant was introduced to the purpose of the evaluation and was instructed to think aloud during each task, letting the evaluator know what she was thinking prior, during, and after each action. The experimenter asked the evaluator to carry out a number of tasks, which included the following: (1) Start the application and create a new user profile; (2) Select the puzzle "Easy" and load the puzzle; (3) Solve as many words as possible. When coming across a word clue that she did not know how to solve, the user was instructed to find a way to get a hint from the system; (4) Exit the application, restart it and continue from where it had been left off.

During the test the experimenter was observing and taking notes on what was happening. Once the process was completed, the user was debriefed and thanked for her valuable participation.

The results verified the findings of the expert-based evaluation, namely that the narrator did not provide adequate feedback when a word was solved and it was unclear when it moved to a new clue, and that repeating the requested word clue at user's will was essential. Furthermore, she noted that it mattered to a blind user to know if a clue was horizontal or vertical, otherwise there is no sense in having two lists and that they could have been in one list.

It should be noted, however, that a single user based evaluation is definitely not enough to draw conclusions, but it certainly affirms the need for more testing and confirms the experts' findings.

5 Conclusions and Future Work

This paper has presented A-Cross, an accessible crossword game for blind and visually impaired users. Aiming to enhance its usability and accessibility by blind users, the game automatically suggests the next clue to be announced to the blind player, by selecting the next clue related to the current word with the fewest missing letters. A fully interactive prototype of A-Cross has been implemented as a dual interface, and it has been evaluated by usability and accessibility experts and by one blind user.

The usability evaluation pointed out a number of usability and accessibility errors that should be corrected before proceeding to a user-based evaluation, which is among the future work plans. User testing is considered irreplaceable in order to successfully assess whether A-Cross meets its goals, and whether the proposed automatic clue suggestion algorithm addresses blind users' needs and ensures an efficient and pleasant gameplay.

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Access-a-WoW: Building an Enhanced World of Warcraft™ UI for Persons with Low Visual Acuity

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Abstract. World of Warcraft™ (WoW) is a virtual 3D game that offers much in terms of entertainment and collaboration and enjoys extraordinary world wide popularity. However like many other applications that deliver the majority of information visually, the default user interface (UI) is potentially only marginally accessible to users with limited visual acuity. This paper describes the enhanced user interface (UI) we constructed to improve accessibility for these users. We performed a study comparing the two user interfaces; users had simulated low visual acuity. The results of the study suggest that our enhanced UI led to significant improvements in user performance and speed of game play. Our current enhanced UI and planned future work have great potential for expanding opportunities for a user group to participate in the WoW community more fully than is possible with the current UI.

Keywords: Human-Computer Interaction, Accessibility, Accessible Gaming.

1 Introduction

Computer games and 3D virtual environments have become prominent entertainment mainstays with video game sales rivaling those of blockbuster movies. Besides pure entertainment value, these games and virtual environments can be utilized to offer educational services as well as a setting for multi-user social and gaming interactions. However, because these environments are visually intensive, users with low visual acuity may have difficulty successfully interacting with certain elements of the user interface (UI). Furthermore, many commercial products do not give the user the option, or means, to substantially improve the accessibility of the product to fit ones needs.

World of Warcraft™ [1] (WoW) is a 3D virtual environment that includes elements of social interaction, quest completion and combat. Unlike other virtual 3D environments, such as Second Life [2], that emphasize social interaction and educational services [3], the gameplay elements of WoW place demands on the user for fast processing of primarily visual information; the speed contributes to the challenge and fun of the game [4]. Further, the size of the WoW user base is almost two orders of magnitude greater than that of Second Life (11.5 million versus 250,000 [5][6]) indicating a broad appeal to a potentially diverse user population.

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Inside of the WoW environment, users interact with the virtual world by relying mostly on the visual information provided to them in their game environment. This is a serious constraint for users with low visual acuity and can severely hinder these users' ability to perform necessary in-game tasks such as successfully navigating around the world. Due to the visual nature of the default user interface in WoW and the quick pace of the game, users with low visual acuity may find it difficult to use information from the UI in real "game time", thus finding the game hard to play and the worldwide community difficult to join.

This paper describes an alteration to the default user interface of an existing commercial 3D virtual world, World of Warcraft. By creating an enhanced user interface, we aim to improve the ability of a user with low visual acuity to perform vital in-game tasks such as navigating the virtual space and completing combat-based missions. Our hope is that our modifications and design principles can be applied to similar virtual environments to afford users with low visual acuity the chance to engage in and join these virtual gaming communities.

2 Related Work

With the growing popularity of 3D games and virtual environments, there has been a substantial amount of interest toward improving their accessibility, assessing games at both the macro and micro level. On the macro level, current research focuses broadly on improving the overall state of 3D game and virtual world accessibility. Bierre et al. performed case studies evaluating the accessibility features available on numerous commercial games [7]. Their focus was to evaluate how game developers and individuals within the gaming community attack accessibility issues facing various disenfranchised users (e.g. deaf or blind users). Grammenos et al. describes the concept of universally accessible games (UAG) (i.e. games designed to meet the needs of all users without alteration for a specific set of users) [8]. They validated their concept of UAG by designing, implementing and evaluating a set of case studies.

On the micro level, researchers have focused on improving the accessibility of existing gaming platforms or developing games with an emphasis on accessibility. Trewin et al. describe *PowerUp* [9][10], a virtual 3D world designed with accessibility in mind. In the system, users are given the option of setting several different accessibility options, aimed to improve the experience for users with varying impairments. AudioQuake [11][12], is an updated version of the first person shooter Quake, designed to be playable by users who are blind or suffer from low visual acuity. Other games augmented to be accessible for visually impaired users include *Blind Hero* [13] and *Rock Vibe* [14], both of which use a combination of haptic and auditory feedback.

Prior research efforts have focused on rebuilding visual interfaces of social virtual environments for users who are blind or visually impaired, but they have not had the WoW constraint of keeping the underlying game fast and fun. Second Life, a commonly utilized platform, shares similar qualities to WoW (e.g virtual world navigation). However, unlike Second Life, WoW requires the user to engage in quick responses to changes in the game state (e.g combat). Conducted research in the Second Life environment has included adding screen reading technology [15], and enabling a command-based interaction [16] to the client software. Using haptics in virtual environments for users who are blind or have low vision has been explored [17], and Pascale et.al incorporated haptics technology into the Second Life software [18].

WoW poses a unique challenge as it encompasses elements of a 3D game and a large scale virtual environment. In order to keep the underlying gameplay elements fast and fun, the user must be able to receive and interpret the visual information in a timely matter. For users with low visual acuity, we have the opportunity to utilize their residual vision in order to display information visually [19]. By highlighting relevant information and removing non-relevant/distracting information from the screen, users will have a better chance of understanding and reacting to the visual data.

3 WoW State and UI Analysis

In WoW, each user has a 3D virtual avatar that completes quests and activities in a fantasy world. In this world, game state information from the UI: is context dependant, will vary throughout the user's gaming experience and is delivered to the user through a default UI (see Fig. 1). In the default UI there are two core sections that deliver the majority of information to the user: the open worldview screen and the action bars. The worldview screen has UI elements, such as the mini-map, that are spaced apart along the top and bottom edges of the screen, with the players' avatar located in the center. The action bars, located at the bottom of the screen, house clickable icons which represent the avatar's different abilities.

In general, the core game play of WoW consists of two states: navigation and combat. In the first, a user's primary concern is to effectively get from their current location to their destination; the main UI elements are the mini and world map. In the latter, the primary concern is to effectively kill their target while mitigating the amount of damage to their avatar; the main UI foci are: health, resources and combat abilities. Low visual acuity users may find the UI difficult in both situations, requiring alternating focus on elements located at the top/bottom/center of the screen.

Following a universal design strategy approach [20], our enhanced avatar centric UI reduces the need for users to continually change their focus among elements spread across the screen. Essential (depending on state) interface elements will appear around the avatar. For example, in the navigation a state, a user's mini map is more valuable than their combat bar, so the combat bar is not displayed (see Fig. 1).

3.1 Navigation

In the navigation state, key UI elements for location information are from the mini-map and the world map. Both show the user's orientation, large buildings and geographic structures (lakes, mountains, etc). However, the world map does so at a macro level, while the mini-map provides detail, localized around the player. While in the worldview the mini-map is the only resource a user has available, as the world map is available only in full screen.

When a user accepts a mission, icons are placed on the world-map to allow the user to know the location of their current destination. As this information can only be viewed in the full screen world-map view, users must repeatedly open their world map to ensure they are moving in the correct direction. To alleviate this, in our enhanced interface, a waypoint arrow is placed above the user's avatar. Constantly updated, the waypoint arrow indicates the direction of the user's destination as the avatar moves through the environment. To improve the visibility of the user's position icon while viewing the world map, the world map size was increased by 40% and the player position icon size was increased by 100%, changes endorsed on a blog in the AbleGamers community [21]. Crosshairs were added to help focus the user's attention to their icon position (see Fig. 2).

Fig. 1. The default navigation UI (left) and our enhanced navigation UI (right)

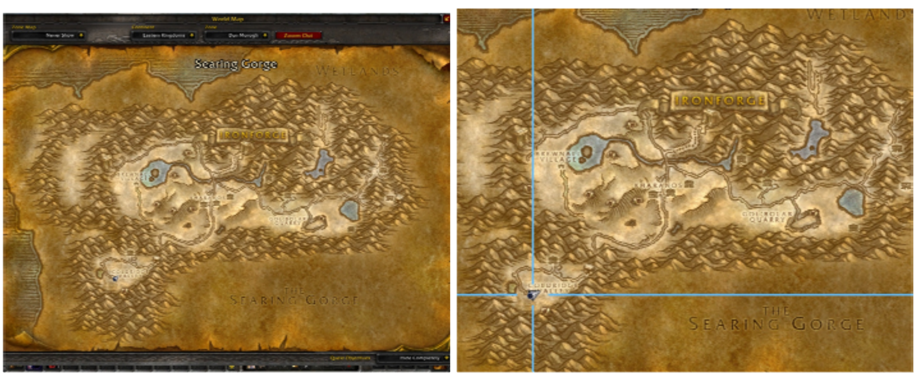

Fig. 2. The default world map UI (left) and our enhanced world map UI (right)

3.2 Combat

In the combat state, the key UI elements are the action bar and the unit frames. In a combat situation the user must focus on the unit frames (located on the top left of the screen) to monitor their avatars health and resources, along with the health of their enemy, and the action bar (located on the bottom of the screen) to monitor their avatar's available abilities (see Fig. 3). At the same time, the user must also focus on his or her avatar to ensure they are properly facing and in close proximity to their enemy.

To focus the user's attention toward their avatar, in our enhanced combat UI, we removed empty slots from the action bar, increased the size of the ability icons by 100% (placing them under the avatar) and created arced health and resource bars around the avatar (see Fig. 3).

Fig. 3. The default combat UI (left) and our enhanced combat UI (right)

4 Implementation

The augmentation to the DUI was constructed using AddOns, scripting programs written in Lua, a lightweight scripting language. AddOns are injected directly into the client and run within the WoW scripting system [22]. These programs are able to capture information from the game client in order for it to be displayed to the user. They are popular within the WoW community because they give the user the ability to customize their interface to their liking. They are also viewed as a utility as they help players perform certain roles inside of the game. Although many developers have created AddOns for public use, none have been directly aimed at improving accessibility for users with low visual acuity.

Working with the WoW environment has constraints imposed by the developers. One major limitation is the inability for automated user actions. Actions such as auto-walk and auto-target/selection are prohibited and cannot be implemented in AddOns. Also, unlike Second Life which has been made open source, WoW is proprietary software and does not allow changes to the source code. This limits what accessibility features we can add to the game and forces us to focus on the visual information displayed in the UI.

Our EUI was developed using several different open source Addons from the existing WoW AddOn community [23]. By utilizing the capabilities of certain AddOns, changes to their settings allowed us to alter their functionality to meet our game state design goals. Other AddOns required us to insert new code into the original for added features. Users who experienced our EUI were not required to change or adjust settings in order for the UI to appear as the interface loads when the user enters the virtual world.

5 Usability Study

To test the effectiveness of our enhanced UI, we conducted a comparative usability study. Eight novice users, with 20/20 (or corrected) vision, participated in the study. The study compared the default UI to the enhanced UI (DUI vs. EUI), utilizing a repeated measures design. Each user completed the set of tasks in both UIs, in separate environments. The order of presentation of UIs, (i.e. the environment in which the user was in with each UI) was counterbalanced. Throughout the experimental section of the study, all users experienced simulated low visual acuity, set at 20/200 (which is the best vision a legally blind user could have), through the use of the Zimmerman Low Vision Kit™.

Users completed the following task sequence in each UI: navigation, combat, navigation and navigation. For each UI, the users were extensively trained and allowed to ask any questions about the interface before proceeding with the experimental task. During each navigation portion, the following measurements are collected. First, a map is brought up on the screen and the user gives a verbal statement of their position relative to a specified destination marked on the map. Second, X, Y coordinates of the user's current perceived position on the map, collected from a mouse click. Third, the distance travelled by the user's in-game avatar to the specified destination that was marked on the map. Throughout the task, at one-second intervals, the coordinates of the in-game avatar were automatically collected and summed to give the total distance travelled.

In the combat portion of the task the user engaged in a battle with a predetermined opponent at a location indicated on the map. In order to win the battle, the user was required to engage in specific behaviors. These behaviors included: using a health potion when health was below a predetermined threshold (50%) and using special abilities that inflict higher damage on the opponent. To execute these behaviors, the user had to find and track these elements in the UI. Several measurements were again taken for the combat portion of task. These included the total battle time, time until the user took their potion, length of time between the availability of special ability and its use, as well as whether the subject died in battle. Following the combat encounter in each UI, the user stopped interacting with the game and filled out a questionnaire about the just completed combat situation. The combat questionnaire asked users to rate various aspects of the interface in regard to their helpfulness or harmfulness while in combat (e.g. difficulty of tracking health and ability status, level of frustration, etc.). If the user's avatar died in combat, the user was manually started on the following navigation task by an experimenter while completing the combat questionnaire.

After completing the in-game experimental section of the study, users were asked to complete an exit questionnaire regarding numerous aspects of the interfaces (both the DUI and the EUI), as well as their interactions and perceptions of working with them. The exit questionnaire is focused on overall user satisfaction with the UIs in addition to their experience, and asks users to comparatively rate the experiences in both UIs (e.g. difficulty of navigation tasks, efficacy of numerous UI elements, level of frustration, etc.).

6 Results

The results of the study can be best grouped into two categories, performance data from the in-game portion of the study, and the questionnaire data comprised by the combat and exit questionnaires.

Looking first at the in-game performance data, it should be noted that there were no order effects across any of the dependent variables (DVs) so the data sets were collapsed into DVs for each of the two UIs (i.e. DUI and EUI). For navigation, there were two DVs: distance traveled and number of times the world map was opened. The difference in the UIs had a significant effect on these DVs, with the EUI leading to better performance. (Distance traveled ($F(1, 7) = 27.24$, $p < .01$. Number of times world map was opened: ($F(1, 7) = 23.86$, $p < .01$). There were four combat performance DVs: total battle time, time of first potion use, time of first ability use, and outcome of battle (i.e. win/live or lose/die). The UI difference was significant for length of battle time ($F(1, 7) = 11.681$, $p < .05$). There were no significant differences between DUI and EUI for time of potion use, time of first ability use, or outcome of battle.

Table 1. Means and standard deviations of significant variables

Variable	UI	M	SD
Distance Travelled	DUI	133.13	29.72
	EUI	67.88	23.59
World map openings	DUI	44.00	24.51
	EUI	0.75	1.50
Length of battle time	DUI	32.63	7.50
	EUI	44.13	9.34
User rating of battle rating	DUI	5.88	1.36
	EUI	8.00	2.07
User rating of overall frustration	DUI	7.00	2.56
	EUI	3.38	2.97

Reviewing the questionnaire data, there were two important factors in which the enhanced UI led to significantly higher user ratings. In battle, users rated the EUI significantly better ($F(1, 7) = 6.19$, $p < .05$) than the DUI. Users also reported significantly less ($F(1, 7) = 8.99$, $p < .05$) frustration in the EUI vs. the DUI overall.

While no significant differences were found between the DUI and EUI in the user ratings of navigation related tasks, or in specific interface elements, these areas did appear in a number of important correlations. The performance measure of world map openings (DUI) was significantly correlated with both the user rating of overall frustration (DUI) ($r(6) = .93$, $p < .01$) and the user rating of how frequently they viewed their world map (DUI) ($r(6) = .84$, $p < .01$). Along the same line, the performance measure of distance travelled (DUI) was significantly correlated ($r(6) = .92$, $p < .01$) with the user rating of overall frustration (DUI). Switching to combat, another performance measure, length of time until potion use (DUI), was significantly correlated with both the user rating of difficulty in tracking their health (DUI) ($r(6) = .85$, $p < .05$) and the user rating of battle frustration (DUI) ($r(6) = .95$, $p < .01$). Continuing with combat, the performance measure of length of time until ability use (DUI) was significantly correlated ($r(6) = .82$, $p < .05$) with the user rating of battle frustration (DUI). Finally, the user rating of battle frustration (EUI) was significantly correlated ($r(6) = -.72$, $p < .05$) with the user rating of the battle interface.

7 Discussion

At this time, WoW is the most played online video game ever. Access to this phenomenon should not be available only to people with high visual acuity. Our study has shown that with improvement, this need not be the case. Navigation and combat comprise the fundamental game states of WoW, and the analysis of results can best be understood when breaking along those same lines.

Looking first at navigation, the EUI led to a number of significant improvements over the DUI. These improvements included significantly less distance travelled between tasks, and significantly fewer world map openings throughout the task. Both of these factors show that the user in the EUI as being better equipped to navigate inside WoW. Reviewing the correlation data, we see that ease of navigation played an important role in overall frustration. Overall frustration in the DUI was positively correlated with both the number of world map openings in the DUI and the distance travelled in the DUI. Due to the significant reduction in both world map openings and distance travelled in the EUI, we see why users reported having significantly less frustration in the EUI vs. the DUI. When creating and/or adapting a product for people with visual impairments, reducing frustration is a vital component.

Moving to combat, the EUI was again shown to provide important improvements in the subjective experience of the user, but also their objective performance as well. In combat, users in the EUI had significantly longer battle times than in the DUI. Though this could be interpreted to mean that in the DUI users were able to defeat their enemy more quickly, this would be a mistake. Unfortunately for the users in the study, coming out victorious in their combat situation proved rather difficult, which casts the battle time statistic in a different light. Instead of users in the DUI defeating their enemy more quickly, a more accurate interpretation would be that users in the EUI survived longer in the battle than when in the DUI. Bringing in the correlation data, another important story unfolds. User reported frustration in battle for the DUI was positively correlated with both time until potion use in the DUI as well as time until ability use in the DUI. Time until potion use in the DUI was also positively correlated with user reported difficulty in the DUI with tracking their health in combat. What all this means is that, in the DUI, users had trouble tracking and finding certain elements in the UI, which led directly to worse performance in battle, and as a result, higher frustration levels during combat. In addition, just as frustration played a role in the overall rating of EUI besting the DUI, frustration seems to have been a strong factor for users when rating the battle interface, as the EUI was rated significantly better than the DUI in combat. This relationship between frustration and interface ratings is corroborated by a negative correlation between user reported battle frustration in the EUI with the user reported battle interface ratings in the EUI.

Outside of navigation and combat, the positive correlation between the performance measure of world map openings in the DUI and the user reported measure of how frequently they viewed their world map while in the DUI was an important result. Though this correlation does not shed light on the purpose of the study, it does reveal that the subjects of the study were reliable in the ratings of their own performance, which serves as a validation to the methodology used in the study.

Despite the alteration constraints put in place by Blizzard Entertainment, our study has shown that even minor improvements can vastly improve navigation, combat and reduce frustration in users whom the original creators chose to disenfranchise. Future work on the project plans to include improvements aspects of the interface utilized in other important aspects of WoW (such as quest completion, which requires the user to identify a specific person and read a piece of text). In addition, incorporating the performance and questionnaire results to create a newer enhanced version that will attempt solve many of the shortcomings in the EUI. Finally, we plan to expand our assessment of users' individual spatial and navigational abilities by utilizing psychometric tests.

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Audiopolis, Navigation through a Virtual City Using Audio and Haptic Interfaces for People Who Are Blind

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Abstract. This work studies the usability of an audio and haptic-based virtual environment for learners with visual disabilities, intended for orientation and mobility purposes. To this end Audiopolis, a videogame for navigating a virtual city through interaction with audio and haptic interfaces, was designed and evaluated. Iconic and end-user usability evaluations of the videogame were administered. The results show that Audiopolis is highly usable and understandable for end users. An ongoing cognitive evaluation of navigation skills as a result of using Audiopolis is being implemented.

Keywords: Usability Evaluation, Navigation, Orientation and Mobility, Haptic and Audio Perception.

1 Introduction

Haptic perception implies two components: tactile feedback, which consists of what is perceived through the skin (temperature, texture, shape), and force feedback, which consists of what is perceived through muscles (hardness of objects, viscosity, the force of an object) [9]. There are advanced devices that allow for simulating three-dimensional spaces, forces and textures, and which are used in different applications such as medical simulators, virtual reality environment simulators, and videogames, among others [3, 6]. In particular, if virtual reality is combined with haptic perception, it is possible to convey visual information from the virtual world to the blind user through a haptic device [8]. One device that allows for this is the "Novint Falcon" [4], which provides high-fidelity force feedback, allowing for movement on the three axes of the Cartesian plane, and thus for movement through the entire space [14]. The device allows to represent the textures, viscosity, hardness and force of the various objects in the virtual environment. This provides a higher degree of reality to the virtual world represented, and in this particular case, allows for modeling visual elements and perceiving them through haptic perception [4].

In audio perception the main element is the ear, which is the receiving organ through which acoustic stimulus becomes an audio sensation that then travels to the brain where the auditory cortex processes it and distinguishes from what sound source it has come [12].

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For people who are blind or who have serious visual limitations, the sense of hearing is more important than normal, in that together with haptic perception, these two senses become the main receptors of information from the environment, allowing people who are blind to interact and relate with the environment in the best way possible. In addition, the way in which the human being perceives sound depends on the physical fact that people have two ears, which allows for the perception of the direction of any given sound, providing spatial information regarding the location of the source of the sound and helping with the perception of objects in the environment [14].

Orientation is a process through which an individual uses the various senses to establish his position in relation to other significant objects in the surrounding environment. Mobility is the ability, will and facility to move about in the surrounding environment [5]. Orientation and mobility (O&M) skills are interdependent, as to be able to move about in space efficiently, safely and independently, one must dominate both skill sets [11].

Three basic orientation abilities can be identified: 1. Knowledge of spatial distribution: the ability to know where the destination is located and to establish relations between it and objects in space. 2. Spatial updating: the ability for an individual to know his position in space at any given moment, as well as in relation to the surrounding objects and individuals. 3. Knowledge of spatial concepts and systems: an individual's ability to plan his navigation from a starting point to a destination [10].

To orient oneself, an individual must establish his own position and relate it to the relative locations of the various significant elements in the environment. As one moves about, this position must be updated, as the relation between the individual and the objects is modified in a dynamic process in which both perceptive and cognitive factors come into play [15]. For people with visual impairment, the ability to develop consciousness of the environment is a result of concentration and practice following a period of learning [6].

Orientation and mobility in outdoor, unknown spaces for people with visual impairment is a significant challenge [1]. If the fact that most transit and mobile signals are visual is considered, simple and everyday tasks can become extremely complicated for people who are blind [1].

With the purpose of developing O&M skills, this study proposes the creation of a virtual, 3D world through audio and haptic interfaces, which allows the user to navigate through virtual space and identify the surrounding objects and thus orient himself. Other videogames have been developed in this area that seek to develop O&M skills cognitively, as well as through spatial-temporal structuring and navigation [1, 12]. One of these videogames is AudioDoomII [2], which is a virtual space that consists of a maze based on a stereo-sound audio interface, through which blind users are able to locate elements within a set of virtual hallways. AudioHapticMaze [13] emerged as the evolution of this videogame, as it extends the previously described virtual environment by adding rooms, and an additional interface. These projects are characterized by modeling indoor environments for users who are blind, for which reason it is relevant to explore the modeling of outdoor environments.

As a result, in this work the videogame Audiopolis was designed, and its usability was evaluated. The objective of this game is to develop O&M skills in people with visual impairment, for navigation in outdoor environments through the use of audio and haptic based interfaces. Audiopolis seeks to mentally and gradually represent the map of a virtual city, in order to simulate and run practices of certain situations and trips, which increasingly stimulate the creativity, confidence and problem solving abilities of blind users, in addition to teaching basic norms of safe pedestrian transit through the city in a ludic manner.

2 Design

Audiopolis is based on a detective metaphor, in which the user plays the part of a detective who must find a band of thieves and the objects they have stolen. Initially, the detective starts out at the crime scene, where he has to identify the first stolen object in which the first clue is hidden, indicating the location of the following clue. Afterwards, the player must navigate through the city following the various clues until he finds the thief. The thief, once under arrest, will provide the detective with a set of three stolen objects, and the detective has to correctly identify which is the object he is looking for.

The videogame is a three-dimensional virtual simulation of the outdoor environment of a city, which includes the simulation of floor textures, environmental volumes and sounds. Initially, the player is provided with instructions on the tasks that must be completed, and afterwards he is free to navigate through the virtual space. The player can ask for information in order to arrive at a given destination, utilizing the clock technique [7] with the purpose of providing orientation. Once the player arrives to the indicated destination, a contextual question about the place is formed as a clue, which the player must answer using the keyboard to then receive information regarding the next place that he must go to. When the player arrives to the last place in each stage, he must recognize a set of objects simulated three-dimensionally and represented by geometric shapes.

Fig. 1. Visual interface of Audiopolis

The game has 3 modalities in accordance with the interfaces involved, and a graphic interface to work with a facilitator, teacher or instructor (See figure 1):

1. *Audio Interface Modality*: the player must use the 3D environmental sounds to locate and orient himself in the environment, and the keyboard to navigate through

the space. Recognition of geometric shapes is achieved through indications from special sounds regarding the shape of an object, such as the number of sides.

2. *Haptic Interface Modality*: the player must achieve O&M with the information on the space that is provided through a haptic device, utilizing it like a cane. In this interaction, the player navigates through the space using the buttons on the haptic device or on the keyboard. Through the use of the device the user explores the place in which he is located by moving the joystick control on the device. In this exploration, the user feels the different volumes that make up the city in his hands, such as the floor, sidewalks and walls. In addition, the user perceives different textures that provide information on the space, as for example the streets, sidewalks and walls all have different tactile sensations associated to them. The recognition of shapes is achieved by using the haptic device as a hand, and the questions are made through audio feedback.
3. *Haptic and Audio Interface Modality*: consists of a combination of the two previously described modalities, in which the available information on the virtual environment is provided through both interfaces.

3 Methodology

3.1 Evaluation

In this work, a usability evaluation of Audiopolis was implemented. This evaluation was designed to evaluate how easy it is to use the videogame designed, the different elements of the interfaces included in the videogame (sounds), and the haptic device associated with the game. The evaluation is made up of two parts: an iconic usability evaluation of the videogame's components, and then an end-user usability evaluation. Regarding the iconic usability, it was sought to evaluate whether or not the user correctly associates the various elements of the videogame, for which reason sound recognition, real geometric shape recognition and geometric shape and texture recognition with the haptic device were all evaluated. In the end-user usability evaluation, the general usability of the videogame was evaluated after having made changes and redesigns according to the results obtained in the iconic usability evaluation.

As the evaluation of the videogame's cognitive impact is currently underway, it is sought to evaluate the learners' development of O&M skills as a result of their interaction with the videogame. This evaluation consists of a preparatory stage, the application of a pretest, the reiterated interaction with the videogame together with a set of related activities, and finally a posttest. This cognitive impact evaluation is ongoing.

3.2 Sample

For the iconic usability evaluation of the videogame, a sample of 18 learners with severe visual impairment was selected, with ages between 10 and 15 years old and who were enrolled between fourth and eighth grade courses at the Hellen Keller and Santa Lucia schools for the blind in Santiago, Chile. In the end-user usability evaluation a subset of 9 learners from the previously described sample participated, corresponding to the group of learners from the Helen Keller School. In this case, the sample population was divided into 3 groups of 3 different learners, in which each group corresponded to: (1) Interaction with the videogame's audio interface. (2) Interaction with the videogame's haptic interface. (3) Interaction with both audio and haptic interfaces integrated together.

3.3 Instruments

For the usability evaluation two questionnaires were utilized: (1) The SUE questionnaire (Software Usability Elements), which serves to evaluate the iconic usability of the sound and graphic elements of the videogame during the first stage of development, asking the user what he associates each element with. In particular, a set of 42 sounds, 41 real shapes, 10 virtual shapes and 8 textures was evaluated. (2) The SUBC Questionnaire (Software Usability for Blind Children Questionnaire [7]), which allows researchers to measure the degree of the users' satisfaction regarding the videogame's usability. This is made up of a set of 18 statements that the user must evaluate, based on a scale of appreciation with values between 1 and 10, in which 1 is 'very unsatisfactory' and 10 is 'very satisfactory'; it also includes 8 open-ended questions that seek to collect information of interest regarding the users' opinions of the videogame.

Prior to the cognitive evaluation, preparatory activities with the videogame were held, which consisted of activities that allowed for a preliminary experience with the contents, lessons and components involved in the videogame. In this way, it is assured that the users would be able to adjust to the videogame's requirements. To these ends three guidelines were applied, in which each item is assigned a score (0 = not achieved, 1 = in process, 2 = achieved): (1) *Preparatory sounds guidelines*: for each sound, it is evaluated whether or not the user correctly associates its meaning, and if it is correctly associated in the context of the videogame. Here there is a total of 26 possible points. (2) *Preparatory geometric shapes guideline*: Evaluates the ability to recognize concrete and virtual shapes, associate the concrete shape with the corresponding virtual shape and to concretely represent the shapes. In this guideline there is a total of 52 possible points. (3) *Preparatory clock technique guideline*: Evaluates the ability to recognize the location of the various hours on the clock utilizing concrete materials, the ability to turn towards different hours and the ability to move about utilizing this technique. This guideline has a total of 22 possible points.

For the cognitive impact evaluation, three kinds of guidelines were also used: (1) The guidelines utilized to measure the videogame's effect on the development of O&M skills, which is an adaptation of the guidelines used to evaluate O&M strategies and knowledge, and cane mastering used in educational and rehabilitation programs for the blind. Just as in the case of the preparatory guidelines, each item evaluated is assigned a score, and in this case the total possible score is 166 points. (2) The observation guideline, which was constructed in accordance with the activity performed, and which seeks to measure the level of the learner's achievement through the score that he is assigned. (3) The in-depth interview guideline, which is an instrument based on open-ended questions with which it is sought to collect the learner's perception of the game and how much it contributes to his development of skills and learning.

In addition, as part of the cognitive evaluation a pretest and posttest were both designed based on the O&M guideline, in order to evaluate the O&M skills of each learner before and after applying the cognitive tasks through the use of the videogame. These tests were used with the purpose of comparing the gains obtained, and to calculate whether or not these are statistically significant.

3.4 Procedure

One and a half-hour work sessions were designed, considering that the research team included the support of three facilitators to implement the intervention. A total of 24 sessions were held, which involved the usability evaluation, preparatory tasks and the cognitive evaluation.

The SUE questionnaire was applied during six, 1.5-hour work sessions with a group of 18 learners. In the first two work sessions with sounds, each learner worked for 15 minutes. Each sound was played sequentially, and after each one the learner was asked to identify the sounds. In the following two work sessions, the concrete shapes were evaluated through 15 minutes of individual work. In the fifth session, each learner worked for 10 minutes with the haptic device. The work consisted of virtually touching, through the Novint Falcon device, the virtual contours of each of 10 shapes modeled for haptic perception, and identifying them. In the sixth and last session, each learner had 10 minutes to evaluate his tactile sensation of the textures, virtually represented through the Novint Falcon.

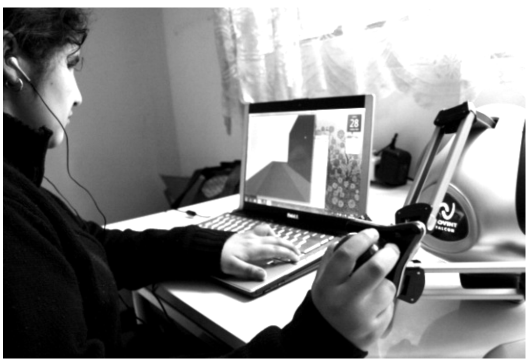

Fig. 2. Blind user interacting with the videogame and the Novint Falcon device

Afterwards, the end-user usability questionnaire was applied to 8 learners, after each one had interacted with the videogame during a 30-minute session (See figure 2). For the cognitive impact evaluation, four kinds of tasks were planned: (1) *Preparatory tasks*: designed to level out the knowledge and skills that the users must possess in order to successfully utilize the videogame. (2) *Navigation tasks*: Designed so that the user is able to navigate through the simulated environment with the purpose of becoming familiar with it. (3) *Development tasks*: Designed so that the students perform the activities available in the game. (4) *Representation tasks*: Designed so that the student represents both graphically and concretely the mental map that he has constructed of the space that has been navigated.

To date, three 45-minute preparatory sessions per student have been held with a group of 9 learners. Afterwards, the pretest evaluation was applied during two

45-minute sessions with each of the same 9 students. Currently, a set of cognitive tasks is being held involving the use of the videogame and the corresponding supportive activities, in 45-minute sessions with each learner. In this process, it is sought to hold a total of 12 sessions in order to then apply the posttest.

4 Results

Regarding the results obtained from the iconic evaluation of the videogame with the application of the SUE questionnaire, it was possible to observe that an initial group of sounds, corresponding to horns, cars, doors and environmental sound, were identified correctly for the most part. However, the sounds corresponding to steps over different kinds of surfaces were confused with bumping sounds. Due to this problem, a second set of sounds was utilized, which when evaluated was more readily identified.

Concerning the iconic usability evaluation of concrete shapes, the results obtained from the guideline show that the students correctly identified simple geometric shapes, such as regular polygons, but presented problems with identifying complex shapes. In the same way, in evaluating shapes with the haptic device it was observed that most of the learners identified regular shapes with the device, achieving an average percentage for the correct identification of such shapes of 75.4%; however, this was not the case with complex shapes. This could be attributed to the fact that in order to recognize a shape with the device, the users obtained information by counting the sides or corners of each shape.

In evaluating the iconic usability of the virtual textures represented with the haptic device, the results show that the learners were, for the most part, able to correctly describe the textures (79.4% recognition), although they were not necessarily identified with a specific concrete material. In addition, when asked if each texture was pleasant to the touch, in general the majority of the learners responded that the textures were pleasant, and that they did not have too much difficulty interacting with the device (82.4% satisfaction).

From the results obtained in the end-user usability evaluation, it was observed that Audiopolis is highly usable and understandable to the users with visual impairment (see figure 3). For the statements that correspond to the “Satisfaction” category, those which obtained higher scores from the users surveyed were “The videogame is interactive” and “I like the videogame”, with a mean score of 9.6 and 9.3 points respectively, out of a total of 10 possible points. The statement “The videogame is challenging” obtained the lowest score, with an average of 6.7 points, as the users found the videogame to be relatively easy.

Regarding the results obtained for the statements that correspond to the “Control and Use” category, it was observed that for the users it is easy to use the videogame. The statement “The videogame is easy to use” obtained the highest score with 9.1 points, while the lowest score was assigned to the statement “I felt in control of the situations presented by the videogame”, with 7.8 points, which is still within the range considered to be an acceptable degree of satisfaction.

In the “Sounds” category, all of the statements obtained average scores higher than 9, which means that the application resulted in the expected results even before an iconic usability evaluation was applied, as the sounds chosen were widely accepted by the users. In the "Haptic device" category, it was observed that the users liked to interact with the device and that it provided them with relevant information regarding the objects in the virtual environment. Also, in the open-ended questions, the users commented that in general the videogame was fun and interactive, but that it would be good to add more elements from a typical city environment.

Regarding the preparatory activities with the clock technique, the users achieved an average score of 79.3% accuracy when using the instrument. In the case of geometric shapes they achieved an average score of 81.8%, and in the case of sounds they reached an average of 83.8% accuracy.

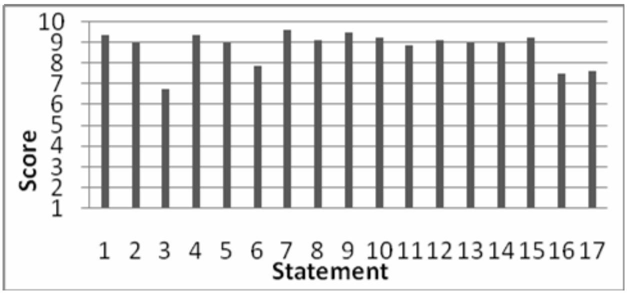

Fig. 3. Results for the End-User Usability Evaluation. (1) I like the videogame, (2) The videogame is fun, (3) The videogame is challenging, (4) The videogame makes me fell active, (5) I would play this game again, (6) I felt in control of the situation in the videogame (7) The videogame is interactive, (8) The videogame is easy to use (9) The videogame is motivating, (10) The videogame adapts to my rhythm, (11) The videogame allowed me to understand new things, (12) I like the sounds of the videogame, (13) The sounds of the videogame are clearly identifiable, (14) The sounds of the videogame provided me with information, (15) I like the tactile sensation of the haptic device in the videogame. (16) The elements of the videogame are clearly identifiable by touch using the haptic device. (17) The tactile sensation of the haptic device provided me with information.

5 Discussion

This study presents the design and evaluation of Audiopolis, a virtual city represented by audio and haptic feedback for the development of O&M skills in people who are blind. In particular, this study informs about the results regarding the usability of interface elements from the virtual environment, the end-user usability and the tasks in the process for a further cognitive analysis of the skills acquired through the use of the videogame.

From the usability evaluation, it was observed that most of the users perceived the sounds, textures and shapes (both concrete and virtual) without any trouble, through the use of audio and haptic interfaces. The users associate the majority of the sounds with the elements represented in the virtual environment thanks to the previous iconic usability evaluation, which allowed the development team to rule out the sounds that could generate confusion for the users at an early stage. In the same way, they are able to identify various simple geometric shapes with their hands by touching the contours of the shape, but are unable to do so with complex shapes. This is due mainly to the fact that, in order to detect shapes in this way, the users counted the number of sides and/or corners of the shape, characteristics that are not common in irregular, complex shapes. In the case of textures, the users were able to recognize most of them adequately, although in some cases (such as glue and sand) they could only describe them without identifying them by name. This is due in part to the fact that such users are not normally familiar with these elements.

The textures were all recognizable to the users, and although they were unable to always associate the textures with a concrete material in the real world, they were able to identify them within the virtual environment. This means that if at point A they experienced a particular texture, at point B they were able to identify if the new texture they encountered was the same as that from point A or not.

In addition, the users were able to interact relatively easily with the videogame, and were able to quickly adapt to its mode of use. They found the videogame to be motivating, and stated that they would use it again. Thanks to the iconic usability evaluation, it was observed during the end-user usability evaluation that the sounds were widely accepted by the users, that the textures and the haptic interface provided the information desired, and that the users perceived them just as they expected to.

Currently, the cognitive impact evaluation is being performed, through planned cognitive tasks using the videogame designed to develop O&M skills. The promising results obtained from the preparatory tasks assure us that the elements of the videogame's interface have been correctly identified during the users' interaction with the game. Once the cognitive evaluation has been completed, it will be possible to determine if there are significant gains in the development of O&M skills as a result of having used the videogame.

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Implications of Cloud Computing for People with Cognitive Disabilities

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Abstract. A public workshop was convened in the Fall of 2010 to bring together leaders from industry, education, public policy, disability advocacy, and government with a shared focus in shaping our national information and computing infrastructure to improve the lives and independence of people with disabilities, particularly those with cognitive disabilities. The workshop provided introductory presentations about the state and future of cloud computing technology, cognitive accessibility, and policy considerations, and was followed by interactive panel discussions about technical directions and opportunities; the potential benefits, opportunities, and challenges of cloud computing from the viewpoint of people with disabilities, caregivers, and advocates; and legal and regulatory barriers to accessing technology in "the cloud." This paper summarizes insights about how cloud computing could improve the lives of people with disabilities from the perspective of leading representatives from industry, academe, government, and advocacy organizations.

Keywords: cloud computing, cognitive disabilities, disability advocacy, law and public policy.

1 Introduction

On October 20, 2010 a workshop was held by the Coleman Institute for Cognitive Disabilities in partnership with the Silicon Flatirons Center for Law, Technology and Entrepreneurship, to explore how emerging developments in cloud computing could enrich and enhance the lives of people with disabilities, with a focus on people with cognitive disabilities. To this end, the workshop featured invited speakers and organized panel discussions across broad participative communities: disability experts and advocates; technical academic and business leaders; and law and public policy experts. Presentations and panel discussions were free and open to the public, presenting opportunities for interaction with the workshop participants.

This paper will present key insights from workshop discussions about how cloud computing has the potential to radically improve the lives of people with disabilities from the perspective of leading representatives from industry, academe, government, and advocacy organizations. It is important to share these perspectives so that designers and developers of future technologies have the vision to create technologies that are inclusive and accessible for all users in the near and distant future.

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2 Historical and Current Assessments about Cloud Technology, Cognitive Accessibility, and Public Policy

2.1 Historical Developments and Cloud Computing

Mr. William Coleman[1] opened the workshop by analyzing some important historical developments that frame a view of where cloud computing is today and where it is headed in the future [1]. Two key historical developments include the invention of language and the printing press. These developments were significant because they supported the widespread creation, communication, and sharing of information, and the preservation of knowledge for future generations.

The recent rise of information technology and cloud computing likewise has the potential to provide orders of magnitude improvement in knowledge creation, communication, and preservation. Information no longer resides on isolated computers where it may become inaccessible due to technical failure or obsolescence. In the cloud, knowledge is stored and preserved in a distributed network where it can be more easily searched, accessed, shared, and preserved with historically unprecedented economies of scale.

2.2 Technology Cycles and a Critical Historical Inflection Point

The current information age has been characterized by rapid cycles of innovation resulting in (1) invention, boom, and bust; (2) the build out and consolidation of information technologies and infrastructure; and (3) the commoditization of technology. Within this framework, the information age is now at *a critical inflection point* and will soon be revolutionized by the widespread commoditization of cloud technologies as a highly efficient, and low cost utility platform.

Before cloud computing can reach this level of efficiency and low cost, it is important to understand the disruptive nature of new technical innovations. In order to be disruptive, new technologies must present at least an order of magnitude better value for users. The cloud will deliver this value increase through three key services:

- Software Applications as a Service (SaaS);
- Computing Infrastructure as a Service (IaaS); and
- Platform tools as a Service (PaaS).

Cloud technologies are disruptive because they support significantly improved economic value that leverages and isolates enabling technology layers. Cloud services also provide tremendous opportunity for customization and control, and support the rapid development of new information and knowledge services.

Evolution of the cloud to a utility platform. The cloud will evolve from a collection of web-based services to a *pervasive utility platform* in three major phases:

[1] Mr. Coleman is a Silicon Valley entrepreneur and founder of technology startups including BEA Systems and Cassatt Corporation. Mr. Coleman is also founder of the Coleman Institute for Cognitive Disabilities.

- **Cloud 1.0** (timeframe 2000-2010): This stage is characterized by software, infrastructure, and/or platform, as a service. Since services are discrete, Cloud 1.0 is neither a platform nor a utility.
- **Cloud 2.0** (timeframe 2010-2020): This is the era of the Cloud as a platform, but not a utility. Cloud 2.0 is characterized by connectivity and convergence of: internal and external clouds; online and mobile worlds; and applications and data. This phase allows a Client as a Service (CaaS) model.
- **Cloud 3.0** (timeframe 2020-2030): This represents the final commoditization and consolidation of information computing technology - and emergence of cloud computing technology through "utility service providers."

Life on the web in 2040. Assuming the future trend of "the cloud as a utility platform," Mr. Coleman foresaw a future that allows individuals to customize and leverage vast expanses of the technology infrastructure at very low cost. Individuals will create a web presence with virtual capabilities that augment their native abilities, and transcend personal disabilities. This future vision includes a "self-aware proxy for life" with customizable "dashboard" controls, and identity technologies that ensure secure privacy and civil liberties. This vision also includes a dramatically improved productivity that enables most of the world to advance into a "middle class" society.

If this vision is to be realized, several near-term issues must be addressed:

- the development of new business models that support the creation of enabling technologies supporting Cloud 3.0;
- the need for common standards that reward creativity while enabling interoperability; and
- identification of legal, privacy, and security requirements necessary for widespread acceptance, adoption, and use.

2.3 Cognitive Disabilities and Technology Accessibility

Dr. Michael Wehmeyer[2] presented historical and modern contexts for understanding disabilities. Historically, a disability was viewed as a personal characteristic or problem within an individual's internal health state. In 1980, this view began to shift toward understanding disability in the context of a person-environment fit or interaction model. In 2001, the World Health Organization introduced an International Classification of Functioning, Disability and Health (ICF) schema that reflects impairments, disabilities and handicaps in terms of the impact that the disability has on a person's external functions, activities and social contexts. Within this modern framework, a disability serves as an all-inclusive term for describing limitations or restrictions on participation in daily activities and social environments [2].

Diagnostic methods for cognitive disability have likewise shifted from historical frameworks that considered internal measures of intelligence (intelligence quotients and mental age estimates) to modern methods that evaluate a person's functional impairments and the restrictions which those impairments have on daily activities and

[2] Dr. Michael Wehmeyer is President of the American Association on Intellectual and Developmental Disabilities, a Professor of Special Education, and Director of the Kansas University Center on Developmental Disabilities.

social participation. This approach represents a shift from "fixing the person" to understanding and addressing the gap(s) that may exist between a person's capabilities and the demands of their environment. This approach is "strengths based" and outcomes oriented.

Since abilities often coexist with disabilities, it is important to identify long-term personalized supports that empower and leverage a person's strengths, while addressing disabilities in manner that is appropriate and acceptable to the person and his or her social context. Technology represents an important tool that can be applied to narrow the gap between one's capabilities and the environment.

To design a technology that is *cognitively accessible*, a design should also incorporate features that accommodate people who may have problems with:

- visual perception;
- auditory reception;
- language ability;
- reasoning and idea production;
- memory and learning; and
- cognitive speed.

Strategies for designing cognitively accessible software interfaces include, but are not limited to:

- *Providing approaches that minimize errors*: remove unnecessary controls and buttons, rather than graying them out.
- *Designing for flexibility and simplicity*: reduce display clutter; provide only needed functionality; consistently place familiar buttons in the same place; minimize cryptic metaphors and images – images of paperclips and floppy disk icons may convey little meaning to a person with a cognitive disability.
- *Minimizing physically challenging controls*: operations that require double clicking or dragging objects and manipulating scroll bars may present accessibility barriers.
- *Providing multi-modal presentation and translational options*: some examples include text captioning, text to speech, TTY, and hearing aid support.

Creating accessible interfaces and websites is only part of the solution – barriers in hardware design and resident software (operating systems and portal applications) must likewise be addressed to design an accessible system.

2.4 Legal, Regulatory, and Public Policy Concerns for Technology Accessibility

Dr. Peter Blanck[3] presented an overview of recent legal and regulatory policies that impact the lives of people with disabilities. Technology accessibility represents the next major barrier in a struggle that people with disabilities have historically faced to gain access to public buildings and services, education, and employment. Because of challenges in obtaining suitable accommodations in the workforce, people with disabilities suffer significant underemployment and a lower standard of living [3].

[3] Peter Blanck, Ph.D., J.D. is a University Professor and Chairman of the Burton Blatt Institute at Syracuse University.

Recent legislative reforms include:

- the 2008 American with Disabilities Amendments Act which provides broad rights to anyone with a disability, without regard to the severity of their disability, and
- the Twenty-First Century Communications and Video Accessibility Act of 2010 which states: "a manufacturer of equipment used for advanced communications services, including end user equipment, network equipment, and software, shall ensure that the equipment and software that such manufacturer offers for sale or otherwise distributes in interstate commerce shall be accessible to and usable by individuals with disabilities" [4].

While such laws provide broader accessibility rights for people with disabilities, there are also public policy considerations:

- Could national accessibility laws and regulations create a competitive disadvantage for businesses and entities competing in international markets?
- How will conflicts between international and national laws be resolved?
- Must foreign-hosted services comply with national laws and regulations?
- In the U.S., public places must be accessible – is the internet also a "place" for the purposes of the Americans with Disabilities Act, or is it something else?
- Is privacy an evolving concept, or will it be a static property that can be regulated?
- Should copyright laws evolve to permit synthesis of existing protected materials to create new intellectual property?
- Could legislation, regulation, and public policy provide standardized access to technology at the expense of future creativity and innovation?
- How can laws, regulations, and public policy keep up with the evolution and innovation of new technologies?

3 Multidisciplinary Perspectives about Potential Opportunities and Challenges of Cloud Computing for People with Disabilities

The preceding presentations were followed by multidisciplinary panel discussions. Panels were comprised of mainstream and assistive technology experts; disability advocates; and government, legal, and public policy experts. Panelists were invited to make short presentations or statements within their areas of expertise, followed by interactive public discussions. Panel discussions were organized into three major areas: technical opportunities and commercial infrastructure; potential benefits, opportunities, and challenges of cloud computing for people with cognitive disabilities; and legal and regulatory barriers to accessibility "in the cloud." Findings from each of these panels will now be summarized.

3.1 Technical Opportunities and Commercial Infrastructure

A panel of industry, academic, government, and assistive technology experts made short presentations about the opportunities and challenges of building a technical infrastructure that is accessible and usable by people with cognitive and physical and disabilities. The panel offered the following insights.

Disabilities, technology, and accessibility. Disabilities are often viewed as a special interest problem that affects only a small portion of society. With improvements in health care and longevity, a growing number of mainstream users will require some form of assistive technologies and services in the near future. As discussed in Dr. Wehmeyer's overview, disabilities should not be viewed as a personal trait but rather a relative condition where there is a mismatch between a person's abilities and his or her environment. To design for accessibility, it is helpful to focus on approaches that support a range of functional preferences and needs. This design approach has been described as "what I need" vs. "what I am." Within this framework, accessibility is viewed as the ability to customize a particular technology to fit the needs and preferences of a user.

When designing technology to serve people with disabilities, no single technical solution will satisfy all users. Instead, accessible design requires a common language for specifying and managing personal needs, preferences, and service delivery frameworks.

Technical landscape, opportunities, and issues. Industry experts project that infrastructure speed, bandwidth, and quality of service currently available on desktop platforms will soon be pervasively available on wireless mobile devices and handsets. Most assistive technology applications are custom tailored for a delivery platform (desktop, laptops, handsets, personal digital assistants, etc.) and are purchased as an "add on" at a significant cost to the consumer. In the future, assistive technologies will be universally available through cloud applications and services, regardless of what device is used by the consumer.

As assistive services are more available on the cloud, there is a question of how accessibility innovation will evolve on mainstream hardware interfaces. Will manufacturers continue to invest in built-in assistive technologies (text to speech, screen readers, etc.) if there is a widespread perception that assistive technology is readily available through cloud services? There is also a question of how cloud technology developers can understand the needs of users with disabilities who remotely access their services. Will concerns about online privacy and security create barriers to participation and acceptance by caregivers and families who share a concern about potential vulnerability and welfare of their clients?

Technical initiatives and research opportunities. The Global Public Inclusive Infrastructure (GPII) initiative [5] is exploring how National Public Inclusive Infrastructures (NPIIs) can be built in various countries to work collaboratively and enhance broadband infrastructure. One aspect of the GPII initiative is to explore how user profiles can be defined and used to create inclusive technologies appropriate to a user's capabilities and preferences. For example, if a person has a visual deficit, text to speech and descriptive voice captioning of visual objects and animations may be appropriate to access a presentation with complex animations. User profiles would support the creation of secure and persistent accommodations so if a user changes or upgrades a device, the accessibility profile would still be available to automatically adjust the new device and serve the user's information in an appropriate modality.

In a world of multimedia presentations, portals, and animated widgets, user attention is a scarce resource and design simplicity is a virtue. More research is needed to understand the cognitive and physical barriers created by user interface complexity, and what strategies and services might be useful to reduce or eliminate these loads.

3.2 Potential Benefits, Opportunities, and Challenges from the Viewpoint of People with Disabilities, Families, Caregivers and Advocates

A panel of advocacy and public policy experts explored how cloud technology could potentially benefit people with cognitive disabilities and their caregivers. The panel indicated that the current economic climate has further eroded support for federal and state funding that assists people with disabilities. Many states maintain waiting lists for people with cognitive disabilities who seek community-centered living services. As they wait for openings after completion of secondary schooling, families often provide daily care, guidance, and explore opportunities for independent living and employment.

It is a widely held misconception that people with cognitive disability are unable to effectively use consumer technology. Since a majority of people with cognitive disabilities are classified as having moderate to mild impairments, most are able to learn to use a computer with proper coaching. Many people with cognitive disabilities who have access to a computer can learn to communicate on email, browse web sites, and play games.

Cloud technology has the potential to foster new opportunities for people with disabilities through social networking, vocational training, and electronic health care records. Social networking sites can facilitate meeting others in the local community with common interests, and offer support through informal groups for caregivers. Vocational training and tutorials may also be offered on the cloud, enabling a person with a disability to prepare for a new position and obtain job coaching outside of the home if necessary.

Cloud services that store electronic health records could also play a major role in improving quality of life and providing continuity in health care over the lifespan for patients who have memory or communication issues. This is especially important when experiencing major life transitions, such as a move to or within a community centered service provider, or when a mentor or knowledgeable caregiver is no longer available to communicate the health history of a patient.

Disability advocates feel that access to the internet and cloud computing services fosters a strong sense of independence, self-determination, and empowerment for people with cognitive disabilities. Designing content with appropriate vocabulary and navigational controls is critical to making cloud services accessible. Elimination of distractions, such as pop-up ads, may also be very helpful for many people with attention problems. Using appropriate language and eliminating the need to scroll for "hidden information" is also a useful strategy for designing accessible sites.

3.3 Legal and Regulatory Barriers to Accessibility "In the Cloud"

Details about where information is hosted, where it is requested, and how it is served can present legal and public policy challenges due to copyright, privacy, and digital rights management regulations and laws. For example, if text-based web content is requested by a user with visual disabilities through a cloud-based screen reader service, content is "transcoded" into a different modality and then served to the user. While this type of service allows cloud content to be accessed by a broader audience, it can also present legal challenges for the service provider if the accessed materials are protected by copyright or digital rights management laws.

Services that access content hosted in foreign countries may also present problems if that country has restrictive national, regional, or local laws. Customs and practices also shape the future technology landscape, and concepts such as personal privacy, copyright and digital rights management may not be mutually respected or strictly enforced across international borders.

In the U.S., a National Broadband Plan [6] was initiated to make high-speed internet services accessible so all Americans have the same opportunities for education, civic engagement, and participation in the global information economy. While many details are being defined and debated, this initiative represents a major national effort to create comprehensive plan that addresses the need for an accessible national public information infrastructure supporting broad societal participation.

4 Implications for Creating Accessible Cloud Technologies

Designing technologies and services that support the needs of people with disabilities has shifted from an "after market" activity (a feature or service added to a system after it is designed, built, and purchased) to a first class design imperative. While it is easy to view this shift as a positive development for people with disabilities, it also has the potential to benefit *all users* because of:

- shifting market demographics, with a growing global population of elderly users who may have decreased physical and/or cognitive function;
- the demand for cloud services by distracted users who are multitasking while using mobile devices with small displays in noisy real world environments;
- economic pressures seeking lower cost delivery platforms for formal education, training, media, entertainment, and personal communications; and
- legal and regulatory changes that are shifting toward a view of information access as a fundamental human right in an information society and economy.

The central issue is no longer about *why* information services should be accessible, but *how* accessibility standards can be created to make information systems and services usable by the broadest user audience. Basic research is needed to support the creation of effective standards that support accessibility for people with disabilities who need cloud computing services. This research should include longitudinal participative design with disability experts and advocates who face broad and diverse physical and cognitive challenges and consider how people actually use technology in activities for daily living, as well as their social and environmental contexts.

Accessibility standards must ubiquitously support privacy, security, customization, and personal preferences. Standards will allow accessible design to move from proprietary "one-off" technical demonstrations and support industry design methodologies that build upon technical substrates with embedded accessibility standards.

The challenge is how to create effective accessibility standards that are open and flexible, while simultaneously supporting innovation, creativity, and unforeseen technical opportunities.

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Website Design and Usability Assessment Implications from a Usability Study with Visually Impaired Users

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Abstract. Outdoor recreation websites present complex design considerations because of their wide range of potential users and the variety of their needs. Usability testing allows users to interact with websites and give feedback on its usability. Knowledge acquired during the usability testing process can be used to improve the information architecture of the website and its content. This study included usability tests with both visually-impaired and sighted participants visiting the Natural Resources Management Gateway, a complex information-rich website. The study identified best practices for designing and testing websites that effectively and efficiently meet the needs of visually-impaired and sighted website users. In addition to design recommendations, the study also looked at the impact of visual impairments on usability test duration, determining a rule of thumb for allocating time for usability testing of websites.

Keywords: Usability, visually impaired users, disability, public website, outdoor recreation website, usability testing duration.

1 Introduction

Large public websites, such as those for outdoor recreation (e.g., the NRM Gateway), present complex design considerations due to the large amount of information they contain and their wide range of potential users. The need to provide sites that are accessible to individuals with disabilities has grown as the range of disability-friendly activities has increased (including recreation). According to a Harris Interactive/Open Doors Organization market study, more than 21 million American adults with disabilities (69% of American adults) spend more than $13.6 billion a year on travel-related services. Persons with disabilities travel at least once every two years (approximately 63 million trips), and 51% of them use the Internet to plan their travel [1]. These numbers show the high rate of Internet use for people with disabilities, especially with respect to travel. Travel and leisure websites must support the needs of a diverse audience to address this significant market.

Usability refers to how easily a specific task can be accomplished with a specific tool. The International Organization for Standardization (ISO) defines usability as the

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"extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [2]. Effectiveness is defined as "accuracy and completeness with which users achieve specified goals," efficiency is defined as "resources expended in relation to the accuracy and completeness with which users achieve goals," and satisfaction as "freedom from discomfort, and positive attitudes towards the use of the product." While other conceptualizations of usability have been proposed ([3], [4], [5]), the ISO definition is the most widely accepted and is used by Michigan State University Usability/ Accessibility Research and Consulting (UARC) in evaluating website usability. The value of conducting baseline usability testing is to identify usability issues within a site using a systematic, performance-based approach.

Including usability research in the website design process can save time and costs associated with development, maintenance, training, support, documentation, and litigation. It may also increase sales, traffic, revenue, user satisfaction, market share, productivity, and trust ([6], [7]). The return on investment for usability efforts is high:

- Cost-benefit ratios can exceed 1:100 [8]
- Traffic and sales commonly increase by over 100% [9]
- User satisfaction can increase by as much as 40% [10]
- Training and supervisory time can decrease by 30-35% [11]
- Productivity can be increased by 70% [12]
- Employee turnover can be reduced by 20% [8]

The earlier usability is included in the production process, the greater the benefits and savings. It is estimated that for every $1 spent fixing usability problems in the initial design of a system, $10 needs to be spent once it is in development, and $100 once it has been released [13].

1.1 Usability for Persons with Disabilities

Ensuring that websites are usable for persons with disabilities will greatly expand their potential audience. Worldwide, 650 million people or about 10 percent of the world's population are living with some kind of disability [14]. In 2008, the overall percentage of people with a disability for all ages in the US was 12.1 percent (36 million), 6.9 million of whom (2.3%) were blind or visually impaired. Disabilities affect many more people than is generally realized [15].

According to the 2008 Disability Status Report for U.S. [15], a significant number of persons with disabilities are employed and have substantial incomes, albeit at lower levels than persons without disabilities. For example, the overall employment rate of working-age people with disabilities in the U.S. was 39.5 percent, with the second highest employment rate for people with a "visual disability," 43.4 percent. Median earnings of people with disabilities (full time/full year) in the U.S. was $35,600, compared to $40,700 for people without disabilities (full time/full year) [15]. Moreover, as the general population ages, the number of persons experiencing a disability will grow, further increasing the number of persons with disabilities.

The Internet is also a significant and positive resource for persons with disabilities. It has the potential to increase the independence and social connectedness of persons with visual impairments, since it removes the barrier of physical proximity for shopping and communicating. Bradely and Poppen [16] found that Internet access improved how individuals with disabilities evaluate their level and quality of communication with others. Moreover, Internet use enhanced their sense of independence and self-determination [17]. More recently, Smedema and McKenzie [18] found that there was significant positive association between Internet use and overall sense of well-being.

Depending on the availability of assistive technology and the type of disability, however, websites may be more or less accessible. To be fully accessible, websites must include special instances of HTML code that enable adaptive technologies to provide additional context or flexibility [19]. For example, proper coding enables individuals who are blind and use screen readers, such as JAWS, and people who have low vision who use screen magnifiers, such as ZoomText, to navigate through a site, understand its content, and operate its features. Without accessibility-oriented coding, using a website may be impossible for persons with disabilities. Inaccessible websites remain a problem, with up to 90 percent of F100 corporate website home pages found to have at least one accessibility issue [20], and over 70 percent of the 50 states and the District of Columbia home pages do not meet accessibility standards [21].

This combination of interest in recreation, disposal income, personal benefit from using the Internet and continued website inaccessibility for persons with disabilities, led the Corps of Engineers to initiate an accessibility review of their Corps Lake Gateway page, which we conducted in early 2008. We in turn structured our research so that we could determine which aspects of their website would be more difficult for persons with visual impairments to use, and identified research-based design recommendations based on the findings.

1.2 Impact of Visual Impairments on the Duration of Usability Tests

In addition to design recommendations, we looked at what must be taken into account when conducting usability tests with persons with disabilities. Based on our prior experience, conducting tests requires a modified approach. One of the key differences is the amount of time that participants take to complete tasks, which in turn impacts the maximum time per task, the number of tasks per session, and the overall length of the session. One common rule of thumb, based on anecdotal evidence, is that blind individuals take 3-4 times longer to complete a task than sighted individuals without impairments. It has been observed that persons with low vision require additional time as well. No specific references in the literature exist to support these guidelines, and in order to create a clear rule to be of use to practitioners, we looked for differences between groups in our study of the Corps Lakes Gateway.

2 Case Study Background

To gain a better understanding of how different types of users interact with an information-intensive website and identify best design practices, researchers at Usability/Accessibility Research and Consulting at Michigan State University have been performing a series of user experience evaluations on the Corps Lakes Gateway website for the past three years. The current usability evaluation on the Corps Lakes

Gateway website within the Natural Resources Management (NRM) Gateway was performed to identify best practices for enhancing the website for persons with disabilities, including those with visual impairments. The NRM Gateway is a knowledge management system used by over 2,500 Corps of Engineers natural resource professionals. The Gateway contains over 90 thousand pages of content and had over 9 million hits in 2009. The Visitors section of the NRM Gateway, called the Corps Lakes Gateway, targets the general public interested in recreation opportunities provided by the Corps of Engineers. (See Figure 1.) Information is available for each of the lakes within the Corps. This site received over 46 million hits in 2009.

Fig. 1. Corps Lakes Gateway homepage

3 Research Methodology

In order to understand the similarities and differences in browsing strategies across user groups, we evaluated the Corps Lakes Gateway in one-on-one usability sessions with 34 participants, including 18 users with normal vision, 8 users who are blind (working with the JAWS® screen reader), and 8 users with low vision (working with the ZoomText® screen magnifier).

Key usability metrics and goals included effectiveness, which refers to how well a system does what it is supposed to do; efficiency, or the way a system supports users in carrying out tasks; satisfaction, which relates to the subjective responses users have to the system; and accessibility, which addresses whether the system adequately supports users with disabilities (who may rely on assistive technology, such as a screen reader).

Participants completed typical tasks beginning at the Corps Lakes Gateway homepage, and each group's performance was measured by task completion rates, time to complete tasks, errors, satisfaction ratings, and verbal feedback.

4 Results and Recommendations

4.1 Usability Testing Results

Users were successful in finding information within the Corps Lakes Gateway website for pages with concise, straightforward content, but were less successful for pages containing complex tables. User satisfaction ratings demonstrated that, overall, participants found the website useful. Our usability testing identified several design problems, reflected by difficulties encountered by users with visual disabilities.

Many of the difficulties and errors in completing tasks were a result of page layout. Before reaching the main content, users of assistive technology had to wade through confusing links and graphics. Unlike sighted users, persons who are blind or have low vision cannot see the whole page at once. Screen reader users listen to content as it is read from top to bottom and low vision users enlarge the page and can only see a small part of it at any one time. Without additional information to provide context for screen reader users or effective clustering of information for ZoomText users, participants would sometimes find the correct page but miss the relevant content. Complex tables and dropdown menus further decreased success rates and increased the time needed to be successful.

4.2 Duration of Usability Tests for Users with Visual Impairments

In our study, we found that participants with low vision took 2.95 times longer than participants with normal vision to complete tasks, while participants who were blind took 3.44 times longer. The result for individuals who are blind is therefore consistent with the general rule of thumb of 3-4 times the duration of sighted users. Low vision users needed even more time, although there are no rules of thumb for comparison.

The time required for individuals with low vision ranged from being comparable to sighted individuals to taking longer than blind inviduals, with tasks taking from 1.15 to 6.26 times as long as those with normal vision. The time for blind individuals had less variability, from a minimum of 2.96 to a maximum of 4.28 times as long. It is clear that the particular characteristics of a task play a large role in determining how long a participant will take relative to baseline. The results further suggest that pilot testing is more important when working with low vision than blindness in determining the length of time that should be allotted for each task, due to the increased variability.

5 Implications

5.1 Implications for Website Designers

Taking into account performance data, facilitator observations, and user ratings and comments, we provide the following recommendations for information-intensive websites. While we have provided specific recommendations for screen reader and screen magnification users, the general recommendations also apply to persons who are blind or have low vision.

General Recommendations for All Users:

- Ensure that all links are worded clearly and concisely.
  - If you must include two links that have similar wording, offer a brief clarifier or description to indicate where each link leads.
  - For major topics of interest, consider having one page that serves as a portal to other resources on the topic, rather than using similar and potentially confusing links to different pages that contain related information.
- Always warn users when a link will open a new window.
- Provide a concise and simple main navigation menu.
- Place all functionality on the top or left side menus of the Web page where they will be expected, rather than limiting a feature to the content area in the middle of the page.
- Ensure that the search function responds appropriately to common user queries.
  - If text is already present in the search box when the page loads (such as "Search" to indicate the function), automatically remove the text when users click into it to ensure that users do not mistakenly add their search terms to the existing text string.
  - If there are no search results, display a message to that effect instead of displaying an empty page.
- Ensure that drop-down menus function according to users expectations.
  - When the same drop-down menu is present on multiple pages, it should retain the selection when user moves between pages.
  - If a drop-down menu provides more detail than the prior menu, it should only include choices relevant to the prior selection (information should cascade hierarchically).
- Do not bury important information in long paragraphs.
  - Use lists rather than paragraphs to present related information in a concise way whenever possible.
  - Break up large blocks of text into shorter blocks of information to improve readability.

Use paragraph headings to enhance scanning.

Recommendations for Users who are Blind:

- Ensure headings are used to identify sections and subsections so that screen reader users can easily scan pages that contain large amounts of information.
- Provide accurate and descriptive alternative text for all graphics and non-text content.
- Provide a link to the homepage at the top and bottom of all pages.
- Tag PDF files for accessibility so that they render properly with assistive technology.
- Provide a site map to help users understand site organization and content.
- Make sure that drop-down menus work with the "Enter" key, which is the expected behavior for screen reader users.
- Ensure that all form fields and radio buttons have labels that are descriptive and associated with input fields.

Recommendations for Users who have Low Vision:

- Make page information concise to reduce the need for horizontal scrolling and to enable quick scanning.
- Avoid italic type, as it is more difficult to read.

5.2 Implications for Usability Practitioners

Usability practitioners should use a 1:3:3.5 (normal vision : low vision : blind) rule of thumb for determining the amount of time to allot for usability testing of websites. Pilot testing is also recommended whenever possible, as the variability in task times is high, especially for low-vision participants. When pilot testing is not possible and a more conservative estimate is needed, it is recommended that a 1:4:4 ratio be used.

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Disabled Youth in Sport Rivalry: What are the Trends – Virtual or Real Competition?

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Abstract. A computer with properly selected software provides aid in recreation of the disabled people. Its benefits are undisputable – assistance in individual physical, intellectual and psychical development. However, it seems that like in the able-bodied environment also here one should consider more or less conscious social isolation resulting from fascination by virtual world. It is more likely since the isolation is still fuelled by a problem of architectonic and psychological barriers that still exist in the environment and are not experienced in the cyberspace. The subject of presented research is a comparative analysis of sport-oriented behaviours of disabled young people against the background of trends related to the rapid development of computer games. The first part of the study discusses problems of active recreation in the Polish society and video games development directions with particular focus on the needs and restrictions of people with disabilities. The application section presents the research work targeted on the one hand to define the role of virtual competition of disabled youth in their everyday life and on the other, to check how it may jeopardize the health-oriented sports competition in the real world.

Keywords: computer in the disabled people's environment, sports of the disabled, computer video games.

1 Introduction

We should not fight with the future but wisely and in advance prepare for its coming.

One of the targets of research conducted for the benefit of the disabled is raising our awareness of problems related to disability and of the rights and hopes of the disabled. It makes its own sense not only in the light of the society's increasing respect for these people but also because of the fact that what in a given live period for an able-bodied person seems easily accessible, in a proverbial moment may for such a person appear an insurmountable barrier. With this in mind, we must recognize that seeking universal solutions to shape the human environment should be treated as an obvious issue. This in turn means that when shaping the everyday use or architectural objects a designer should be guided by the same degree of both technical knowledge and empathy. In other words, his professionalism should be manifested in ability to adapt to the human environment and not vice versa.

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The main areas that determine human life quality is his home, work and leisure (i.e. recreation and relaxation). For the environment of people without disabilities each listed area of life may have its different and independent place of realisation. For people with disabilities it is often different. This quality is on the one hand conditioned by opportunities to overcome external barriers (i.e. of psychological, architectural and information nature) and on the other by internal ones (i.e. individual possibilities of functioning). That is why a home functions not only as the place of residence but also, somewhat forced, place of work and leisure. The same home becomes both an asylum and a "prison". In such circumstances it is hardly surprising that a computer with suitable software (i.e. the Internet, education software, games) and peripherals (consoles, pads or motion controllers) may act as an always present and true friend.

Thus it seems reasonable to identify the following issues: whether and how contemporary, revolutionary changes in digital technology influence the society of people with disabilities and especially the young generation. Do they contribute to their social isolation or maybe on the contrary are an alternative to the desired integration processes? It seems appropriate (though obviously not the only) direction of research on the given question is comparison of the disabled youth attitude to active participation in real sport confronted with virtual sport.

2 Recreational Sports vs. Virtual Sports in the Environment of People with Disabilities

Recreation which is an element of leisure may take various forms, for instance: of sports or touristic activity, a visit to a shopping mall, doing DIY, cooking, reading, playing board or computer games.

In the research presented, attention was focused on a form of active relaxation that requires taking up physical and emotional effort and competition on the one hand seeing in it a method of enhancing self-esteem (I dare to face someone to a peaceful confrontation) and on the other an undisputed way to increase fitness. It seems that in the nearest future the formula will include not only the "archaic" real recreation but also the "ultramodern" virtual recreation.

In order to develop the issue it is essential to highlight a multifaceted role brought by the recreational sports and confront it with a serious competitor of great potential: the state-of-the-art computer video games like Playstation Move or Natal which use motion controllers.

2.1 Recreational Sports as a Method to Minimize Social Isolation Phenomenon

Pierre de Coubertin, the initiator of the modern Olympic Games revival (Athens, 1896) considered sport not only as the means to harden off the body but mainly as an universal method of contemporary human education in a spirit of peace. According to him, in a sportsman's live it is a possibility to compete which is crucial but not the victory. Sir Ludwig Guttmann, the founder of the Paralympic Movement also supported the motto. He wanted physical activity of people with disabilities not to be merely associated with rehabilitation activity but aimed at restoration of body and mind activeness of the disabled through sports. He claimed, which is hard to disagree, that the essence of social reintegration is instilling self-esteem, self-discipline, spirit of competition and friendship. To this day practicing sports and the accompanying positive competition is for many disabled people a kind of psychotherapy giving a chance to rebuild self-esteem.

An example to confirm rightness of Guttmann's theory are conclusions of research conducted by scientists of Academy of Physical Education (AWF) in Katowice (Poland). In 2005 they surveyed students with mild intellectual disabilities whose task was to describe their attitude to the Olympic Games and PE lessons at school. The research impressed on recipients that these young disabled people often identify themselves with able-bodied athletes and eagerly experience their success with non-disabled peers. In turn, an opportunity to participate in competitions in the living environment would in the research results commentators' opinion contribute to improve their position in the peer environment. Physical Education lessons are perceived very positive by the respondents, either [1][2].

Other equally interesting studies have been undertaken in the blind teenagers environment. Answers to questions defining their attitude to participation in sports activities have been sought. It was enquired what motivates them, what type exercise they prefer and whether they perceive a relationship between physical fitness and live quality. The situation is similar to that of the youth with intellectual disabilities. Despite serious constrains caused by poor spatial orientation, the blind youth who likes sports strives to continuously improve their skills and results [4].

Research has confirmed sports being a crucial element of the disabled person's live and the adopted work methods related to physical education shape a disabled child's "strengths" . Such statements give a clear signal that the recreational sports of the disabled should be invested in.

However, the disabled youth's willingness to play sports is just a piece of the puzzle. There is another, extremely important issue: providing places of recreation. To provide them it is not enough (e.g. on the EU conditions) to assume a priori the *European Charter for Sport for All* of 1986 which specifies the Member States tasks. For instance the Chart Part B devoted to the issues of disability includes information according to which governments are expected to guarantee participation in sports opportunities to each disabled person and at any (i.e. elite, club or recreational) level. In reality it means a necessity to prepare adequate sports and recreational infrastructure which includes a project, construction, maintenance, promotion etc. Pursuant to the document, the disabled should also be guaranteed an access to regular, integrated activeness and organisation of integrating sports events [5].

Though the enumerated targets are clear (i.e. let us even chances) and seem to be an effect of empathy it is wondered to what extent they are realistic to be met. The fundamental barrier is not a reluctance particularly of the young and able-bodied society to people with disabilities [10] but also a variety of illnesses met and therefore problems with providing full sports integration [12].

Many associations which organise and encourage able-bodied and disabled people to take part in various recreation and sports events, successfully operate in Polish reality. On the other hand, sports and recreation areas that are recently being built in our country are built with an intention of creating universal architecture (i.e. without architectural barriers). It is worth wondering though why no disabled persons can be met at these facilities, why neither they compete between themselves nor with the able-bodied ones? Can it mean that the "abled disabled" isolate themselves in their environment of their own choice and are not interested in their sports world of the disabled?

After a thorough analysis of the problem one may conclude that there are different barriers than the architectural ones which affect the difficulties in universal sports facilities organisation in modern times. These include for example dispersal of people with disabilities in the city or the mentioned variety of ailments. This means that really only the school, clubs and mentioned associations provide the disabled with a chance and an unfettered opportunity to realize sport ambitions. It moreover means that virtually only in these environments one may wait until the infrastructure is adequately prepared (i.e. gyms, swimming pools, outdoor facilities and others) and ideas of integration events are made.

On the one hand it seems logical and justified but on the other it is hard to perceive there an idea of real, broadly defined integration with able-bodied people. Sorry to say this, but the existing reality we deal with, implies an idea of pseudo integration since the activities take place exclusively owing to family, closest friends and involved activists care but are not the result of natural social interaction.

Currently, a positive aspect of the recreational sports of the disables which is worth continuous support is undoubtedly an effective aid in minimizing their social isolation.

2.2 Modern Computer Games as a Tool of Active Relaxation

Learning and / or playing with computer have undeniable advantages. Many studies have proven that nowadays a computer with properly selected software provides help in rehabilitation of the disabled people. For example the system operation itself which requires using a keyboard or mouse, improves hand skills, exercises visual and motor coordination. Develops mind concentration and perceptiveness skills as well as other perception functions.

In addition to providing good fun, the objective of computer games is also motivating to competition (e.g. with a virtual character) in accordance with an electronic scenario. A disabled person participates in the game with immense joy and hope since he or she might feel the same as each "normal" i.e. fully able-bodied player who having a console in front of him / her can freely compete with others, run on the screen with a virtual character which is rather impossible in real life. Furthermore, owing to the games does not feel discriminated and marginalized. The opponent nether ridicules nor reproaches the disability because he does not see a player from behind a monitor but a virtual character.

The contemporary computer games market is dominated by modern video games where a standard gamepad has been reinforced by a so called motion controller thus introducing a new use and play quality. Microsoft and Sony offer games which have earlier been come across only in science–fiction films where the mentioned motion controller is one's own body and in the future (surely will be common) also the mind. The device used for the challenge is called Kinect (earlier Natal, where the payer's body is a controller) and Playstation Move (here the controller looks like an "improved" version of the Wii console). Imagination tells that in a subsequent stage of Gears of War, Call of Duty or Battlefield the player will be able to run, playing the characters of professional soldiers and hiding every now and then behind an an armchair to avoid firing and to attack. In FIFA or NBA games one will be able to enter into the skin of a well-known player and in front of the TV make movements that resemble real game: dribble with the ball at his feet and score goals or dribble and throw the ball to the basket.

The latest generation of these games is also seen as a future rehabilitation method of the disabled people. However one cannot hide that with marketing such a controller like Kinect but without implementation of other than used motion mapping methods, people with disabilities may be left out (especially these with restricted motor skills). They will not be able to perform movements in front of the screen like the able-bodied which means they will not feel full satisfaction and taste of fun [3].

2.3 Can Participation in Computer Video Games Replace Active Recreation?

Advantages of practicing adventure sports and participation in computer games have already been mentioned. However let us present also a negative scenario. When one is free from duties having a choice how to spend free time he may run into a dangerous trap called computer addiction (cyberholism). It means that staying in the company of the computer can (and the phenomenon is likely to be enhanced) lead to the surfer's / player's unconscious isolation from people and the real world. This increasing tendency, if not reversed early enough, may with a time give rise to a serious social problem. A certain consolation for the time being (we do not know what happens in 10-15 years) is an intuitive awareness and understanding of the younger generation that the computer is a kind of threat for the leisure time freedom of choice and one of the methods to get out of the computer addiction trap is taking part in active recreation [9].

An alarming phenomenon related to perceiving the world from the computer angle is also dealt with by British scientists for example. Their studies have revealed that less than half of little kids aged 2-5 know their address, 11% is able to lace up shoes and only two out of ten can swim, whereas 70 % kids can easily cope with online computer games, over 70 % easily use a computer mouse and one fourth naturally surfs the Internet. The researchers claim parents are to blame since they have less time and treat electronic devices as children carers [7].

The situation is paradoxical among disabled people who like the computer since it helps them to become free though they would in fact prefer to leave their homes without embarrassment. On the one hand they become isolated not by their own fault and on the other falling into cyberholism may become secondary isolation victims [10]. Here, like in the group of the able-bodied youth, active recreation may appear an antidote.

It seems in the face of such vision of the future that the latest generation computer video games which require authentic physical activeness, might in the disabled environment become an alternative to real, sports and recreation rivalry (which requires leaving one's home) without exposing the player to slow social isolation.

To fulfil it, it seems two conditions at least must be met:

– the computer video games launched to the common market together with integral consoles should be constructed to provide the disabled persons' with an opportunity to take part in the game;

– the games should be of universal and multi-player character (more than one person would have to participate).

3 The Method of Conducting the Research

Referring to presented issues, the author has attempted to identify the problem in the disabled youth environment available. Teenagers residing in various cities of the Upper Silesia (i.e. the area of southern Poland), attending one special school in Zabrze city participated in the survey conducted at the end of the year 2010. Among the surveyed persons a group was slightly mentally handicapped (aged 16-23) and another group with hearing defects (aged 14-20).

The research emphasis was focused on defining the computer role in the disabled youth's free time and defining the youth attitude to recreational sports.

Conclusions have been formulated in the light of the following questions:

– What is the significance for a young disabled person of sports competition in the real world and what in the virtual environment?
– Can the world of cybernetics dominate a disabled person or will his/her own physical activeness be more appreciated?
– What factors, from the disabled youth point of view, determine a choice of real or virtual rivalry?

40 questionnaires have been analysed, 25 of them were filled in by mentally handicapped persons (14 boys and 11 girls), and 15 by persons with hearing defects (9 boys and 6 girls).

The persons surveyed were asked a dozen or so both closed and open questions. A part of answers are presented in the tables, in three thematic groups:

I. 6 closed questions defined the surveyed youth's passion for sports and / or computer (Table 1),
II. 2 questions gave a picture of social isolation risk caused by lack of accompanying person while playing (Table 2),
III. 1 question was to show the predominance (or not) of one option of spending free time (Table 3).

The other data provided for final conclusions formulation.

The replies verification has been performed in the mentioned two groups of disability and with division into sex. The results[1] shown in tables picture on the one hand probably underestimated or unnoticed problems and on the other indicate development directions of physical activeness and methods of the disabled persons social integration support.

[1] The author is aware of doubts concerning the study results credibility because of probably insufficient study sample. However an argument in favour of their accuracy is firstly the respondents dispersion (i.e. they come from different cities and environments) and secondly the study objective which is merely indication of active free time spending general development tendencies as well as threats leading to social isolation which may be prevented.

Table 1. Recreational sports and computer games I – preferences (in %) of mentally disabled students (sample A1-boys, A2-girls) and students with hearing disabilities (sample B1-boys, B2-girls)

			A1	A2	B1	B2
SPORTS	1	I like rivalry in sports.	70	45	90	65
	2	I practice at PE lesson eagerly.	70	70	100	65
	3	I practice sports in my free time.	50	10	75	50
COMPUTER	1	I like playing computer games.	90	90	90	50
	2	I play computer games at home.	90	70	75	50
	3	I play computer video games.	65	10	55	15

Studies confirm that in the environment of disabled teenagers both sports and computer play a significant role. There are still objective difficulties for these activities to be treated also as entertainment in the time free from school duties. The problem exists due to mental, communication (i.e. verbal and material) and architectural barriers still omnipresent in the Polish society.

The data received make us also aware that the mentally disabled girls are the most alienated group in the „non-compulsory" sports. It seems that green light given to physical activeness and integration through sports opens opportunities to develop computer video games adapted to possibilities / restrictions of the disabled. However, so far (at least in the Polish society) their knowledge, especially among girls is very limited.

Table 2. Recreational sports and computer games II – preferences (in %) of mentally disabled students (sample A1-boys, A2-girls) and students with hearing disabilities (sample B1-boys, B2-girls)

		A1	A2	B1	B2
SPORTS	I play in my free time together with another person (other persons)	45	10	80	50
COMPUTER		30	30	30	~~70~~ [2]

Table 3. Recreational sports and computer games III – preferences (in %) of mentally disabled students (sample A1-boys, A2-girls) and students with hearing disabilities (sample B1-boys, B2-girls)

		A1	A2	B1	B2
1	Playing computer games is my passion.	27	18	0	0
2	I spend free time „in sports" most gladly.	27	18	11	33
3	I like playing computer games and being active in sports.	27	36	78	33
4	I prefer doing quite different things.	19	28	11	33

[2] The result received in the group of deaf girls is deemed not credible since half of the group does not have a comuter at home.

No less important problem is connected with an opportunity to spend free time in the family circle and /or with friends. Among the respondents, virtually only boys with hearing disabilities live an integration way of life with sports playing a crucial role. The others, irrespective if the competition takes place in the real or virtual world do not have an opportunity and / or occasion with somebody else.

In the theme of pro sports behaviours the surveyed youth overall result was positive[3] and this is a result adequate to similar tendencies among the Polish able-bodied youth[4]. The results presented in Table 3 also indicate that „a computer" has neither dominated the mentally disabled youth nor the youth with hearing disabilities which should be treated as a positive phenomenon. An argument that boys with the hearing disability do not very significantly feel (at the background of other respondents) inconveniences related to disability and do not confine themselves in "their own" world.

4 Conclusions

Integration processes are extremely arduous and unrewarding. They may be successful only if their able-bodied and disabled participants will be mentally trained from an early age. So far, a stopgap of such activities are kindergartens and schools offering integration groups. Nevertheless this direction of searching for bonds seems insufficient, especially since the mentally disabled, deaf and blind persons are in fact excluded from the process.

The greatest hope in the subject matter is brought in the case of real recreation by school education with its foundations in a well-thought-out educational strategy whereas in virtual recreation the empathy of video games originators and producers.

In both circumstances the point is not to by an assumption be guided by dissimilarities and even worse programme distinct solutions in that spirit. Searching for mutual sports competition plane is a key to positive changes. However such thinking should not be associated only with lowering standards for the able-bodied people (though it cannot be excluded). In many situations it might be just the opposite. The priority should be to indicate and use strong points of people with disabilities.

Would teaching the able-bodied children and teenagers the rules of games and organizing integration competitions in disciplines the disabled cope with excellently be for instance such a big problem? In the case of real sport it might be sitting volleyball, wall climbing, goalball (discipline for the blind), recreational bicycle races and many others [12]. Virtual competition also has its future. Still popular "ordinary" computer games have for a long time given a chance to widen the integration processes although their drawback is a limitation to virtual but not real integration. This may be changed by video games based on motion controllers which would play in parallel the role of rehabilitation and strengthening social habits (it would work in both ways), if the disabled person could participate "live" in the mutual play. The games would have to use tools enabling the disabled participant to obtain similar effects on the screen like these obtained with the use of a gamepad.

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[3] If in each respondent group replies to questions 2 and 3 are summed up, it appears that over a half of the respondents likes physical activity.

[4] Among Poles aged 15-17 physical activity is 76%, and aged 18-24 decreases to 56% [research of PBS (Social Studies Laboratory) of 2006].

The author's studies conducted (enclosed in tables and analysed in the context of other responses) confirm a conviction that the disabled youth practices sports enthusiastically. Unfortunately, playing possibilities are restricted mainly to activities at school. The problem on the one hand is an outdated sports infrastructure located close to the place of residence and on the other difficult to manage the disabled friends dispersion throughout the city and even the region. In an overwhelming majority of cases it means the need of travelling and often (somehow automatically) carers engagement. It does not foster spontaneous enjoyment in recreational sports.
Almost all respondents have a computer at home. which is their companion for a good way of spending leisure time. However, those who have a playing opportunity, do play individually. Though an offer of accessible computer video games for more participants and participation in which would require physical effort is wide and fairly easily accessible (i.e. in online shops), a limited budget of the carers and too little advertising seems an insurmountable barrier.
The studies presented in chapter three showed also that trends referring to the real and virtual rivalry go hand in hand. So far, common social isolation in the disabled people environment caused by computer addiction has not been a problem.

It seems that both promotion of opportunities to the disabled participation in the real sports (through relevant education and spatial organisation of physical activity facilities) as well as fostering virtual competition (through adapting the software to expectations, individual possibilities and mutual fun) is a proper direction of social integration.

Therefore the direction to consolidate the environment of the disabled people with the able-bodied by means of real and virtual competition seems to make sense. The movement should support the integration processes thus preventing social isolation.

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Advances in Game Accessibility from 2005 to 2010

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Abstract. The research in the area of game accessibility has grown significantly since the last time it was examined in 2005. This paper examines the body of work between 2005 and 2010. We selected a set of papers on topics we felt represented the scope of the field, but were not able to include all papers on the subject. A summary of the research we examined is provided, along with suggestions for future work in game accessibility. It is hoped that this summary will prompt others to perform further research in this area.

Keywords: game, accessibility, disability, multimodality.

1 Introduction

Game accessibility is about adapting a game's hardware and software (such as game controllers, difficulty level, or feedback modality) to individual needs, regardless of having a disability or not. This makes the target group potentially large. The need for game accessibility may become more urgent with certain disabilities for some game genres. As gamers grow older, they are more likely to become disabled. Further, with the advent of using games in public schools, accessibility may become mandatory for games where accessibility is required by law. This paper presents a literature study of the advances in game accessibility research, based upon 38 published papers between 2005 and 2010. This is done to follow up our previous paper for HCI International 2005 [1]. While great effort has been put into making a fairly complete description, this paper does not claim to include every single research effort in this field.

The research can be broadly grouped in two categories: (a) papers related to creating games concurrently accessible by several groups of people with disabilities; and (b) papers presenting games or interaction techniques targeted to people with a specific disability.

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2 Comparison of Selected Research between 2005 to 2010

2.1 Visual Disability

Savidis et al. [2] discuss the development of a 2D pong-type game space that supports directional auditory and haptic feedback to enable blind users perceive the position of moving targets, also offering a visual interface for sighted players. The game is fully configurable, regarding the auditory grid, the behavior of the force feedback, the graphical appearance and various sound effects. Moreover, different levels of difficulty are supported, affecting speed and the game arena (i.e., circular top-bottom sides).

Atkinson et al. [3] describe how they managed to make a commercial 3D game (Quake) accessible to blind gamers. The paper mainly focuses on rendering techniques, focused on facilitating fast-paced gameplay and was based on the idea of "earcons", employing three different features: (a) consistency within referent types, where a basic earcon is defined for each type of object or event and some properties of it according to each state or type; (b) variance across reference types, i.e. different types of objects use distinctively dissimilar earcons; and (c) natural reference points, where earcons include an in-built point of reference. The authors also suggest techniques for allowing vision-impaired users to edit 3D structures, which might also benefit non-impaired users.

Archambault and Olivier [4] discuss the creation of "Blindstation" developed in order to function as a way to help redesign games by separating game components (e.g., buttons) from game logic in order to allow them to work with any kind of input/output device such as tactile boards and Braille devices. Several games were adapted and designed using the "Blindstation" system. The authors note that adapting games using this system results in a higher cost due to having to redesign the game but feels it is worthwhile because it allows visually impaired children to share their gaming experience with their sighted peers.

White et al [5] interviewed computer literate blind and visually impaired users to identify mobility and orientation skills needed in (1) the real world, (2) virtual environments, and (3) learn about their expectations and desires for virtual worlds such as SecondLife with regard to user interface, use scenarios, and interaction with others. Navigation issues were considered as a much greater issue compared to features like content creation and trade, since navivation is a recurrent issue for most blind and visually impaired users and a core concern for all MUVEs. The authors present an excellent overview of alternative navigation systems, including multi-modal audio and haptic interfaces.

In [6] Gutschmidt et al use haptics and audio to make the game of Sudoku accessible for blind, to try out how to use haptics for conveying common accessibility issues for blind like overview and state feedback. The haptics is implemented with a two-dimensional braille display with 60 rows of 120 dots each. It can represent both text and graphics. Vibrations, pulsations and other dynamic effects can be generated, and it accepts gestures as input. The two-dimensional display alone helped in emulating the sighted player's game, but using both audio and haptic modalities were found to be better.

The paper by Sepchat et al [7] presents their work with tactile video games for blind using a one-dimensional Braille display alone (without audio). It has just one row which consists of pins in four lines and two columns per sign. These pins can be raised or lowered to form e.g. a maze in a game. A semi-automatic game generator was developed, to ease the development of tactile games. Evaluation shows that sighted gamers quickly understood how to play the game presented on a regular display. Sight disabled had harder to understand the braille display, but a 5 to 10 minutes of explanations helped.

In [8] Archambault et al define game accessibility and provides an overview of research made in different game genres, mainly for visually impaired people. Further, they describe their work in proposing a programming framework to simplify the process of making mainstream games accessible for all.

Roden and Parberry [9] propose a framework for creating interactive narrative-based, 3D audio only adventure game aimed not only at the visually impaired but as an augmented-reality game for a mass audience with implications for mobile computing and devices, such as smart phones and iPods.

Sanchez & Saenz [10] relied on a 3D sounds system to help users orient, avoid obstacles, and identify the position(s) of objects and other people within a virtual edutainment environment. The players experienced that the 3D sound helped with spatial orientation. Additionally, the authors included a 3D versus 2D visual format, additional audio cues (such as sound associated with opening a door being the opposite of the sound associated with closing a door), and increased visual contrast greatly helped those players with some residual vision.

Morelli et al [11] evaluates the effectiveness of using multimodal (tactile/audio) cues versus unimodal (audio only) cues for visually impaired with VI Tennis, a Wiimote based exercise game ("exergame") which emulates the game play of Wii Tennis. Results from an accessibility point of view, was that the children "scored significantly better with the tactile/audio version and also enjoyed playing this version more".

Oren et al [12] created a 2D, side-scrolling game world where the player navigates by hopping on platforms, based on the same concepts as early Mario Brothers platform games. The researchers created two versions of the game: (1) an audio-only version, which two experimental groups played by one group of gamers with normal vision and one group of legally blind gamers and (2) an audio-visual version played only by gamers with normal vision. The authors were interested in finding out if "mental maps" of game levels differed after playing each level. Interestingly, the mean scores of mental map accuracy did not vary significantly between groups, suggesting that neither game type presented difficulties in perceiving spatial relationships and routing information.

Sanchez and Elias [13] took a look at real world navigation aids such as the "white cane" and Electronic Travel Aids (ETAs). This was done as a way to explore issues present with ETAs in an effort to create a games that would allow for a better orientation system. The primary issue that the authors focused on was that ETAs often convey too much information causing cognitive overload and, thus, confusion. The authors interviewed blind children and conclude with the recommendation that a game-oriented approach allows children to become exposed to unknown virtual environments that can help to improve navigation and orientation skills in the real world.

Folmer et al [14] looked into the problems encountered by visually impaired people when accessing virtual worlds. They developed a text based interface for Second Life. They discovered that many of the objects found in a virtual world did not provide sufficient information about themselves to allow the researchers to easily generate a text description. In areas with a large number of objects remained an issue, since it was difficult to aggregate information. Finally, the use of a text interface was slower than the usual direct manipulation of objects that a sighted person was able perform.

Pascale et al [15] propose two haptic-based input modes – supporting most major haptic devices – to help the visually impaired navigate and explore Second Life through exploiting the force feedback capabilities in many haptic devices. Two new input modes were created: (1) Blind Walk, which uses a standard joystick to control in-world walking and flying with force feedback used to indicate collisions and (2) Blind Vision in which objects and other avatars are felt via different speed, strength, and type of vibration frequencies. Sighted, blindfolded players reported being satisfied by their experiences and found that finding and reaching other avatars easy. However, like Folmer et al [14] found, telling how large groups of avatars and objects were proved difficult.

The AudioOdyssey game by Glinert and Wyse [16] was interesting because it allowed sighted and visually impaired players to use the game together. The game allows the players to create songs as a DJ at a club. There was also an online version of the game that masks what set of controls a player is using, so a sighted player may not know their opponent has a disability. The game is also set up to allow the use of the Wiimote as a controller.

Miller et all [17] developed "Finger Dance" as a way to create an audio-only of "Dance Dance Revolution". To replace on-screen visual information to indicate which keys/buttons to press, players would press one of four keyboard keys mapped to sound pitch (high or low) and speaker (left or right. The version first used variable drum rolls that lasted either one, one half, or one quarter of a beat, presented before the user was to press the key that correctly corresponded to the audio cue given. The second version had a constant (ie, one beat long) synthesized sound. Blind gamers enjoyed the challenge of the first version even though it was much more difficult while the sound cues in the second version were preferred but the game was found to be too easy.

Allman et al [18] modified Rock Band® for players with visual disabilities. In order to provide the players with feedback about which drums to strike in the game, the researches created bands that could strap on the player's arms and legs. These bands contained a small vibrator that was activated when the player needed to perform a specific action. The players found that this approach was effective and did not require much effort in order to remember the required actions. The users did indicate that the ability to alter the audio feedback would be a welcome addition to the game.

Yuan and Folmer [19] created "Blind Hero", av version of Guitar Hero. The researchers created a glove that "re-routed" visual information by placing pager motors on the tips of each finger to indicate to the player that they needed to press the corresponding button on the guitar controller. Despite having to make game play compromises (e.g. having to leave out the "look ahead" feature), Blind Hero was reported by the players – both blind and sighted, to be a fun an enjoyable experience.

A different use of a custom haptic device was seen in the work of Sanchez, Saenz and Ripoll [20]. A "Digital Clock Carpet" was developed to teach blind children navigation skills. Because of the device's similarity to a clock and through the use of time type of commands, the children were able to use the device easily. Audio feedback was used to tell the students how well they did in accurately lacing their feet. A sandpaper like texture was placed in the middle of the device to help the student know where to place their feet when starting to use the device. A navigation game, MOVA3D, was created for use with the device and met with enthusiastic acceptance by the students.

2.2 Hearing Disability

Brashear et al [21] developed a game to teach American Sign Language to students. One of the interesting features of this research was the use of wireless gloves with accelerometers to help the computer recognize the signs being shown by the students. In addition, a machine learning technique was used to allow the program to learn to recognize the signs in use. By allowing the program to learn the signs, it is possible to have unscripted conversations.

2.3 Motor/Dexterity Disability

Lepicard et al. [22] designed a Virtual Paddle, as a generic tool for making some types of games accessible to motor-impaired players. The paddle includes four arrow buttons and eight action buttons. Alternative versions of the concept were designed., Four of them were implemented and evaluated with nine users with motoric impairments. Based on the evaluation results, an improved (but not tested) design prototype is suggested.

Sporka et al [23] experimented with controlling the game Tetris using either speech or humming to which was more effective. It was determined that humming worked better than speech. This type of work could easily be adapted to players who cannot utilize a keyboard.

Norte and Lobo [24] developed a version of Sudoku that used two alternatives to controlling the game using either speech or a single switch/button system, the latter making use of a scanning system. One interesting feature that the experimenters found was that including the addition of a “sound scanning” system in concert with the visual scanning system increased the usability of the game.

2.4 Cognitive Disability

Unfortunately, the research literature on games and approaches for those with cognitive disabilities remains lacking, which is of great concern to the authors of this paper. This is obviously a rich opportunity for research work in the game research community and it is our hopes that this is remedied in the near future.

2.5 Multiple Disabilities

Archambault et al. [25], provide an overview of game accessibility and explain how it differentiates from the accessibility of mainstream applications. Subsequently, they review previous approaches and state of the art, and suggest the creation of a new “Game Accessibility Framework”, allowing game developers to design accessible games. As first steps, they suggest: (a) the development of a typology of game interaction situations and (b) a characterization of Accessibility in terms of functional requirements.

Grammenos et al. [26] are also concerned with proactively designing games to be concurrently accessible by people with a wide range of diverse (dis)abilities. They introduce a structured design method. The basic steps include: (1) Abstract task-based game design; (2) Polymorphic specialization with design alternatives; (3) Appropriateness analysis for the design alternatives; (4) Compatibility analysis among design alternatives; (5) Prototyping and Usability and Accessibility Evaluation. The process is participatory, user-centred, and iterative involving various stake holders and allowing evaluation and backtracking at each step.

In [27], the method presented in [26] is further elaborated and tested through four case studies: a web-based chess game, a space invaders-type action game, [28] a universally inaccessible game used as an educational tool, and an improved version of the invaders game. Although most of the examples included in this article refer to 2D games, the concept and principles of UA-Games are not bound to any particular game technology or genre.

In contrast to the aforementioned approaches, Ossmann et al. [29] re-use the code of an existing game, and making the appropriate adaptations to make it accessible to several groups of people with disabilities. The game was adapted to support various input and output modalities, as well an automatic movement feature of the focused object (for a single switch mode). Additionally, an accessible configuration feature has been added to set the user preferences. The paper's findings reinforce the fact that games designed for all are possible, but also that in order for the development effort to be time and cost- effective, accessibility aspects need to be considered since the very early design stages.

In [30], Trewin et al attempted to create a virtual world with features that could support players with a variety of disabilities. An important set of findings were gathered from the set of players who played games. Players described issues they had with games in the past and described strategies they used to address the problems described. In addition, they provided a list of possible design implications. Further, a set of core accessibility features they implemented in their game were described.

Ossmann et al [31] propose a new type of assistive software that is also fun to use. Instead of focusing on a particular disabilities, their Assistive Game Interfaces (AGI) tool would (1) consider the type of game (e.g., racing) and the interactions specific to games in that game genre and (2) objects generic to games using the same game engine (e.g., the Unreal Engine) and what systems such as captioning could be standard for all games using that particular engine.

The paper "Accessibility in Virtual Worlds" by Trewin et al [32] was a description of the work that was described in more detail in [30]. This paper provides a very readable summary of many of the challenges gamers with disabilities may encounter within a virtual world.

2.6 Tools for Game Accessibility Development

The AGI [31] by Ossman et al would be a part of a larger effort toward achieving a Game Accessibility Framework (GAF) that would create games accessible for more but not necessarily focused on creating a universally accessible gaming framework.

In [33] Westin and Näckros propose a Game Accessibility Implementation Model, based upon a comparison of four games, with accessibility features for either blind or deaf. The paper concludes that accessibility solutions for games within the same genre and the same disability group may be quite different. Also, solutions for either group may have similar solutions on an abstract level. This framework is further elaborated upon by Westin and Nordeson [34] with a subsystem for serializing operations in C++.

In [35] Tollefsen and Flyen present a project with the aim of creating guidelines for game accessibility, based upon development of an accessible computer game for those with mental disabilities, or a combination of severe motor and perceptual disabilities.

In [36] Yuan et al presents a survey of game accessibility which includes a generalized game interaction model and estimates of how many in the United States who may have difficulties playing games due to a disability. The interaction model illustrates what problems disabled gamers have when playing games and is used to find the number of people "who are estimated to have their disability affect their ability to play games" [36]. Combined with estimates of how many play computer games (e.g. by age), ~0.4% are unable to play computer games while ~2.3% "suffer from a reduced gaming experience" [36].

In [37] Westin presents the results of a survey to which 500 gamers responded, most of them non-disabled. The purpose with the survey was to find out in what way (if any) do non-disabled gamers find games inaccessible? The most obvious result shows that gamers had trouble handling controls and/or understanding what to do, in one way or another, although the issues were less urgent than for disabled.

In [38] Torrente et al presents how an educational game can be made accessible for visual, hearing, motor and cognitive disabilities. Based upon a user model, a game adaptation profile with rules is included in a game adaptation engine. Adaptation encompasses input/output, game flow and in-game tools. The user model provides input to the system about which adaptation is needed. In the user model, a student profile takes the individual's condition into consideration. Further, an environmental profile takes the conditions of the context where the game is being played into consideration.

In [39] Trewin et al presents a requirements gathering based upon a survey, which include requirements of players who are/have blind, low vision, deaf, hard of hearing and cognitive impairments. The requirements are structured into "Problems/ Preferences", "Strategies" and "Design implications" which is useful as a tool for designing accessibility features for other virtual worlds and games. These requirements were used and evaluated while creating the accessibility features of the virtual world PowerUp.

3 Discussion and Further Research

Exploring ways to use haptics or tactile as complimentary feedback to sound is a promising approach for blind, especially when the hardware gets cheaper. Although lack of vision is an area which has got much focus of research, it is among the groups which has very few accessible mainstream titles. Adapting the visuals (e.g. high-contrast or large fonts) and using audio like speech and sound effects are useful approaches [39] which has the added benefit of working with regular hardware. The use of braille displays with one or two dimensions should be explored more, used in conjunction with audio to present information [6-7]. A recurring pattern was found regarding the benefits of multimodal presentation of information for visually disabled, (audio and tactile/haptic). While using haptic or tactile feedback alone was possible, it was harder to understand without explanations [7]. A careful balance of presenting some information with audio was found to be better [6]. It was more enjoyable and easier to get higher scores with a multimodal approach [11].

Hearing is one of the easiest things to implement accessibility for, as it is mainly about presenting text and visuals on the screen [38]. However, there are still many games which does not include closed captioning or even subtitling of dialogue. Hence it is vital to reach out to society with sources like [36] to convince publishers about the potential for reaching new groups of gamers.

Motor or dexterity related accessibility features can be achieved by allowing a remap of controllers. Allowing modification of the response speed is also important. For cognitive disabilities, finding ways to accommodate for different levels of understanding are essential, e.g. a bread-crumb trail or hints. [39]. Very little research has been found in the selected papers about cognitive games, so it might also be a good subject for further research, which is also proposed in [36].

Research should also focus on a development framework and code libraries which could enable developers to more easily implement features [8, 38], as well as end user tools like a game generator [7].

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Tactics Choice Behaviors Represented in a Programming Language in the Map Tracing Problems

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Abstract. Various kinds of method that decrease the language effects have been tried for understanding the spatial cognition of hard of hearing students. An experimental method and its application are proposed that uses a programming language in this article. The communication using a simple language and graphical interface is expected to give us a useful way for students' understanding the question and expressing their ideas. The navigation problems in the experiments were built using the programming language. Operational indications of the subjects were described and collected using it as well. Comparable records of both hard of hearing and hearing students' reactions were obtained and analyzed.

Keywords: tactics choice, programming language, map tracing.

1 Introduction

Hard of hearing students are said to have their difficulty of developing spoken and written languages' performance because of the disability of audio channel. Extracting the meaning of questions and expressing replies may depend on each respondent's language handling competence in the ordinary natural languages [2], [3], [5].

Programming languages have less expressional flexibility generally, compared to that of natural languages. However they have clearly defined syntactic rules and semantics in turn [1], [6]. The authors expect to be able to decrease the effects of competence difference if such programming languages can be utilized as a tool.

Hyperlogo is a mathematically enhanced member of the Logo language family [7], [8].

Outline of the study and experiment itself was reported previously [9]. On the way of analyzing subjects' response, the tracing tactics choice problem for map was found. In this article, this expanded problem is discussed that is the behavior of subjects when they had to modify their navigation actions on a route.

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It was planned to understand the subjects' general behavior when they happened to be in the situation where they had to solve the problem for continuing their navigation [4]. Two kinds of tactics were extracted from the preliminary experiments: adjustment and retrial. The adjustment tactics denotes that the succeeding steps make the difference smaller. The retrial tactics denotes that the inappropriate commands are canceled and the new commands that serve his purpose are issued. It was also the interesting item that which coordinate system was preferred to use for directions.

2 Overview of the Experiment

2.1 The System

Hyperlogo is the language system which the authors designed and implemented for their research work. It is based on the function programming paradigm. The three-dimensional (3D) graphics is equipped as the interface tool to the Hyperlogo. Usage and commands of the graphics follow the original Turtle Graphics invented by Seymour Papert.

The turtle in this system is made by a computational object programmed by the Hyperlogo language, i.e. the functional closure, that stores the location and posture information in it such as present place coordinates, heading direction, tilt angles of the body and drawing-pen status. The activity control of a turtle is performed by the message passing method to the objects.

The graphics of the system treats three-dimensional (3D) world. All figures are generated in the 3D virtual space. The traditional two-dimensional (2D) world is represented by the handling of view.

Figure-1 shows the schematic structure of the graphics system.

The implemented movement commands consist of two groups, commands based on the turtle's local coordinates such as "right-turn" and commands based on the global coordinates of the virtual world such as "head".

The erase command cancels the last action and returns to the former state.

2.2 Subjects

Two groups of the subject have provided their input data.

- Group-A: ten hard of hearing students
- Group-B: seven hearing students

They are university students of the same age bracket and have not much experience in handling computers.

2.3 Problems for the Experiment

Shows a bird-eye view of the simple model area, in which some streets, crossings, some shops, mountain and pond are located. Asks students to drive a turtle from the given

Table 1. Movement commands

<Local group>					
right <d>	left <d>	up <d>	down <d>	roll-cw <d>	roll-cc <d>
<Global group>					
move <p>	roll-reset	head <t>	north	south	east
west	northeast	northwest	southeast	southwest	
<Common group>					
forward <s>	backward <s>				
<Erase operation>					
rewind					

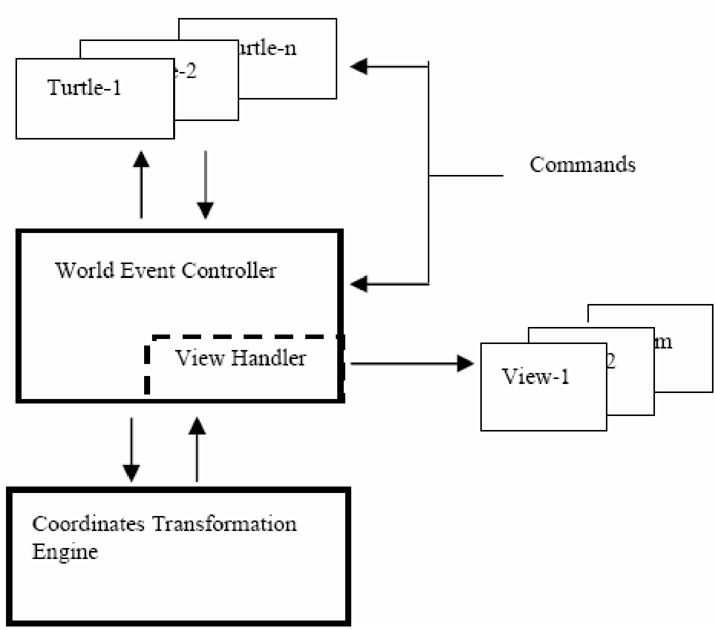

Fig. 1. Schematic structure of the graphics system

start point to destinations. The students' commands and their issue sequences including withdrawals are recorded entirely.

Figure-2 shows the model town map. It has the compass points, and a few landmark spots are located along the street. Every street intersects at right angles with each other except some crossings, so as to coincide with the compass directions. The mountain and the pond can be in sight at a certain places on the street. Different set of the target places are drawn at every problem.

<u>Instruction</u>

"This is a map of the Nowhere Town. You are asked to go on errands. Now you are at the start point on the map. Drive your car and drop by the places in order."

Four routes on the map are presented for the problems. Initial directions on the starting points are chosen to vary. Problems were prepared in sequence from Problem-1 to Problem-4.

Problem-1: Starting Point 1 → Hamburger Shop → Post Office → Movie Theater → Railway Station

Problem-2: Starting Point 2 → Market → Hamburger Shop → Post Office → Movie Theater → Railway Station

Problem-3: Starting Point 3 → Movie Theater → Bank → Post Office → Gas Station → Market → Dental Clinic

Problem-4: Starting Point 3 → Dental Clinic → Post Office → Laundry → Gas Station → Market → Hamburger Shop → Mountain

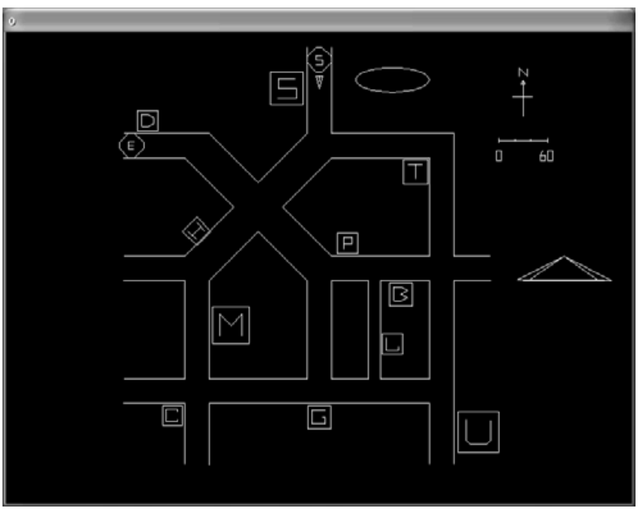

Fig. 2. An example of Town Map

3 Analysis of the Subjects' Response

The locations on the map were classified into two groups: corners and straights. Subjects' indications were grouped in accordance with the location. Grounds are that changing direction commands are mainly issued at a corner, and proceeding commands on a path.

Every input of subjects was recorded in sequence including inappropriate operations and retraction commands as well.

The use of commands based on the local coordinates and commands based on the global coordinates in the situation are also examined.

The map on the display stands vertically. Everyday sense of direction such as upward, downward and rightward may have some effect on the choice of tactics on the two dimensional plane. To estimate this bias, two relations were examined in the preliminary experiment: relation between the tactics choice and the specific locations on the map, and relation between the tactics choice and the approach directions at the corners. The characteristic trend could not be found from it.

3.1 Outline of the Subjects' Response

Table-2 is a partial example of input records. The whole elements were sorted out and arranged to the Table 3.

Table 2. A part of subjects' input records (corner)

		subject-1				subject-2			subject-3			subject-4				
		#1	#2	#3	#4	#1	#2	#3	#1	#2	#3	#1	#2	#3	#4	#5
map-1	corner-1	northeast				rt 50			southeast	northeast		rt 90	rt 45 fd 100 rt 90	rt 45 fd 100 rt 90 fd 100	fd 10 rt 55	fd 10 rt 55
	corner-2	rt 90				rt 60 rt 30			southeast			rt 45	rt 65	rt 75		
	corner-3	lt 45				north rt 60			east			lt 45 fd 10 rt 15 fd 100	lt 10			
	corner-4	north				north			north			north				
	corner-5	west				rt 120 rt 40 rt 50			west			west				
	corner-6	north				north	lt 30		southeast			north				
map-2	corner-1	east	west			west			west			west				
	corner-2	north				north			north			north				
	corner-3	northeast lt 20 rt 10 fd 80	rt 40 fd 70	rt 10 fd 80	lt 5	east			northeast			northeast				
	corner-4	rt 90				north rt 80 fd 20 north fd 5 rt 120 fd 10 east			southeast			east rt 35				
	corner-5	east				north			east			east				
	corner-6	north				west			north			north				
	corner-7	west				north			west			west				
	corner-8	north				west			north			north				
map-3	corner-1	east				east			east			east				
	corner-2	south				rt 90			south			south				
	corner-3	west				west			west			west				
	corner-4	south				south			south			south				
	corner-5	west				west			west			west				
	corner-6	north				north rt 30			north			north rt 5 rt 5				
	corner-7	rt 40 rt 10 lt 5				rt 40			northeast			rt 45				
	corner-8	lt 90				lt 80 lt 30			northwest			lt 90				
	corner-9	west				west			west			west				

Table 3. Subjects' input summary

Group-A

corner

	subject	a1	a2	a3	a4	a5	a6	a7	a8	a9	a10
problem-1	# of corners	6	6	6	6	6	6	6	6	6	6
	adjustment	0	0	1	0	3	2	0	5	0	0
	retrial	0	0	0	0	1	0	1	7	0	1
	global c.	1	2	0	4	3	0	7	3	4	0
problem-2	# of corners	8	8	8	8	8	8	8	8	8	8
	adjustment	0	0	0	3	1	2	0	1	0	0
	retrial	0	0	0	4	0	0	0	0	0	0
	global c.	0	1	0	8	10	0	8	8	5	0
problem-3	# of corners	9	9	9	9	9	9	9	9	9	9
	adjustment	0	0	1	1	2	1	0	1	0	0
	retrial	2	0	0	0	0	2	0	0	0	4
	global c.	0	0	0	7	6	0	9	7	5	0
problem-4	# of corners	13	11	11	11	12	11	12	12	12	12
	adjustment	2	0	0	2	3	2	0	1	1	1
	retrial	1	1	0	2	0	0	0	0	0	1
	global c.	0	4	0	11	9	0	12	7	4	0

straight

	subject	a1	a2	a3	a4	a5	a6	a7	a8	a9	a10
problem-1	# of straight	7	7	7	7	7	7	7	7	7	7
	adjustment	8	4	7	4	4	4	4	5	7	5
	retrial	6	2	1	1	1	1	1	3	1	3
	global c.	7	0	0	0	5	0	0	7	4	0
problem-2	# of straight	9	9	9	9	9	9	9	9	9	9
	adjustment	6	7	9	9	7	7	3	7	6	6
	retrial	5	2	0	4	1	4	5	7	3	2
	global c.	0	0	0	0	2	0	0	9	3	0
problem-3	# of straight	10	10	10	10	10	10	10	10	10	10
	adjustment	8	6	10	9	7	7	6	7	12	6
	retrial	6	4	0	2	1	2	0	4	5	1
	global c.	0	0	0	0	10	0	0	8	1	0
problem-4	# of straight	14	12	12	12	13	12	13	13	13	13
	adjustment	12	6	10	9	9	8	9	7	10	7
	retrial	3	3	0	4	0	1	4	2	1	1
	global c.	0	1	0	3	3	0	0	2	2	0

Group-B

corner

	subject	b1	b2	b3	b4	b5	b6	b7
problem-1	# of corners	6	6	6	6	6	6	6
	adjustment	0	0	2	0	0	1	0
	retrial	1	0	2	0	1	0	0
	global c.	7	4	0	1	7	6	6
problem-2	# of corners	8	8	8	8	8	8	8
	adjustment	0	0	0	0	0	0	0
	retrial	1	0	0	0	0	0	0
	global c.	9	5	2	1	8	6	8
problem-3	# of corners	9	9	9	9	9	9	9
	adjustment	2	0	0	0	0	0	0
	retrial	1	1	1	0	0	0	0
	global c.	12	2	2	1	9	6	9
problem-4	# of corners	13	13	12	13	11	12	12
	adjustment	1	1	0	1	2	1	0
	retrial	0	0	0	0	0	0	0
	global c.	14	8	8	1	13	10	12

straight

	subject	b1	b2	b3	b4	b5	b6	b7
problem-1	# of straight	7	7	7	7	7	7	7
	adjustment	5	8	6	5	6	6	7
	retrial	3	5	2	3	1	5	2
	global c.	3	2	0	0	0	0	2
problem-2	# of straight	9	9	9	9	9	9	9
	adjustment	6	7	9	10	10	7	8
	retrial	2	1	2	4	3	1	1
	global c.	2	0	1	0	2	0	1
problem-3	# of straight	10	10	10	10	10	10	10
	adjustment	10	9	10	9	8	6	9
	retrial	5	4	0	2	3	1	0
	global c.	8	0	0	0	2	1	0
problem-4	# of straight	14	14	13	14	12	13	13
	adjustment	12	5	12	7	9	8	8
	retrial	3	4	2	2	2	4	1
	global c.	3	0	2	0	0	1	1

Average behaviors of the subjects are listed in Table-4.

Table 4. Medians of the subjects' behavior

Group-A

		problem-1	problem-2	problem-3	problem-4
corner	adjustment	0	0	0.5	1
	retrial	0	0	0	0
	global c.	2.5	3	2.5	4
straight	adjustment	4.5	7	7	9
	retrial	1	3.5	2	1.5
	global c.	0	0	0	0.5

Group-B

		problem-1	problem-2	problem-3	problem-4
corner	adjustment	0	0	0	1
	retrial	0	0	0	0
	global c.	6	6	6	10
straight	adjustment	6	8	9	8
	retrial	3	2	2	2
	global c.	0	1	0	1

Table-5 is the occurrence rates of the tactics at the places normalized by the number of places.

Table 5. Occurrence rates

Group-A

corner	adjustment	0.11	(c.f. 0.47)
	retrial	0.09	
straight	adjustment	0.74	(c.f. 0.05)
	retrial	1.82	

Group-B

corner	adjustment	0.04	(c.f. 0.77)
	retrial	0.04	
straight	adjustment	0.83	(c.f. -0.66)
	retrial	0.26	

And the rate of using global coordinates command is shown in Table-6.

3.2 The Comparison of Revision Tactics

When subjects are driving a car along the road on the given map, some command may cause an inappropriate action on the occasion. He/she withdraws an issued command and orders new action. The authors are interested in their revision tactics at that time.

Table 6. The rate of using Global coordinates command

Group-A

corner	0.42
straight	0.19

Group-B

corner	0.72
straight	0.12

For the whole navigation operation, it can be said that the choice of tactics depends on each subject. However at the straight in particular, the difference among subjects is significant ($X^2(16) = 39.7$, $p= 0.0009$).

It is also examined whether there is some difference between the choices on the groups.

Changes in a group. The occurrence comparison was examined between the merged result of Problem-1 and -2, and that of Problem-3 and -4 first. Then the results of Problem-1 and Problem-4 were compared.

The use of retrial tactics at the straights decreased significantly for both groups (Wilcoxon signed rank test, Group-A: T=5, N=10, $p<0.05$, Group-B: T=1, N=7, $p<0.05$). Group-B's also decreased in the test between Problem-1 and 4 (Wilcoxon signed rank test, T=1, N=7, $p<0.05$).

The significant changes on both groups were not found for the use of adjustment tactics.

The comparison between groups. The adjustment tactics was used more at the straight by Group-B in Problem-1, the initial problem (median test, p=0.026). The difference was not significant at the other places and problems for both groups.

For the retrial tactics, the difference was not significant.

3.3 The Use of Global Coordinates Commands

As a whole, the rates of use show the difference of tendency. There may be some difference between two groups on abstraction degree for handling the concept of direction on the map.

Changes in a group. The occurrence comparison was examined between the merged result of Problem-1 and -2, and that of Problem-3 and -4 first. Then the results of Problem-1 and problem-4 were compared.

For Group-A, the difference at the corners was significant between the merged results (Wilcoxon signed rank test, T=2, N=7, $p<0.05$). The occurrence in Problem-3 and -4 decreased. No significant difference was found for Group-B. However it can be supposed that the frequency of use increases slightly as the experiment proceeds for Group-B.

Comparison between the groups. Comparison was made for every problem. The significant difference can be seen at the corner's data in the Problem-4, the last problem (median test, p=0.024). Group-B is using the global coordinates commands more than Group-A.

4 Discussion of the Result

Each subject has his/her own tendency to choose tactics according to the property of locations in an ordinary sense. From the limited analysis up to the present, locations as a group has seemed to have some effect to the tactics choice. However no significant difference by each location has been found yet.

By the residual analysis, it is likely that Group-A seems to prefer the adjustment tactics and Group-B the retrial tactics generally.

As the experiment went forward, use of the retrial tactics decreased by Group-B. The tendency of Group-A's was almost the same but the rate was a little low.

It is considered that using the local coordinates is a concrete indication and using the global coordinates is an abstract one. Group-B uses the global coordinates commands more than Group-A, particularly at the corners. Group-A may prefer the indication based on the realization of everyday situations.

Change of tactics along the time coordinate is the interesting problem. The analysis is on the way now at the succeeding steps. It is expected that a tactics change can be observed which is brought about by the learning effect.

Further studies must be required for drawing the conclusion whether the cognitive difference exists between them. Collaborations with the other method such as the video review session will bring us the fruitful results.

5 Conclusion

Objective of the study was to make clear the possibility of using programming languages for interface tools. Hyperlogo was used for the presentation of problems and collection of subjects' response. For both groups, the interface functioned properly for the purpose without prominent differences of carrying out the experiments. It has brought to decrease the expressional ambiguity. The authors could compare and analyze the result impartially.

It has become clear that using the mathematical programming language is suitable for this kind of experiments for both hard of hearing and hearing students.

It may be difficult to extract the inside mental process if the appearance of subject's reaction by the observation is the only key. However, a little further clue may be obtained if such a programming language is used as a tool.

The number of subject for this research is regrettably so small at present. Attribute requirements for them such as programming experiences may have been a little strict. The authors would like to study further and show the feasibility of this approach.

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Part IV

Cultural and Emotional Aspects

Age-Related Accessibility Biases in Pass-Face Recognition

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Abstract. Accessibility and security are often depicted as conflicting aspirations. Accessible systems may be less secure and secure systems may be less accessible. The search is on for greater security for logging onto systems, whilst achieving acceptably high levels of accessibility. Pass-faces are based on the twin axioms of greater accessibility and security. A new user of a pass face system is asked to select "n" faces from an array of faces, where n is at least two and usually more. The user is required to memorize those faces and to recognize them again when represented to you as part of larger display. It has been suggested that this approach is less susceptible to poaching than are alphanumeric methods. There has been a considerable volume of work to evaluate the usage of pass face systems, but little work on the psychology of pass faces. Equally, pass face systems have received little attention from researchers in accessibility. In the present study, two previously unrelated themes were investigated in two experiments. First, are pass face systems acceptably usable? Second, how do pass face systems rely on the reliability of human face recognition memory? In two experiments, two types of pass face system consisting of (a) older faces; over 50 years of age and (b) younger faces; under 30 years of age were created. It turns out that younger participants are often better at recognizing younger faces than older faces in the context of pass face security, whilst older participants are sometimes better at recognizing older faces than younger faces in the context of pass face security. Thus an experiment that used only younger faces would falsely conclude that younger participants were better at face recognition memory than older participants in general. These results were checked and confirmed by literatures reviews of pass face security and human recognition memory for faces. These results show that universal access cannot be applied on a one-size-fits-all basis. They also suggest that the security-related disciplines of HCI and psychology would benefit from greater interaction between them.

1 Introduction

This research tackles two prominently held concerns that are very important for universal access. The first concern is that accessibility and security interests are in

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conflict, the so-called "Security vs. Access Paradox". On one hand, a website or an application must be accessible to intended users, but, on the other hand, adequate security is vital. The World Wide Web is designed to be accessible, but does this focus on the user automatically support security? It is been argued that such a focus can lead to less security. For example, a truly secure browser would request approval for every action, from launching popup window to executing a small script. It would wait for a reply before acting. This will never happen, of course, because most users would simply turn off a system or choose to ignore it, when it asked for a continual stream of approval responses [1]. A shared theme of both accessibility and security is the safe and accurate identification of an intending user. In this study, the use of pass face security systems to support effective user identification is explored. (Such systems are often called "pass-face" systems as they employ faces rather than words or numbers).

The second concern is that older adults are often likely to perform less well than younger adults at cognitive tasks. There is a vast literature that demonstrates cognitive decline through the lifespan (see reference list below for a small sample). Experts tell us that aging leads to "normal" declines in cognitive effectiveness. In particular, such changes include reduced processing speed, greater tendency distractibility plus reduced capacity to process and remember new information i.e. working memory." Such changes can create negative stereotypes about older adults, though they are to be expected and are not symptoms of clinical, cognitive impairment. If so, the rapid presentation of materials, frequent focus changes combined with distractions and intrusions may reduce understanding and recall of information by older adults. In contrast, face recognition is purported to demonstrate an own age bias. If so, older adults may actually be better recognizing older faces from memory than their younger colleagues do. Or at least they may be better working with older faces than younger faces. If such results hold, they would provide important counter examples against the age as total decline viewpoint.

So, here these two concerns about (a) the "Security vs. Access Paradox" and (b) the total age-related decline view, through investigations of pass face security systems are addressed. In so doing, we attempt to bring together two previously unrelated and important themes that both concern pass face systems. Such systems rely on users deploying their recognition memory skills to recognize previously selected faces from amongst presentations of larger sets of faces. The correct selection of these faces acts as the equivalent of the correct selection of a pass word or pin number from a conventional display. First, the user experience of using simple pass face security systems is investigated. How well do users readily learn to use such systems when they encounter them for the first time? Second, since there is research evidence that the efficacy of human recognition memory is influenced by the age of the user and of the faces used, namely an own-age bias, face recognition memory too is explored in this context. Since pass face systems rely on human recognition, then it follows that older users might be expected to perform better with older faces (i.e. of their own age group), whilst younger user might show the opposite preference, being better with younger faces (i.e. of their own age group). To test these predictions, a simple experiment was performed, combining younger and older users with younger and older faces in a pass face system.

It is generally agreed that older adults often perform more poorly than younger adults on a range of cognitive tasks involving perception, memory (recall or recognition) and problem solving. It is said that tasks that require experience and maturity are the only exceptions to this generalisation to be found. If so, then exceptions to this rule are important theoretically and may have important practical implications.

It now turns out that there is some evidence of superior performance by older adults on a specific memory task, including, but not limited to recognition memory for faces. Older adults are reported to be better than younger adults for recognition memory for older faces. In contrast, younger adults are reported to be better than older adults for recognition memory for younger faces. One explanation offered is that people are better at recognition memory for faces for groups with which they can identify e.g. older people with older adults, younger people with younger people etc and that, perhaps, they process such information more thoroughly. The data suggest that this might be an age-specific result.

The focus of the present work is also on some important, practical implications of these results, namely to create a log-in function that is based on recognition memory for older faces, in order to provide older adults with a system that they will find more accessible cognitively.

2 Experiment One

2.1 Introduction

The first study involved the creation of two simple, pass face prototype systems, one using younger faces and one using older faces. The aims were two fold: The first aim was to see if our prototypes were usable, accessible and acceptable to our users, both older and younger. The second aim was to look for an own-age bias in face recognition memory using our pass face prototype systems. The prediction was that older adults would do better than younger adults for recognition memory for older faces. Conversely, younger adults would be expected to do better than older adults for recognition memory for younger faces. In this first study, the focus was on investigating the user experience, ease of use of a pass-face prototype and the learning curve associated with learning to use simple, pass-face systems.

2.2 Participants

The participants were in two samples, (a) older adults (over 60 years of age) and (b) younger adults (under 30 years of age). There were seven participants in each group. The age of each person was recorded but their identities and other demographic details were not (e.g. occupation, location etc) in order to protect their anonymity. Participants were recruited from local sources, subject to the following conditions: No copyright issues were involved and no famous people, no people judged to be unique, very unusual or very easy to recognise were included.

2.3 Materials

The pass-face systems were based on arrays of nine faces at a time, on the screen of a standard laptop, based on simple word processed documents, with included hyperlinks for target words and faces. Half the arrays used younger faces (under 30 years) and the other half were based on older faces (over 60 years of age). Age groups were not mixed within arrays. For each prototype, a pass-face key (a pass-face equivalent to a password) was created. To form the pass-face keys, each time two faces were chosen at random from the sample of younger faces and two faces were chosen each time at random from the sample of younger faces. The pass-face sequence alone was presented before each prototype. Subsequently, a random array of nine faces was presented on one screen, within which the pass-face items were included at random locations. The participant was to select one key face at each presentation. The background items were selected at random from the sample of faces of the correct age group, excluding the current pass-face sequence. Next, a second array of nine faces was presented on one screen, within which the pass-face items were included at random locations. Each face was linked by a hyperlink to an appropriate response page that provided feedback to the participant.

2.4 Methods

Each participant was tested alone. They were each shown a pass-face key of two faces for five minutes and asked to study the faces so that they would be able to recognise them in a bigger set of faces (nine at a time). They were then shown a display of nine faces that included the pass-face sequence items at randomly chosen locations. The participant then selected any one of the two pass-face key items by cursor clicks. As each face depiction was a hyperlink, the act of selection of a face took the participant to a new screen. If their response had been correct, the new screen would contain the message "Well done, that was correct. Now select another one of your faces" and an array of nine faces would be displayed. This process continued until the participant correctly selected both pass-face key items. At this point, the participant was able to a simple Internet based selection task where they could select screens that reflected their hobbies and interests. If the wrong face was selected, the participant was redirected to a different screen that simply said "Apologies, you will have to start again."

At the start, each participant was given a practice session in which an incorrect response took them back to the initial pass-face sequence on a new screen that contained the message "Apologies, you will have to start again." To simplify this first experiment, order of testing was held constant for all fourteen participants. Every participant, worked first with five trials with older faces, followed by five trials with younger faces. This allows an initial evaluation of the use of pass-face systems, some indication of own-face recognition bias and the learning curve for such systems. The instructions emphasised accurate performance, asking participants to work as quickly as possible without making errors.

2.5 Results

The time per trial and errors were recorded. The resulting time data are summarised in table one above. An analysis of these data suggests that older faces take significantly longer to use than the younger faces ($F = 16.74$, df 1,68, $p<0.0001$), though this effect could be due to the confounded influence of practice. The two age groups did not differ significantly in overall time to complete tasks ($F = 1.6$, df 1,68, n.s.). There was some indication of an interaction between age of participant and age of face, though

Table 1. Experiment One – Mean time to complete task (seconds)

	Younger faces	Older faces	Overall
Younger adults	16.83	30.26	23.54
Older adults	24.40	30.00	27.20
Overall	20.61	30.13	25.37

Table 2. Experiment One – Analysis of variance summary table

A = the between-subjects variable (rows) older versus younger adults					
B = the repeated-measures variable (columns) older versus younger faces					
Source	SS	df	MS	F	P
A	468.11	1	468.11	1.6	0.210
B	3168.26	1	3168.26	16.74	0.0001
A x B	536.26	1	536.26	2.83	0.097

this did not reach conventional statistical significance (F = 2.83, df 1, 68, p = 0.097, n.s.). For subsequent experiments, an inspection of the above mean scores suggests that a more powerful experimental design might detect that the younger adults were faster than older adults for younger faces but not at all faster for older faces.

Errors were recorded, but were few occurred and no significant differences were seen. This indicates that the participants were acceptably successful in following the instructions to work carefully. Finally, analyses of the learning curves were predominantly power functions for both the younger adults (F = 15.71, d.f. 1,8, p < 0.005) and for the older adults (F = 13.86, d.f. 1,8, p < 0.01). These curve fitting analyses will be reported in more depth in the longer version of this paper.

2.6 Discussion

This initial experiment provides a number of very important leads for our second experiment. First, our participants showed substantial learning, in the form of a power function that indicates moderate levels of motivation, as shown in other, ongoing work in the CIRCUA lab. (A report of this work is available on request). Second, the older faces took more time to process than younger faces, though we have confounded type of face with practice level, as this gives a simpler design to allow a clearer view of the resulting learning curves. On the basis of the present experiment, therefore, it is possible that the observed types-of-face difference is due, at least in part, to practice. This point will be examined in the second experiment. Third, our participant made few errors, suggesting that they were reasonably well motivated and that speed–error trade-offs do not significantly contaminate the observed performance times. Fourth, perhaps most intriguing, the data suggest, but do not prove, an own-age bias. In these data, younger adults were better than older adults than with younger faces, but for older faces younger and older adults performed at the same level, with a hint that older adults could perform better than younger adults. The best response to such speculations is a further experiment and that is the next step.

3 Experiment Two

3.1 Introduction

The second experiment builds significantly on the evidence provided by the first study. The present work again involves the creation of two types of pass-face prototype systems, one using younger faces and one using older faces, used by a sample of older adults (over 60 years of age) and younger adults (under 30 years of age). In the second experiment, order of testing of the different conditions was counter-balanced across participants. The quantity of pre-test practice was increased to four trials, as there as some indication that the participants in experiment one were slower on their first trial, as they were still inclined to study the instructions one more time. Finally, the size of the pass-face key (equivalent to password in a conventional system) was varied, such that half the pass-face keys were made up of two faces and the other half were based on four faces.

3.2 Participants

The participants were in two samples, (a) older adults (over 60 years of age) and (b) younger adults (under 30 years of age). There were eight participants in each group. The age of each person was recorded but their identities and other demographic details will not (e.g. occupation, location etc) in order to protect their anonymity. Participants were recruited from local sources, subject to the following conditions. No copyright is involved, no famous people are involved and no people judged to be unique, very unusual or very easy to recognise were included. Each participant worked alone.

3.3 Materials

The pass-face systems were based on arrays of nine faces at a time, on the screen of a standard laptop, based on simple word processed documents, with included hyperlinks for target words and faces. Half the arrays used younger faces (under 30 years) and the other half were based on older faces (over 60 years of age). Age groups were not mixed within arrays. For each prototype, a pass-face key (a pass-face equivalent to a password) was created. To form the pass-face keys, two or four faces were chosen at random from the sample of younger faces and two or four faces were chosen at random from the sample of younger faces. The pass-face sequence alone was presented before each prototype. Subsequently, a random array of nine faces was presented on one screen, within which the pass-face items were included at random locations. The background items were selected at random from the sample of faces of the correct age group, excluding the current pass-face sequence. Next, a second array of nine faces was presented on one screen, within which the pass-face items were included at random locations. Each face was linked by a hyperlink to an appropriate response page that provided feedback to the participant.

3.4 Methods

At the start, each participant was given four practice sessions in which an incorrect response took them back to the initial pass-face sequence on a new screen that contained the message "Apologies, you will have to start again." Order of testing was counterbalanced across participants as shown in table three. The instructions emphasised accurate performance, asking participants to work as quickly as possible without making errors.

Each participant was tested alone. They were each shown a pass-face key of two faces for five minutes and asked to study the faces so that they would be able to recognise them in a bigger set of faces (nine at a time). They were then shown a display of nine faces that included the pass-face sequence items at randomly chosen locations. The participant then selected any one of the two pass-face key items by cursor clicks. As each face depiction was a hyperlink, the act of selection of a face took the participant to a new screen. If their response had been correct, the new screen would contain the message "Well done, that was correct. Now select another one of your faces" and an array of nine faces would be displayed. This process continued until the participant correctly selected both pass-face key items. At this point, the participant was able to a simple Internet based selection task where they could select screens that reflected their hobbies and interests. If the wrong face was selected, the participant was redirected to a different screen that simply said "Apologies, you will have to start again."

All participants were told that the purpose of the work was to evaluate the two prototypes (Older faces or younger faces) to see which, if any were better. It was emphasised that the prototypes were under test and not the participants themselves. All participants were told that they would try out the prototypes a number of times but the exact number of times, so as to avoid end-of-session effects. All participants were told about the idea of the pass-face concept and to expect either two faces or four faces. They were also told that some collections of faces would be older faces and other collections were of younger faces. They would always select from nine faces and those sets faces were always older or younger faces but never mixed age. Samples of older faces (over 60) and younger faces (under 30) were collected from local sources, subject to the following conditions. No copyright is involved, no famous people are involved and no people judged to be unique, very unusual or very easy to recognise were included.

Since the study involved two types of pass-face; one was based on two faces and one based on four faces. Half the trials used two faces and half the trials used four faces. The pass-face sequences were used in two blocks of trials, such that the first half of the session used one type of pass-face sequence, whilst the second half used the other type of pass-face. Half the participants received the two face version first and half received the four face version first. The trials were also divided into older faces and younger faces. Within the two blocks, half the participants received the same age-group faces first and the other half received the different age-group first. The design is shown by the following table. Note that this design allows for analysis in terms of both "same-age versus different age" and "older faces versus younger faces" Each block of trials consisted of four trials, each with a new pass-face sequence each time.

Measures of performance were; time to complete a trial and number and types of errors made.

Table 3. Experiment three counter-balancing conditions and order of testing

Group	Practice block	First block	Second block	Third block	Fourth block
1	Four practice sessions	2 faces different age	2 faces different age	4 faces same age	4 faces different age
2	Four practice sessions	2 faces different age	2 faces same age	4 faces different age	4 faces same age
3	Four practice sessions	4 faces same age	4 faces different age	2 faces same age	2 faces different age
4	Four practice sessions	4 faces different age	4 faces same age	2 faces different age	2 faces same age

Table 4. Experiment two; average times in seconds

YOUNG FACES	YOUNG FACES	OLD FACES	OLD FACES	
BIG GRIDS	SMALL GRIDS	BIG GRIDS	SMALL GRIDS	
113.13	131.13	119.00	100.88	YOUNGER ADULTS
212.25	135.75	166.13	173.75	OLDER ADULTS

3.5 Results

Inspecting the above data, it is clear that for big grids (four faces), older adults are faster with older faces than with younger faces. Also, for big grids, younger adults are faster with younger faces than with older faces. Younger people are faster than older people for both big grids and small grids (two faces). Turning to small grids, older adults are faster with younger faces and younger adults are faster with older faces. This pattern of results indicates a three-way interaction between age of participant, age of faces and size of pass-face key. These data were analysed by means of a three way analysis of variance (ANOVA), with type of participant (between subjects), type of pass-face (within subjects) and size of pass-face size (within subjects). Here is the summary of the ANOVA:

3.6 Discussion

These are important results for the concept of universal accessibility. Whilst younger adults performed better overall than older adults in experiment two, this advantage was lost in experiment one with older faces. The choice of older versus younger faces made a very significant difference in both studies, so should not be ignored when designing pass-face systems for accessibility and security. However, the three significant interactions complicate the picture in experiment two. The age of participants and the age of the pass-faces interacted with each other, as did grid size and age of faces. However, the most striking interaction was the three way interaction between the three factors. This demonstrates that these three factors cannot be ignored when designing pass-face systems, unless you limit your intended users to one age group. It also means that whilst one design may be more accessible for younger users (young faces), a completely difference design would be more accessible for older users (older faces). On that basis, we can conclude that (a) older adults and younger adults have quantitatively different recognition memories and (b) the significance of these results means that the definition of accessibility reflects both the type of user and the task context.

Table 5. Experiment two; analysis of variance (significant factors in bold)

factor	type	description	F value	df	significance level (two tailed)
A	main effect	Age of participants (between subjects)	4.81	1,14	p < .05
B	main effect	Grid size (within subjects)	1.96	1,14	n.s.
AB	interaction	Participant age & grid size	1.96	1,14	n.s
C	main effect	Age of pass-faces (within subjects)	3887.51	1,14	p < 0.001
AC	interaction	Age of participants & age of faces	3884.07	1,14	p < 0.001
BC	interaction	Grid size & age of faces	50.59	1,14	p < 0.001
ABC	interaction	Age of participants & grid size & age of faces	50.96	1,14	p < 0.001

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Affective Climate of Workplace and Its Contributing Factors

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Abstract. The purpose of this study was to investigate factors contributing to affective climate in workplaces. To achieve the purpose, the paper-based questionnaire was employed. Two hundred and sixty-one participants participated in this study. A factor analysis with principal axis factoring extraction method and varimax rotation was employed and showed the eleven factors which were contribute to affective climate. T-test analysis showed that "Intimacy" and "Flexibility" factors were recognized as the most important factors to affective climate at work.

Keywords: Affective climate, Affective Well-being, Affective atmosphere, Workplace.

1 Introduction

Nowadays, almost half of twenty-four hours in one day of everyone are required for working. The contemporary perspective of meaning and function of work are going beyond from providing the basic needs of food, clothing and shelter, and beyond faith to connecting people's contact with the reality, psychologically and socially [1]. Work psychologically provides "a sense of being happy with one's own character and abilities through one's challenge of obstacles and environmental forces", and a social sense of being a part of society. In that sense, the affective concepts, such as affective climate concept, have proposed as sharing affective experiences in work group members [2]. People who have positive affect tend to contribute many advantages for organization [3, 4, 5, 6]. However, the sources that can generate positive affective experiences at workplace have still lacked in the literatures [7]. Thus, it is worth to study the antecedents of positive affective experiences at workplace.

2 Related Literature

Positive affect is associated with a broadened cognition and action scope [3]. In cognition, positive affect leads people to see relatedness and interconnections among thoughts and ideas and to process material in a more flexible way [4]. In action, positive affect will make people search for more variety of information and choices [8].

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Also people with high positive affect perform better on the processes of good decision making [4, 5]. Employees with high positive affect request more information when insufficient to make reasonable decisions. Interestingly, both positive and negative affect relate to turnover intention [6]. From such that viewpoint, the benefits of positive affect tends to give advantages to both employees and the organizations.

The affective climate concept has started to be employed referring to shared affective experiences in work group members. Affective climate construct has used in order to describe "shared affective responses by a work team's members" [2]. They employed the term of affect because affect is traditional term for all of emotions, moods, traits, and emotion-based preferences (like and dislike). Five multi-dimensions of affective well-being at work scale were proposed to be the measurement for affective climate [9]. Five dimensions of affective well-being at work consist of anxiety-comfort, depression-pleasure, bored-enthusiasm, tiredness-vigor, and anger-placidity [9]. Affective well-being at work can reflect the frequency of experience of positive affects and infrequency of experience of negative affects [10], capture subtleties, complexities and changes in the experience of work [11], and measure in relation to the work domain as well [12].

However, we know less than we should about features of work environments that are likely to produce particular moods and emotions among people who spend the majority of their working hours, five or more days a week [7]. People's affective experiences are not only focus on happy and unhappy. There are many feelings out there, angry, tiredness, pleasure, bored, anxious, and so on. Thus, the research question for this study was what at workplace can generate affective climate or what are the antecedents of affective climate. The purpose of this research was to investigate the work environment factors which are contributed to affective climate.

3 Method

3.1 Questionnaire and Procedure

A paper-based questionnaire was prepared and sent to organizations by mail with the paid-stamp envelop for the returns. The questionnaires included three sections: the affective well-being questions, the work environment questions, and demographic questions with the introduction on the cover page. In order to achieve the purpose successfully, participants received a set of document with a clear explanation of what affective climate is and the instruction to complete this participation in the first page of questionnaire.

Affective Well-being Questions. The affective well-being at work scale [9] was employed to measure the affective climate. It consisted of 30 bi-polar question items which are sub dimensions of five dimensions with scale of 1 (never) to 7(always). Five dimensions comprised of anxiety-comfort, depression-pleasure, boredom-enthusiasm, tiredness-vigor, and anger-placidity. In order to let participants understand what affective climate is, this affective well-being at work scale was the first section in the questionnaire. Then the participants were asked to evaluate the extent of 53 work environment characteristics which influence to all 30 affective experiences in affective well-being at work scale.

Work Environment Questions. As the individual, group, and organizational antecedents of various climate types may serve as antecedents for other climates [13], the work environment questions were adopted and adjusted from antecedents of various work climates [reviewed by 13], job orientation questionnaire [14], psychological climate questionnaire [15] and the reasons of why people had stayed in company [16] as potential antecedents of affective climate. Moreover, there are some differences in view of work from members of young generation [17], some items were added into questionnaire such as locus of control and expectation from members. Six scholars were invited to review and response the initial questions. The review findings were discussed with the commentators and incorporated into the survey instrument. Then, the work environment questions were translated into Japanese by professional scholar who is excellent in both Japanese and English languages as well as expert in this field of study. Additionally, the internal reliability of the work environment instrument was examined via the pilot test with 13 undergraduate and graduate students who are familiar with Engineering Psychology field. The purpose of pilot study was to further find whether there was ambiguity in any of questions and help to estimate needed to complete all questions in the questionnaire.

Demographic Questions. In the last section of the questionnaire, participants were required to fill up personal information. To avoid the hesitation feeling, personal information questions were only six questions of gender, age, race, current working position, affiliation, and duration of working experience(s).

4 Results

Two hundred and sixty-one participants from 17 organizations in three countries, Thailand, Malaysia, and Japan participated in this study. They perform a wide range of jobs (banking, administration staff, accountants, and engineers working in several fields such as advanced materials, automobiles, electronic devices and airplanes) with an average work experience of 4.14 years in their current jobs. The proportions of two genders are almost similar, 52.5% of male and 47.5 of female with age between 21 and 65. Ninety-two participants were Thais (age between 21 and 46, M = 28.6, SD = 5.20), one hundred and six participants were Japanese (age between 23 and 65, M = 36, SD = 8.58), and other participants were Malaysia, Indian, and Korean (age between 21 and 47, M = 29.91, SD = 6.37).

The participant were asked to rate their feelings for 30 sub-dimension of affective well-being scale at work. The results of negative experiences, such as anxious, worried, tense, depressed, and miserable, were reversed so that larger scores represented positive affects. The averages and standard deviations of five dimensions of affective climates are shown in Fig. 1.

Figure 1 illustrated that participants had moderate high average of all five dimensions, of affective well-being scale. They had positive experience in pleasure (M = 4.75, SD = 1.00), placid (M = 4.65, SD = 0.85), enthusiasm (M = 4.44, SD = 1.07), vigor (M = 4.19, SD = 0.91), and comfort (M = 4.17, SD = 1.06). The t-test result showed that there were no significant differences between genders in reporting the affective well-being at work.

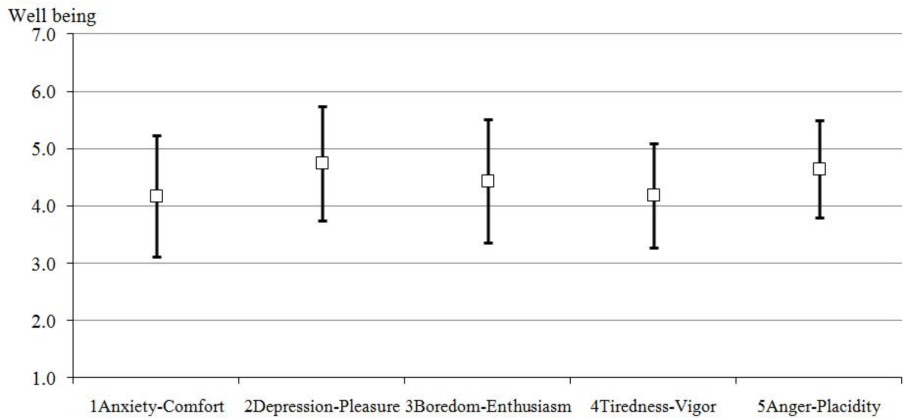

Fig. 1. The affective well-being of participants. Dots indicate averages and vertical lines represent standard deviations.

In order to investigate the structure of antecedents of affective climate, the factor analysis with SPSS was used on the responses to fifty-three items. The principal axis factoring extraction method was employed. The number of factors that were extracted was determined by the eigenvalues before the varimax rotation. Twelve factors were extracted from the fifty-three items with the eigenvalues greater than one. However, only one item, with considerably low factor loading was loaded on the twelfth factor. This item was also loaded on another factor with moderately high factor loading. Thus, only eleven factors were finally considered as the structure of antecedents of affective climate. The cumulative contribution for the eleven factors was 57.60%. Kaiser-Meyer-Olkin (KMO) test, measurement of sampling adequacy, was employed to evaluate the appropriateness of using factor analysis on the data collected. It was 0.88, reporting that the result of factor analysis was meaningful and acceptable. The Barlett test was also significant indicating that the variables are correlated highly enough to provide a reasonable basis for the factor analysis. The factor matrix table is shown as Table 1.

The first factor came with the sense of workgroup cooperation, relationship among colleague, warmth, friendliness, and cohesion. Thus, the first factor was named as “Intimacy”. Items such as career advancement, reward-performance relationship, and payment highly contributed to the second factor with other moderately contributed items such as personal-development and growth, fit to my fulfilling, and job stability. The second factor which represented the sense of advancement in working life was labeled as “Employment Stability”. Items that belonged to third factor were freedom, flexibility, trust, autonomy, independence, and employment-employee relationship. With the sense of freedom and autonomy, it was named as “Flexibility”.

Items which concerned with leader and management such as management style, management policy, leader behavior, leader support, and rule and work procedure were loaded on the fourth factor. This was named as “Management Policy”. The opportunities of being creative and innovative highly contributed to the fifth factor. Besides these two, items which implied the sense of challenging such as problem solving and

Table 1. Factor matrix table by principal axis factoring extraction method and varimax rotation with Kaiser normalization. Loadings < 0.3 are omitted

Work Environment items	Factor Loading										
	1	2	3	4	5	6	7	8	9	10	11
Workgroup cooperation	.71										
Relationship among colleague	.70										
Warmth	.66										
Friendliness	.63										
Cohesion	.62		.33								
Team support	.48								.35		
Expectation from team	.36								.33	.30	
Career advancement		.78									
Reward-Performance relat.		.73									
Payment		.70									
Personal development&growth		.58									
Personal knowledge and skill		.49									
Fit to job/my interest		.46			.32						
Job stability		.45				.31					
Fairness	.38	.42									
Freedom			.82								
Flexibility			.65								
Trust	.32		.57								
Autonomy			.54								
Independence			.52								
Management-Employee relat.			.46	.46							
Acceptance of others			.41								
Humor			.41								
Locus of control											
Management style				.76							
Management policy				.73							
Decision-making policy				.59							
Leader behavior				.58							
Leader support	.45			.56							
Rules and work procedure				.45					.41		
Creative					.82						
Innovation					.80						
Problem Solving					.54						
Variety in duties					.39						
Success		.33			.34						
Material & equipment						.78					
Technology support						.77					
Facilities at workplace						.69					
Physical work environment						.50		.35			.30
Firm Size							.83				
Firm Age							.83				
Pressure to work	.31							.58			
Relationship conflict								.58			.30
Gossip in workplace								.57			
Task conflict								.50			
Team size									.66		
Team tenure									.63		
Respect from others										.72	
Admiration										.59	
Your contribution										.43	
Role ambiguity											.63
Superiority/Inferiority											.47
Nature of job itself		.34									.42

varieties in duty were loaded on this factor. It was, finally, named as "Creative Workplace". Items with high loading on sixth factor expressed the material and equipment support and technology support, further including facilities at work and work environment condition. Thus, the sixth factor was labeled as "Physical Environment".

Two items showed relatively strong loadings on the seventh factor, firm size and firm age. Firm size represents how big of organization and firm age means how long organization had been operated. This factor was simply named as "Firm". Four items which expressed the sense of negative barrier at workplace, pressure to work, relationship conflict, gossip, and task conflict, contributed to the eighth factor. It was named as "Conflict". Two items showed moderate high factor loading on ninth factor, team size and team tenure. Team size is considered as how big of your group work and team tenure represents how long you have been in the team. This factor was plainly named as "Team". Item that had high factor loading on the tenth factor was respect from others. Moreover, other two items, admiration, and your contribution were also loaded on this factor. With strong sense of respective, this factor was called as "Respect". Then, last three items had been loaded on the last factor. They were role ambiguity, being in superior or inferior condition, and nature of job itself. It was clear that this factor meanly contributed to work role. Thus, the last factor was named as "Role".

With the paired t-test, the composite scores of all eleven factors were compared with the paired t-test to figure that which factors were recognized by participants as more important/influence for affective climate. The result showed that there were significant differences in mean between most of factors. "Flexibility" factor was significantly perceived that it could influence to affective experiences at work more than other nine factors, except for "Intimacy" factor and "Employment Stability" factor (all $p < 0.05$). "Intimacy" factor was also perceived to contribute to affective climate, significantly more than other nine factors, except for Flexibility (all $p < 0.05$).

5 Discussion

In this study, the affective well-being at work scale [9] was employed to capture affective experiences at work. Even though the participants were from different workplace, the participants seemed to feel pleasure, enthusiasm, and placid with where they are working. In general, they have positive emotional experiences at workplace as the average of all five dimensions were 4.17 of Anxiety-Comfort, 4.75 of Depression-Pleasure, 4.44 of Boredom-Enthusiasm, 4.19 of Tiredness-Vigor, and 4.65 of Anger-Placidity. The eleven factors found in this study represented the antecedents of affective climate or affective well-being at work. "Flexibility" factor and "Intimacy" factor seemed to be considered as the most important antecedents that can generate affective climate. Thus, to make positive affective climate, Employer may concern more on the how employees are able to have freedom at workplace or how employee get easy reach to their employer. Moreover, the senses of having good relationship, good cooperation, and friendliness among people at workplace are important.

6 Conclusion

This study aimed to investigate work environment factors and how they influence to affective climate. Eleven factors of work environment had been found and they were evaluated based on influencing on five bi-polar affective well-being scales. Employers may focus on “Intimacy” and “Flexibility” factors which showed significant influence to affective climate than other factors. Knowledge of the antecedents of positive affective workplace is still needed. There are still many spaces for researchers to contribute their works in this field. To promote affective well-being at work, work environment factors for affective climate is a new challenge. The limitation of this study was that there might be the differences in organizational culture between companies and the differences in cultures effecting to the results. However, to certain extent results obtained from this study can present the basic important factors of what environments at workplace in general in order to have positive affective climate.

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Learning Culture-Specific Dialogue Models from Non Culture-Specific Data

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Abstract. We build culture-specific dialogue policies of virtual humans for negotiation and in particular for argumentation and persuasion. In order to do that we use a corpus of non-culture specific dialogues and we build simulated users (SUs), i.e. models that simulate the behavior of real users. Then using these SUs and Reinforcement Learning (RL) we learn negotiation dialogue policies. Furthermore, we use research findings about specific cultures in order to tweak both the SUs and the reward functions used in RL towards a particular culture. We evaluate the learned policies in a simulation setting. Our results are consistent with our SU manipulations and RL reward functions.

Keywords: dialogue systems, culture-specific dialogue models, reinforcement learning, simulated users, negotiation, argumentation, persuasion.

1 Introduction

Virtual humans are artificial agents that have a humanlike appearance and behavior. Virtual humans often engage in conversations and can play a number of roles, for example, negotiate with humans or other virtual humans. Having virtual humans with explicit models of specific cultures can be very effective for teaching culture-specific skills because it creates a realistic setting for interaction. Also, having culture-specific virtual humans can make it easier for people of that culture to interact with and understand the virtual humans [12].

In this paper we focus on building culture-specific dialogue policies of virtual humans in negotiation and in particular in argumentation and persuasion, i.e. dialogue policies that dictate what kind of arguments and persuasion strategies the virtual human will use to accomplish its goal depending on the cultural behavior that we want to simulate. This task is particularly challenging for two reasons:

1. There is a shortage of culture-specific dialogue data in negotiation but also in other domains. What we know about culture-specific behavior is usually the result of surveys in which people from different cultures are asked to give their opinions on several matters.
2. Although these surveys can provide valuable culture-specific information it is not clear how their findings can translate into culture-specific models of conversational behavior.

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Note that in this paper when we refer to culture-specific dialogue models we do not mean models of specific real cultures (e.g. Americans versus Chinese) but of dimensions on which cultures are known to vary. Brett and Gelfand [1] identified three aspects in cross-cultural negotiation: individualism versus collectivism, egalitarianism versus hierarchy, and low context versus high context communication. Typically Western individuals are individualistic, egalitarian, and use low context communication while Eastern individuals are collectivistic, hierarchical, and use high context communication.[1] In this paper we focus on individualism and altruism in particular, but the ideas and techniques can be applied to other types of cultural dimensions, such as collectivism.

In order to learn dialogue models of cultural dimensions from data not specific to these dimensions we propose the following novel approach. We use a corpus of dialogues not specific to any dimension and we build simulated users (SUs), i.e. models that simulate the behavior of real users [4, 7, 8]. Then using these SUs and Reinforcement Learning (RL) [3, 5, 6, 11, 13] we learn negotiation policies. Furthermore, we tweak both the SUs and the reward functions used in RL towards a particular cultural dimension, by taking into account research findings about the cultural dimensions of interest. Our research contribution is two-fold:

1. To date, statistical approaches to dialogue management based on RL have focused on information slot-filling applications (e.g. tourist information domains) [4, 13], largely ignoring other types of dialogue with rare exceptions [3, 6]. Here, we use RL for learning negotiation (argumentation and persuasion) policies. As we will see in the following, this is a particularly challenging task due to the complexity of the dialogue state and the large number of system and user actions.
2. With our approach we can learn dialogue policies for a specific cultural dimension without having dialogue data specific to that dimension. Furthermore, unlike Heeman [6] who built hand-crafted SUs we learn our initial SUs from a corpus and then tweak them. While the idea of manipulating the SUs to simulate different types of users is not new [7, 8], to our knowledge the idea of manipulating the reward functions towards a particular behavior is rather novel. In recent work Georgila et al. [5] manipulated the reward functions to learn strict versus flexible system policies for appointment booking but that approach was limited in the sense that it did not involve using different sets of actions for each policy that we want to learn as we do here.

The structure of the paper is as follows: In section 2 we briefly introduce the concepts of RL and SUs. In section 3 we present the corpus used in our experiments. In section 4 we describe how we build our SUs from our corpus and how we tweak them towards a particular cultural dimension. In section 5 we present how we use the SUs built in section 4 in order to learn culture-specific negotiation policies. In section 6, we describe our evaluation experiments. Then in section 7 we discuss our findings together with ideas for future work, and finally in section 8 we present our conclusions.

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[1] In high-context cultures the listener must understand the contextual cues in order to grasp the full meaning of the message. In low-context cultures communication tends to be specific, explicit, and analytical.

2 Reinforcement Learning and Simulated Users

In the Reinforcement Learning (RL) paradigm, managing a dialogue can be seen as a Markov Decision Process (MDP) or a Partially Observable Markov Decision Process (POMDP) where dialogue moves transition between dialogue states and rewards are given at the end of a successful dialogue. The solution to the dialogue management problem is a policy specifying for each state the optimal action to take. Typically rewards depend on the domain and can include factors such as task completion, dialogue length, and user satisfaction.

Several research groups have investigated the use of RL for dialogue management in slot-filling dialogues, including [4, 5, 13]. Slot-filling dialogues are dialogues in which the user presents a complex query or service request (e.g. a hotel booking), and the system iteratively asks for more information to fully specify and confirm a set of "slots" that are needed to generate a database query (e.g. location, price range, room type) and ultimately satisfy the user's request. Dialogue policy decisions are typically whether to ask for a slot value, confirm a slot value, query the database, or present an answer. A typical reward function is to multiply the number of slots that have been filled and confirmed by a weighting factor (e.g. 100 points) and subtract the number of system turns multiplied by a weighting factor (e.g. 5 points) [5].

In contrast to slot-filling dialogue, in negotiation dialogue the system and the user have opinions about the optimal outcomes and try to reach a joint decision. Dialogue policy decisions are typically whether to present, accept, or reject a proposal, whether to compromise, etc. Rewards may depend on the type of policy that we want to learn. For example, a cooperative policy should be rewarded for accepting the other party's proposals. On the other hand a non-cooperative policy should be rewarded for ignoring the other party's proposals. Unlike slot-filling dialogues, the use of RL for learning negotiation dialogue policies has only recently been investigated [3, 6]. More specifically, Heeman [6] reported work on representing the RL state for learning negotiation dialogue policies for a furniture layout task.

The problem with RL is that it requires on the order of thousands of dialogues to achieve good performance. Therefore, it is no longer feasible to rely on data collected with real users. Instead, training data is generated through interactions of the system with simulated users (SUs) [4]. In order to learn good policies, the behavior of the SUs needs to cover the range of variation seen in real users [4]. Furthermore, SUs are critical for evaluating candidate dialogue policies [8].

3 Our Corpus

In our negotiation domain, the data consists of dialogues between American undergraduates playing the role of a florist and a grocer who share a retail space. The dialogues were collected by Laurie R. Weingart, Jeanne M. Brett, and Mary C. Kern at Northwestern University. The florist and the grocer negotiate on four issues: the design of the space, the temperature, the rent, and their advertising policy. The florist and the grocer have different goals, preferences, and use different types of arguments.

We have annotated 21 dialogues using a cross-cultural argumentation and persuasion annotation scheme that we have developed.

This scheme is an adaptation of existing coding schemes on negotiation [2, 9, 10], following a review of literature on cross-cultural differences in negotiation styles (e.g. [1, 14]), and our observations from its application to coding negotiation dialogues in different domains. To our knowledge this is the first annotation scheme designed specifically for coding cross-cultural argumentation and persuasion strategies. Previous work on cross-cultural negotiation [1] has not focused on argumentation or persuasion in particular.

Table 1 depicts an example dialogue annotated with our coding scheme. Actually the annotations are more complex but here they are simplified for brevity since their presentation is outside the scope of the paper.

As mentioned above, in the corpus the florist and the grocer negotiate about four issues and sometimes these issues can be intertwined. For example, there could be trade-offs such as "I will agree on design A if you agree on a low temperature". Given that the task of learning dialogue policies with RL can be very complex even for simple slot-filling applications, in this initial experiment we decided to simplify the problem as much as possible. Thus we focus on learning how to negotiate about only one of the issues, the temperature. The florist is in favor of lower temperatures to keep her flowers fresh whereas the grocer prefers higher temperatures so that her customers feel comfortable.

Table 1. Example annotated dialogue with speech acts in the florist-grocer domain

Speaker	Utterance	Speech Act
Florist	How does that work for you?	request_info.preference
Grocer	Well, personally for the grocery I think it is better to have a high temperature.	provide_argument.logic
Grocer	Just because I want the customers to feel comfortable.	elaborate
Florist	Okay.	acknowledge
Grocer	And also if it is warm, people are more apt to buy cold drinks to keep themselves comfortable and cool.	elaborate
Florist	That's true.	accept
Florist	But what about your products staying fresh? Don't they have to stay fresh or otherwise?	rebut_argument.logic

So we created a new smaller corpus by extracting the parts related to the temperature issue from the original corpus. We also excluded all dialogues with intertwined issues (3 dialogues) and dialogues where one party makes an offer in the first turn and the other party agrees immediately (3 dialogues). Thus we ended up with 15 shorter dialogues. Furthermore, we simplified the speech acts as shown in Table 2. These simplified dialogues were used for training our SUs as we will see in section 4. Also, Table 3 shows some statistics of the simplified corpus used in our experiment.

Table 2. Example simplified dialogue used for training the SUs

Simplified Speech Acts
florist, provide_info.preference
florist, release_turn
grocer, provide_argument
grocer, offer
grocer, release_turn
florist, reject
florist, release_turn
grocer, provide_argument
grocer, elaborate
grocer, offer
grocer, release_turn
florist, accept
florist, release_turn

Table 3. Statistics of the simplified corpus used for training the SUs

	Florist	Grocer	Total
Total # turns	65	65	130
Avg # turns per dialogue	4.3	4.3	8.7
Total # utterances	87	101	188
Avg # utterances per dialogue	5.8	6.7	12.5

4 Simulated Users

Our SUs are built on the speech act level from dialogues in the format depicted in Table 2. Note that we have inserted one more action "release_turn", which was not part of the original corpus to mark the boundaries between turns. Our SUs are based on n-grams of speech acts [4]. For example, valid 3-grams (Table 2) would be:

- grocer,provide_argument grocer, elaborate → grocer,offer
- florist,provide_info.preference florist,release_turn → grocer,provide_argument

The first 3-gram indicates that if the grocer provides an argument and then elaborates on this argument, then a possible action is for the grocer to make an offer. The second 3-gram indicates that if the florist provides her preference on the temperature and then releases the turn, then a possible action is for the grocer to provide an argument. The probability of each action is computed from our corpus. In this experiment we used 3-grams. The list of SU actions (as well as system actions) is given in Table 4. As we can see, our annotated dialogue data does not include information about cultural dimensions such as individualism. Thus we cannot directly learn from the corpus a SU of a particular cultural dimension. In our experiment we consider two different types of SUs, an individualist SU that never compromises, and an altruist SU that is the exact opposite of an individualist. The individualist SU-florist always generates arguments in favor of low temperatures, offers low temperatures, rejects high temperatures, and so forth. The altruist SU-florist always generates arguments in favor of

Table 4. System policy and SU actions used in our experiment

System and SU Actions
request_info.preference
provide_info.preference
provide_argument
elaborate
rebut_argument
acknowledge
offer
accept
reject
release_turn

high temperatures, offers high temperatures, rejects low temperatures, and so forth. Likewise for the individualist and altruist SU-grocers.

5 Learning Negotiation Policies

After we have built our SUs, we have these SUs interact with our system (i.e. a virtual human) using RL in order to learn different policies. A virtual human that learns by interacting with a SU tweaked to care about individual gain, is expected to learn how to negotiate better against this type of conversational interlocutor. To ensure that our virtual human will also learn to simulate a particular cultural dimension we manipulate the reward functions used in RL. For example, a virtual human that cares about individual gain will always be rewarded for actions that lead to individual gain and penalized for actions that lead to individual loss or mutual gain. More specifically we consider two types of policies in the same fashion as for the SUs. Thus the individualistic florist policy is rewarded when the outcome of the conversation is agreement on a low temperature (+800 points) and penalized otherwise (-800 points). The altruistic florist policy is rewarded when the outcome of the negotiation is agreement on a high temperature (+800 points) and penalized otherwise (-800 points). Likewise for the individualistic and altruistic grocer policies. To facilitate learning we have also added one more penalty (-800 points) for some incoherent sequences of actions, i.e. when the action “elaborate” or “rebut_argument” appears before a “provide_argument” and when an “accept” or “reject” action appears when no offers or arguments are on the table. There is also a penalty of -10 points for each policy and SU action. The fastest possible successful dialogue can be for one of the interlocutors to make an offer and the other to accept. Thus the highest possible reward in a dialogue can be 800 minus 4 actions = 760, the four actions are “offer”, “release_turn”, “accept”, “release_turn”. Table 5 shows the reward functions used in our experiment. The goal of RL is to learn the optimal action in each dialogue state so that the desired outcome is achieved (e.g. a high temperature for the individualist grocer, a high temperature for the altruist florist, etc.).

Another issue is how to represent the state so that the problem is tractable and at the same time good policies can be learned. In this paper we used the state representation shown in Table 6, which leads to 864 possible states. We can see each feature with all the possible values it can take. Finally the policy actions are the same as the SU actions (see Table 4).

For training we used the SARSA-λ algorithm [11] with greedy exploration at 30% to explore the state-action pair space. We ran 20,000 iterations for learning the final policy for each condition. More specifically, we learned an individualistic florist policy trained against both an individualist SU-grocer and an altruist SU-grocer, an altruistic florist policy trained against both an individualist SU-grocer and an altruist SU-grocer, and so forth. All possible combinations are shown in Table 7 in the evaluation section (section 6).

Table 5. Reward functions for each type of policy

Type of Policy	Outcome	Incoherent Sequence	Penalty per Action
Individualist florist	low +800	-800	-10
Individualist florist	high -800	-800	-10
Altruist florist	low -800	-800	-10
Altruist florist	high +800	-800	-10
Individualist grocer	low -800	-800	-10
Individualist grocer	high +800	-800	-10
Altruist grocer	low +800	-800	-10
Altruist grocer	high -800	-800	-10

Table 6. State representation for learning

State Representation
Current speaker (florist/grocer)
Most recent temperature supported by the florist (low/high)
Most recent temperature supported by the grocer (low/high)
Is there an argument on the table and by whom? (none/florist/grocer)
Is there an offer on the table and by whom? (none/florist/grocer)
If there is an offer, what is the temperature offered? (low/high)
Is there a rejected offer (the most recent rejection) and by whom? (none/florist/grocer)
If there is a rejected offer, what is the rejected temperature? (low/high)

6 Evaluation of Learned Negotiation Policies

We evaluate our learned policies against our SUs. In some cases these are the SUs used for training which can be a potential problem, and certainly is an issue to be addressed in future work (for example when a florist policy is trained with an individualist SU-grocer and also tested with an individualist SU-grocer). However, due to data sparsity we cannot perform cross-validation. The data would not be enough for training reliable SUs.

We run each policy against all types of SUs (2000 simulated dialogues) and we report the outcome (how many successes we have, how many failures, and how many dialogues end with no agreement). For the individualistic florist policy the dialogue is considered successful if the final agreed temperature is low, in other words if the result of the negotiation favors the florist, and so forth. Results are given in Table 7. The notation is as follows: FI(GA)-GI stands for an individualistic florist policy trained against an altruist SU-grocer and tested against an individualist SU-grocer, and so forth.

The policies perform well (either they win or there is a tie) when interacting (in testing) with the SUs of the opposite culture (e.g. individualistic policy versus altruist SU), which is a good result. When this is not the case either there is no agreement or the SU wins. It is not surprising that the policy does not win in those cases but that the SU wins instead of having a tie (as in interactions FA(GA)-GA and GI(FI)-FI). This is an issue for further investigation. Another interesting issue is that one would expect that a policy trained on a SU of the same cultural dimension, e.g. FI(GI), would not perform well because in training there would always be disagreements. But these policies sometimes behave well, i.e. FI(GI)-GA, FA(GA)-GI, GI(FI)-FA, and GA(FA)-FI, but obviously not as well as FI(GA)-GA, FA(GI)-GI, GI(FA)-FA, and GA(FI)-FI respectively.

Table 7. Evaluation results for all combinations of policies and SUs

Type of Policy	# Successes	# No Agreements	# Failures
FI(GI)-GI	0	536	1464
FI(GI)-GA	1772	228	0
FI(GA)-GI	0	547	1453
FI(GA)-GA	1804	196	0
FA(GI)-GI	1792	208	0
FA(GI)-GA	0	534	1466
FA(GA)-GI	1454	546	0
FA(GA)-GA	0	2000	0
GI(FI)-FI	0	2000	0
GI(FI)-FA	1332	668	0
GI(FA)-FI	0	685	1315
GI(FA)-FA	1661	339	0
GA(FI)-FI	1701	299	0
GA(FI)-FA	0	706	1294
GA(FA)-FI	1287	713	0
GA(FA)-FA	0	1375	625

7 Discussion

Our results are generally consistent with our SU probability manipulations and reward functions, which is encouraging. However, in order to make the problem tractable and learn these policies we had to compromise in many respects. The question that arises is what kind of improvements could be done while at the same time keeping the learning task tractable.

In this experiment in order to keep things tractable we make the assumption that there is no middle-ground behavior, which is unrealistic. In a real setting, it would make sense for the agents to compromise in some cases especially when the individualist florist interacts with the individualist grocer or the altruist florist interacts with the altruist grocer.

Furthermore, the SU-florist or SU-grocer always support one temperature each. In the future we intend to allow the SUs to generate arguments about different temperatures based on a probability distribution and the dialogue context. For example, the individualist SU-grocer will generate arguments in favor of high temperatures with a much higher probability than arguments in favor of middle-ground temperatures. That will lead to more realistic simulations because in our data there are cases where the florist or the grocer provide arguments in favor of their interlocutor or of a middle-ground solution.

We have also limited the number of actions to learn only to 10 and have kept the dialogue state small for tractability (for example we do not take into account the previous actions, which is a very important feature). All these compromises of course affect the quality of the learned policies. In future work we will investigate different state representations and action sets and see how they affect performance. We will also evaluate the policies against one another, not only against SUs.

Finally, the metric that we use for our evaluations is rather crude and it does not give us any insight about what happens in the course of the dialogue (the same is true for metrics that measure the success of RL-based policies as the number of slots that are filled and confirmed in slot-filling applications [4, 5, 13]), but we believe that it is a good first step towards developing evaluation metrics for new types of dialogue other than slot-filling dialogues.

8 Conclusions

We built culture-specific dialogue policies of virtual humans in negotiation and in particular in argumentation and persuasion. In order to do that we used a corpus of non-culture specific dialogues and built SUs. Then using these SUs and RL we learned negotiation dialogue policies. Furthermore, we took into account research findings about specific cultures in order to tweak both the SUs and the reward functions used in RL towards a particular culture. We evaluated the learned policies in a simulation setting. Our results are consistent with our SU manipulations and RL reward functions.

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Dialog Behaviors across Culture and Group Size

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Abstract. This study analyzes joint interaction behaviors of two-person and four-person standing conversations from three different cultures, American, Arab, and Mexican. To determine whether people use joint interaction behaviors differently in multiparty versus dyadic conversation, and how differences in culture affect this relationship, we examine differences in proxemics, speaker and listener gaze behaviors, and overlap and pause at turn transitions. Our analysis suggests that proxemics, gaze, and mutual gaze to coordinate turns change with group size and with culture. However, these changes do not always agree with predictions from the research literature. These unanticipated outcomes demonstrate the importance of collecting and analyzing joint interaction behaviors.

Keywords: Dialog, proxemics, gaze, turn-taking, multicultural, dyadic, multiparty.

1 Introduction

When people converse with others, they participate in joint interaction behaviors, such as proxemics (interpersonal distance and orientation), mutual gaze, and turn-taking, which they may not consciously negotiate. How these behaviors manifest depends on many factors, such as gender, age, personality, culture, and number of participating conversants. Understanding these differences is important for situations where intercultural joint interaction behaviors are necessary for mission success, such as for military personnel in foreign countries. Currently, the United States has soldiers in war zones where they find themselves interacting with people of other cultures. Being able to decode or interpret these local behaviors correctly helps keep soldiers unharmed. Virtual reality training systems have been developed with this in mind (e.g., [1, 2]). In these applications, human trainees interact with embodied conversational agents (ECAs), intelligent virtual characters that possess conversational capabilities. ECAs need models of joint interaction behaviors to behave according to culture and group dynamic. Models based on dyadic or Anglo-American studies may not be appropriate for ECAs representing different cultures and interacting with multiple trainees or ECAs. At the same time, the research literature of interaction

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behaviors has largely focused on dyadic conversations. The joint interaction behaviors for dyadic conversation may differ from those for multiparty conversation.

We have previously reported on the collection of a multimodal multicultural corpus of dialogs comprising four-person conversations on a range of five different activities [3]. A parallel corpus of dyadic conversations by people from the same culture groups on the same tasks was also collected [4]. In the present paper, we examine these corpora for differences in proxemics, speaker and listener gaze behaviors, overlap and pause at turn-transitions, and mutual gaze to coordinate turn. Our central question is how people use joint interaction behaviors differently in multiparty versus dyadic conversation and how this relationship is affected by differences in culture.

2 Review of the Literature

Our study of joint interaction behaviors begins with a brief survey of the sociolinguistic and anthropological literature of differences in conversation behaviors across cultures. We rely especially on the notion of high-context and low-context societies. We then briefly review the interaction behaviors on which our analysis centers.

2.1 Cultural Dimensions in Conversation

Non-verbal behaviors in cultures can be modeled through a structure of six cultural dimensions [5], based on previous work by Hofstede [6] and Hall [7, 8]. Table 1 summarizes these dimensions.

The first dimension is attributed to Hall, who contrasted two conversational styles, high-and low-context. In high-context societies, many things are left unsaid, allowing non-verbal behaviors to play a bigger role. This is typical of cultures that share similar experiences and expectations. Arab and Mexican cultures are considered higher-context cultures [9, 10]. In low-context societies, communication needs to be relatively more explicit, and the value of a single word is not as strong. The American culture is considered a lower-context culture ([9, 10].

The next four dimensions are attributed to Hofstede, who used them to describe cultural variability of people in organizations. Hofstede's individualism-collectivism dimension tends to track Hall's distinction between high- and low-context cultures. Cultures with a high individualism index prioritize individual goals, prefer autonomy and self-assertion while, at the other end, low index cultures emphasize group goals, harmony and avoiding confrontation. Hofstede also defined power distance, uncertainty avoidance, and masculinity dimensions. Power distance can be seen in terms of hierarchism versus egalitarianism and through factors of hierarchism are gender, age or family background.

The last dimension, high/low-contact [11], describes accessibility-inaccessibility in relationships. This dimension deals with immediacy, such as closeness or distance and behaviors expressing approach or avoidance. Examples of highly immediate behaviors include smiling, eye contact, open postures, closer distances and more vocal animation. Cultures with these behaviors are considered as high-contact cultures, because of their preference for close distances and touch [7]; Arabs and Mexican are members of high-contact cultures. On the other end of the spectrum are low-contact cultures, such as Americans, who prefer more distance and less touch [11].

While studies have not verified Hall's space patterns for other cultures, some studies have found significant differences in proxemics between cultures. One study of Anglo-, Black-, and Mexican-Americans in natural settings found that Mexican-American adults stood significantly closer than their Anglo-American counterparts as listed in Table 1 [12].

Table 1. Cultural variation along dimensions

	High/Low - Context	Individualism - Collectivism	Power Distance	Uncertainty Avoidance	Masculinity-Femininity	High/Low - Contact
Arab cultures	High	38	80	68	53	High
Mexico	High	30	81	82	69	High
USA	Low	91	40	46	62	Low

2.2 Interaction Behaviors

The six dimensions of cultural variation may help explain how conversation interaction behaviors, such as turn-taking, gaze and proxemic behaviors, are used in different cultures. The scores rank cultures along those dimensions. Of course, they describe cultural tendencies rather than what individuals of those cultures will necessarily do. While conversational interaction behaviors have been the subject of extensive study, here we briefly review the literature to illuminate our specific hypotheses.

Proxemics refers to the spatial distance between persons interacting with each other and their orientation toward each other. One could argue that proxemics is a relationship rather than a non-verbal behavior, although it may communicate things like a person's intention or emotion. A more elaborate definition of proxemics encompasses eight behaviors, including touch, amount of eye contact, voice loudness, and body-contact distance [13]. Like other joint interaction behaviors, the proxemics between interacting persons can be interpreted differently across cultures. In some societies close distances are reserved for personal relationships and may not be comfortable for interacting otherwise; in other cultures, close distances are not so exclusive and not interacting closely is interpreted as aloofness [14, 7, 8]. While proxemics are culturally defined, there are also variations based on gender, social status, environmental constraints and type of interaction. For a review of this literature, see [15].

With respect to turn-taking, speakers of English signal transition relevance points through use of cues, such as intonation-marked phonemic clauses, sociocentric sequences such as "you know", completion of grammatical clauses, paralinguistic drawl, termination of hand gesticulation or decrease of paralinguistic pitch or loudness of sociocentric sequences [16].

Gaze plays an important role in coordinating turn-taking. A speaker can yield the floor or signal the next speaker by his or her gaze behaviors. Kendon [17] attributed at least four functions to gaze behaviors in a conversation: 1) to provide visual feedback, 2) to regulate the flow of conversation, 3) to communicate emotion and relationships, and 4) to improve concentration by restriction of visual input. He also showed that speakers tend to look away at the beginning of an utterance and look at the listener at the end of an utterance. In a later study, gaze played a role in coordinating turn-taking, where 42% and 29% of turn exchanges involved a mutual-break and a mutual-hold pattern, respectively [18]. Mutual-break is a term that describes a pattern where both conversants momentarily gaze at each other at a turn exchange followed by the turn-taker breaking gaze. Mutual-hold is a similar pattern, except that the turn-taker does not break gaze immediately, but later on in the turn.

2.3 Hypotheses

Based on our review of the literature research with respect to cultural differences and dialog interaction behaviors, we proposed a set of hypotheses that related changes in turn-taking, gaze and proxemics as a function of culture and group size. Table 2 summarizes the hypotheses.

Table 2. Hypotheses

Joint Interaction Behavior(s)		Changes observed as group size increases (dyadic to multiparty)		
		American (non-contact)	Mexican (contact)	Arab (contact)
Turn-Taking	Overlap	Decrease	Increase	Increase
	Pause	Increase	Decrease	Decrease
Gaze	By Speaker	Increase	No change	No change
	By Non-speaker	No change	No change	No change
Turn-taking x Gaze: Mutual gaze at turns		No change	No change	Increase
Proxemics		Decrease	Decrease	Decrease

3 Methodology

To address our central question of how people use the joint interaction behaviors of proxemics, turn-taking and gaze differently in multiparty versus dyadic conversation, and how this relationship is affected by differences in culture, we analyzed the conversations collected in the UTEP-ICT Cross-Cultural Multiparty Multimodal Dialog Corpus [3, 4], extended to include dyadic as well as multiparty conversations (Herrera 2010).

The extended corpus comprises approximately 20 hours of audiovisual multiparty interactions in three different cultures and languages. Groups of two or four native speakers of Arabic, American English and Mexican Spanish completed five tasks and were recorded from six angles. The subjects were recruited from local churches, restaurants, on campus, and through networks of known members of each cultural group in the El Paso area, which borders Mexico and has, in part because of the university, many representatives of other nations and cultures. Tasks 1, 4, and 5 were mainly narrative tasks, where the participants can take turns relating stories or reacting to the narratives of others. Tasks 2 and 3 were constructive tasks, in which the participants must pool their knowledge and work together to reach a group consensus. Tasks 3 and 4 were designed to have a toy provide a possible gaze focus other than the subjects themselves, so that gaze patterns with a copresent referent could be contrasted with gaze patterns without this referent. Task 5 was meant to elicit subjective experiences of intercultural interaction. The interactions were recorded with six Apple iMac computers, placed around the periphery of a large open room that serves as a computer lab. We thus recorded six simultaneous views of the subjects as they conversed, making it possible, with rare exceptions, to code the subjects' proxemics, gaze and turn-state.

From the recordings, we produced time-aligned partial codings of each of the 24 conversations. Specifically, we coded two 30-second excerpts of each of the conversations for tasks 1 through 4 for proxemics, turn-taking, and gaze. For proxemics, we measured the distance (in inches) between subjects; we avoided inflated numbers (due to distances in quads of conversants across from each other or standing shoulder-to-shoulder and not interacting) by calculating the minimum spanning forest of the positions of the conversants. For gaze, measurements were calculated respective to the conversant's role as speaker or listener; that is, for an annotation of look-away, the talk state of the subject would be considered such that, if the conversant was talking, it was taken as speaker look-away, and if listening, then listener look-away. For turn-taking, we calculated the average of pause (in seconds) and overlap (in negative seconds) at turn-transitions.

The coding was performed by three students trained in UTEP's Interactive Systems Group. The coders followed written rubrics for each of the behavior types, and entered the data using ANVIL[19]. Coded data were assessed for interrater reliability. For the three behaviors, Kappa was at least 0.80. (For proxemics, positions were considered equivalently coded if they differed by less than 6 inches.) If outliers were found in this cross-check, the videos were revisited and recoded, if needed.

From these data, we calculated summary statistics and assessed each of the hypotheses. For each dependent variable, we conducted a 3 x 2 x (4) mixed factorial ANOVA, controlling for relevant covariates, including gender, age, familiarity and acculturation. Follow-up t-tests were computed to assess differences between conditions that demonstrated significant main effects or interactions. Additionally, within-subject analysis was conducted for the repeated task measure, and its interactions. Finally, the interaction between joint interaction behaviors was examined to find any interesting correlations.

4 Results

For turn-taking, the analysis confirmed our hypothesis that Americans quads pause more at turns than American dyads. The other hypotheses with respect to turn-taking were not confirmed, probably because the effect size was small relative to the sample size. For gaze, most of our results surprised us: contrary to our hypotheses, Americans and Mexicans (speakers and non-speakers) gazed at each other more in quads than in dyads, while Arab (non-speakers) gazed less in quads than in dyads. Again contrary to our hypotheses, mutual gaze at turns declined from dyads to quads across all three cultures. For proxemics, the analysis confirmed our hypotheses that conversants in all three cultures would stand closer to each other in quads than in dyads. Table 3 presents the complete set of results.

Table 3. Results

Joint Interaction Behavior(s)		Changes observed as group size increases (dyadic to multiparty)		
		American (non-contact)	Mexican (contact)	Arab (contact)
Turn-Taking	Overlap	Not confirmed	Not confirmed	Not confirmed
	Pause	Confirmed: Significantly more	Not confirmed	Not confirmed
Gaze	By Speaker	Disconfirmed: Significantly more	Disconfirmed: Significantly more	Not confirmed
	By Non-speaker	Disconfirmed: Significantly more	Confirmed: Significantly more	Disconfirmed: Significantly less
Turn-Taking x Gaze: Mutual Gaze at Turns		Disconfirmed: Significantly less	Confirmed: Significantly less	Confirmed: Significantly less
Proxemics		Confirmed: Significantly less	Confirmed: Significantly less	Confirmed: Significantly less

To assess the possible interactions between joint interaction behaviors, we looked at correlations among speaker and listener gaze, proxemics, turn-transition overlap and pause, and mutual gaze to coordinate turn-transition. Our results suggest that that speaker gaze and listener gaze are significantly correlated ($r = .815, p < 0.01$) suggesting that conversants reciprocate gaze behaviors. Proxemics correlates negatively with speaker ($r = -.268, p < 0.05$) and listener gaze ($r = -.309, p < 0.01$), an unexpected result contradicting the Equilibrium Model [20]; this result may result from the increased gaze and the reduced proxemics in quads.

5 Conclusion

This work was motivated in large part by the need for more realistic models of joint interaction behaviors for digital simulations conversations in, for example, immersive cross-cultural training environments (see, e.g., [21]). A key problem faced by the builders of such systems is how to set the parameters for joint interaction behaviors so that these behaviors would provide realistic training for people who would be expected to interact with people in cultures other than their own. While our results cannot completely determine these parameters, the results do move forward with respect to the way in which the parameters should be set.

In terms of the overall question, it seems that having more conversants has a slightly bigger impact on joint interaction behaviors than do cultural differences for gaze, turn-taking and proxemics. However, culture helps make more accurate predictions. For example, for proxemics, although all quads stood closer, some cultures did not do so as much as others.

Unfortunately, not all of the statistical tests were conclusive, which may be attributable to the small sample size. Even so, and beyond the main hypotheses, the data led to additional insights about the relationship of culture and group size to interaction behaviors.

For turn, Americans were thought to use high-considerateness style, keeping overlap to a minimum and allowing sufficient pause. But in our data, differences between quads and dyads showed marginally significant differences, suggesting American quad conversants had a high-involvement style. Arabs' mean measures for pause/overlap increased marginally in quads, suggesting they use high-considerateness style with more conversants. Mexican mean pause/overlap behaved as Americans, decreasing with more conversants, although the difference was not as large.

With respect to gaze, it appears that the overwhelming factor to consider for quad gaze is the number of conversants, as an increase in the number of conversants provides more persons to look at, thus increasing gaze. Mexicans did not seem to follow Americans and Arabs in this trend, though. Mexican gaze seemed to remain steady across group size.

For mutual gaze to coordinate turn exchange, an odd result was that for Mexicans mutual gaze significantly coordinated a smaller percentage of turn-transitions. These results may arise because their gaze did not increase in quads. It may be that Mexicans, rather than relying on mutual gaze to coordinate turn, simply used the timing of pause/overlap. Perhaps turn-taking was not competitive, and their high tolerance for overlap permitted such an arrangement.

For proxemics, differences did occur for Americans, but not in the direction we had predicted: our data indicated that dyads maintained more distance than quads. In the dyadic case, the conversants seem to prefer a distance comparable to the distances of conversants diagonally across from each other in quad conversation. For Arabs and Mexicans, the results were confirmed, although their differences were not as pronounced as American differences. Quads stood slightly closer than in dyads, but this may be the product of the minimum spanning forest measurement.

5.1 Summary

Our principal result is that joint conversation control behaviors in digital simulations of conversation should reflect the number of conversants. The results suggest that as conversations go from dyads to quads:

- Turn-taking: For Americans and Mexicans, the amount of pause/overlap should decrease; for Arabs, the amount of pause/overlap should increase.
- Amount of gaze: For Americans, the amount of time that speakers and listeners gaze at each other should increase; for Arabs, the amount of time that listeners gaze at the speaker should decrease.
- Mutual gaze at turn transitions: For Americans and Arabs, the amount of mutual gaze at turn transitions should increase; for Mexicans, the amount of mutual gaze at turn transitions should decrease.

- Proxemics: For all groups, the mean distance among conversants should decrease. A reasonable guide would be that the longest distances among conversants in quads should be similar to the direct distance between conversants in dyads.

A second result is that it is probable that joint conversation behaviors do reflect differences between high-contact and low-contact cultures.

- The amount of time gazing at the other participant in dyads should be lower for Americans than for Arabs and Mexicans.
- Interpersonal distances in dyads (significant) and quads (suggestive) should be greater for Americans than for Arabs and Mexicans.

5.2 Limitations and Future Work

The first limitation of our study that ought to be addressed is the small sample size. Although it is a huge undertaking to annotate video excerpts, unfortunately several of the hypotheses produced inconclusive results.

Another issue is how best to select the excerpts to analyze. To the extent possible, 30-second excerpts were selected at the same time into task for all groups, but perhaps it would have been better to select excerpts based on conversational situation, such as many turn exchanges, or specific interactions such as adjacency-pairs, grounding and repair, or using speech acts as a factor. Joint interaction behaviors differed significantly across tasks, and sometimes differed across excerpts. This is not surprising, as some tasks encouraged more turn-taking, and some required closer proxemics, such as the toy-naming task. Similarly, in some tasks, mutual gaze coordinated turns more than in others. To better understand the process that may govern these joint interaction behaviors, it would be useful to consider the context. This would provide more insight into these mechanisms and ease the efforts to annotate the videos.

Our study led to questions both of the cognition involved in interaction behaviors and in the methodologies for understanding these behaviors.

Substantively, it appears that in some tasks mutual gaze played a role in a larger percentage of the turn exchanges. How did conversants negotiate the next turn in other tasks? Did they mainly rely on detecting transition-relevant places? What behaviors can be used to model ECA behaviors to improve turn-taking in group situations?

Likewise, mutual gaze to coordinate turn-transition was different for each culture. For Americans and Arabs, this significantly increased, as did the gaze for speaker and listener, but for Mexicans, it did not. This could be used to modify the turn-taking model in [22], where gaze plays a bigger role in American multiparty conversation than in dyadic, a big role in Arabs, though not much more than in dyads, and a smaller role in Mexican multiparty conversation.

Methodologically, our experience in this study suggests that it would be worthwhile to address the correlation measures for computational models. While speaker and listener gaze are correlated, these correlations are significantly different across cultures. Arabs seem to fall into one category, with high amounts of gaze, while Americans and Mexicans seem to fall into another. Lower values for proxemics do not seem to decrease gaze levels and increase mutual gaze at turn-transitions as well as reduce turn-transition times.

Timing poses another methodological issue. While 0.5 seconds is a good pause/overlap measure for American dyads, quads in all cultures dropped pause/overlap to half that amount. Models that run on half-second intervals may not be adequate for multiparty interaction. The model in [23] uses center of structure to calculate proxemics, while this study analyzed proxemics of the quad using a minimum spanning forest measure. Measures using center of structure may be a more fair measure and should be considered. Nevertheless, significant results were achieved across culture and group size, suggesting that looking at the proxemics differences of quads across culture in more detail could be fruitful.

These improved correlations hold the promise of improving the model of joint interaction behaviors across cultures and, correspondingly, improving both our understanding of the way people coordinate their conversations and our ability to reflect this understanding in digital environments.

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Life in Affective Reality: Identification and Classification of Smiling in Early Childhood*

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Abstract. The present study investigated the development of naturally occurring smiles in infancy and early childhood. Twelve to 35-month-old Japanese children (N = 22) were videotaped during free play time in nurseries. Participants expressed 417 smiles in over 10.5-hours of recording. A 11 category taxonomy was developed to classify the obtained smiles. The skills of language use were measured using utterance data produced by the target children while they were videotaped. One-year-olds showed more "transferring smiles" than two-year-olds. Whereas more "synchronous smiles" and "unsuccessful smiles" were observed in two-year-olds. "Unsuccessful smiles" were made by children who obtain higher language skills. This study established that the situations of smiles changed from solitary to social by children's age and language skills. Two-year-olds smile not only in pleasant conditions, but also in unpleasant ones.

Keywords: Smiling, Laughter, Infancy, Early Childhood, Play, Interaction.

1 Introduction

Wolff [1] is a pioneer in the research of spontaneous smiles that infants show when they sleep. He observed four 5-day-old neonates for an average of 16 hours, and he mentioned that spontaneous smiles were observed "during irregular sleep, drowsiness, and alert inactivity, but never during regular sleep, alert activity, or between bursts of crying [1]." Most data on spontaneous smiles were obtained on neonates, so that some researchers believe that spontaneous smiles disappear at the early stage of development and the smiles are replaced by social smiles and laughs. For example, Kagan and Fox [2] mention that spontaneous smiles disappear at 2-3 months of age. Although there are observational data in six-months-olds [3] and one-year-olds [4], the development of spontaneous smiles and social smiles has not yet been clarified.

Ekman and Friesen [5] proposed four types of adults' smiles; felt smiles, phony smiles, masking smiles, and miserable smiles. Drahota, Costall, and Reddy [6] classified smiles into Duchenne smiles, non-Duchenne smiles, and suppressed smiles by forms of facial expressions. Duchenne and non-Duchenne smiles are often distinguished using the criterion of the activation of the orbicularis oculi muscles. Drahota et al. [6] defined suppressed smiles that involve counteractions of the lip corner raise and cheek raise during smiles. They mentioned that "smiles can express a large

* A part of this study was presented at the 2011 SRCD Biennial Meeting in Montreal, Canada [18].

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variety of meanings, ranging from embarrassment to amusement, triumph, bitterness and even anger." Ekman [7] claims that his technique (i.e., Facial Action Coding System; FACS) can distinguish more than 50 different smiles. There are no adequate observational data, however, that reveals such different kinds of smiles people express. The gap between infants' social smiles and adults' smiles also remains.

Phillips and Sellitto [8] mentioned that "definitions of play usually include joy or pleasure as one of several critical components," but the measurement of emotion used in research on play behavior lacked rigor. This suggests that play situations contain many opportunities to observe smiles, and more accurate observations are required.

Parten's [9] classification of play is widely applied in research on children's play. She divided it into six categories; unoccupied behavior, onlooker behavior, solitary play, parallel play, associative play, and cooperative play. Smith [10] classified children's play into social contingency play, sensorimotor play, object play, language play, physical activity play, and fantasy or pretend play. The category of play activity in this study is based on Parten's [9], because her categorization focused on social development, and that aspect should relate to the development of smiling.

Language acquisition in children is largely studied in the field of developmental psychology. Researchers have revealed the process of language acquisition. There may be a relation between the skill of language usage, social development and development of smiling, but many handbooks in developmental psychology have not mentioned it (e.g., [11], [12]).

The purpose of this study is to investigate the variation and the function of smiles that are shown by children during free play behavior, and clarify what factors relate to the development of smiles.

2 Method

2.1 Participants

Eleven one-year-old children (eight female and three male; the range of months in age was from 12 to 23 months) and eleven two-year-old children (six female and five male; the range of months in age was from 24 to 35 months) who were cared for in public nurseries in Tokyo were observed. They were physically and mentally healthy at the time of observation.

2.2 Procedure

Participants were observed during the free play period in nurseries. Free play periods are defined as nursery school teachers not forcing children to do something (e.g., singing songs, dancing, or exercising together). In such periods, children can select how to play. Free play periods in nurseries were scheduled from 10:00 to 11:00 in the mornings and from 4:00 to 5:00 in the afternoons almost every day.

The observer videotaped 30 minutes per child by using a digital video camera (HDR-XR500, Sony) and a gun microphone (ECM-HGZ1, Sony). The situation of recording was controlled as follows; (1) there were more than two children in the space of play (i.e., the room or playground in nurseries), (2) children could choose how to play, (3) adults' control of play was minimized, and (4) the observer kept 50-200 cm from the target child and did not have any direct or indirect contacts with the child during the recording. The recordings were not always a continuous 30 minutes, because teachers sometimes had to change children's diapers, or the target child went to toilet. If there were some interruptions in the recordings, they were less than 5 minutes.

2.3 Coding Scheme of Smiling

Smiles were defined using the FACS AU12 definition [13]. FACS is the most general facial coding system in the field of psychology. AU 12 means "lip corner puller." In the FACS manual, there is a mention that "AU 12 is a significant action that produces appearance changes in the lips and cheeks that most people would call a smile." Recent researches on smiles in children adopt AU 12 as the definition of smiles (e.g., [14], [15]). Another criterion was that the action had to appear subjectively smile-like when viewed at normal speed [16]. This criterion was adopted to exclude too subtle movement of mouth from consideration.

The onset and offset of smiles were determined as follows. The software for controlling recorded video (Picture Motion Browser Ver. 4.2.00 for AVCHD HDD Camcorder, Sony) could move a video sequentially by 1/30 seconds. When a smile was observed, the video was rewound sequentially to the onset frame (immediately prior to which there were no facial movements). From the onset, the video was forwarded sequentially to the offset (immediately following which there were no facial movements).

Smiles were then classified into 11 categories (i.e., solitary smiles, one-sided smiles, synchronous smiles, transferring smiles, approaching smiles, withdrawal smiles, satisfying smiles, unsuccessful smiles, camouflaging smiles, embarrassing smiles, and singing smiles) by using an original coding guide. The guide was constituted from 93 categories of a check list. The coder checked the speech and behavior of the target child and related others (i.e., other children and teachers) by the list. The check list applied only for the situation which smiles were showed by the target child. Almost all activities which occurred at the situations of smiles were confirmed by this list, and those smiles were classified by it.

Solitary smiles, *one-sided smiles* and *synchronous smiles* were defined by the target child's gaze. *Transferring Smiles*, *approaching smiles*, and *withdrawal smiles* were identified by the target child's physical state. *Satisfying smiles*, *unsuccessful smiles*, *camouflaging smiles*, and *embarrassing smiles* were related to the target child's mental state. *Singing smiles* were different from others. Singing reflects not only physical states of children but also mental states. To identify children's smiles for one category, there was the order of priority. The third group and singing smiles were top priority, the second group was the second, and the first group was the third. Each smile was defined as follows.

Solitary smiles. If the target child looked at not someone but something when she/he smiled, the smile was coded as a solitary smile. In the case which the subject of the child's gaze was unclear, the smiles were determined as solitary smiles.

One-sided smiles. If the target child looked at someone when she/he smiled, but the person did not smile synchronously, the smile was coded as a one-sided smile. In the case which the coder could not see the other person's face, and could not hear the laughing voice, the smiles were counted as one-sided smiles.

Synchronous smiles. If the target child looked at someone when she/he smiled, and the person also smiled, the smile was coded as a synchronous smile. In the case which the coder could not see the other person's face, but could hear the laughing voice, the smiles were determined as synchronous smiles.

Transferring smiles. If the target child simply walked or crawled around without any particular objects to approach when she/he smiled, the smile was coded as a transferring smile.

Approaching smiles. If the target child approached something or someone when she/he smiled, the smile was counted as an approaching smile. It did not matter whether the target child walked or crawled.

Withdrawal smiles. If the target child withdrew from something or someone when she/he smiled, the smile was coded as a withdrawal smile. It didn't matter whether the target child walked or crawled.

Satisfying smiles. If the target child was praised for her/his achievement and/or completed something when she/he smiled, the smile was coded as a satisfying smiles. The praises and completions were almost always determined by a phrase made by the target or the others, for example "I did it," "you did it," or hand clapping.

Unsuccessful smiles. If something which the target child used to play (e.g., blocks or balls) collapsed or fell from somewhere, someone or the target slipped, or the target reported her/his mistakes to someone when she/he smiled, the smile was coded as an unsuccessful smile.

Camouflaging smiles. If the child was scolded or made trouble for someone when she/he smiled, the smile was coded as a camouflaging smile.

Embarrassing smiles. If someone could not understand the target child's act or utterance, or the target could not understand someone's act or utterance when she/he smiled, the smile was defined as an embarrassing smile.

Singing smiles. If the target child sang when she/he smiled, the smile was coded as a singing smile.

2.4 Coding Scheme of Play Behavior

Parten's [9] play categories were adapted for classification of play situation. Actual classification had 11 categories, but they were combined to four categories for statistical analyses. Whether there was a smile or not, every situation was coded for one category. Each category of play was defined as follows.

Non-play behavior. Moments during which the target child did not have a toy or objects for play, were non-play behavior. In this situation, the child usually watched the other children's play, or just crawled, walked, or ran somewhere not for playing. This category was partly derived from Parten's [9] "unoccupied behavior" and "onlooker."

Individual play. Moments during which the target child played alone or independently, were individual play. Even if the child engaged in the same activity which the other child close to her/him did, they did not talk with and not try to influence or modify the activity of the other's. Parten's [9] "solitary play" and "parallel play" were combined to this category.

Group play. Moments during which the target child played with other children were group play. Parten's [9] "associative play" and "cooperative play" were combined to this category. In associative play, "there is a borrowing and loaning of play material" [9] and conversations between the target and other children can be observed. Children share the purpose or goal of playing and organize the division of roles in cooperative play.

Playing with teachers. Moments which the target child played with a teacher were playing with teachers. Regardless of the target's way of playing, the situation which there was a teacher around the target and she (all teachers in this study was female) related to the play was coded as playing with teachers. Teachers' involvement in play was identified by their speech and behavior to lead children.

2.5 Coding Scheme of Language Skill

The skills of language usage were measured by the utterances made by the target children when they were videotaped. The coder made a transcript of all utterances made by the target child and made to the target by others. Every utterance made by the target was labeled. There were seven labels; groan, babbling, one-word sentence, two-word sentence, three-word sentence, four-word sentence, and five-word-or-more sentence. This sequence is arranged in order of developmental stage of language skill. The label which indicated the highest developmental stage of language skill was extracted for each child to identify her/his language skill.

3 Results and Discussion

There were 417 smiles in over 10.5-hours of recording. This means that participants showed 18.95 smiles (SD = 11.82) in average. One-sided smiles (151 times) and approaching smiles (69 times) occurred frequently in this observation. The frequencies of seven kinds of smiles exceeded 20 times [i.e., solitary smiles (45), one-sided smiles, synchronous smiles (47), transferring smiles (23), approaching smiles, satisfying smiles (23), unsuccessful smiles (32)]. Others were excluded from statistical analyses.

Approximately 25 % of one-sided smiles were directed to the observer in this study. As mentioned above, the observer kept 50-200 cm from the target child and did not have any direct or indirect contacts with the child during the recording. This indicates that all smiles which referred to the observer were coded as one-sided smiles. In some cases, the observer was the nearest person for the target child during the observation. The observer spent one to four weeks at the nurseries before the start of the research. Therefore, many children might not imagine that he could not respond to their smiles. This should be a reason that one-sided smiles were observed frequently.

There were no gender differences in frequencies of smiles. Hay, Caplan, and Nash [17] mentioned that "there is little evidence for striking sex differences in prosocial behavior or conflict with peers before the third birthday." The result of this study supports it.

3.1 Relation between Smiles and Age

There were different patterns in frequencies of smiles by children's age. Figure 1 shows frequencies of each type of smile by age. Two-year-old children showed significantly more smiles than one-year-olds overall, χ^2 (1) = 7.87, $p < 0.01$. The participant who showed the most frequent smile was a 32-month-old girl. She smiled 54 times in a 30-minute observation. She was a factor of this result, but other factors must be found in developmental differences between one and two-year-olds.

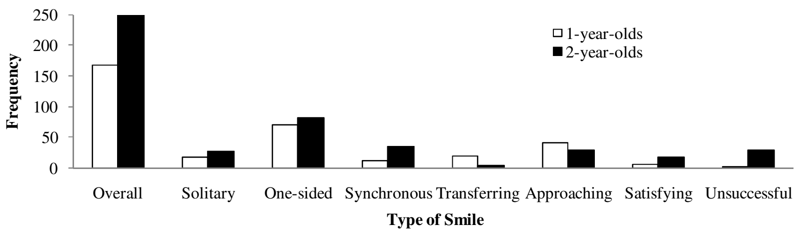

Fig. 1. Frequencies of each type of smile by age

Table 1 indicates the actual frequencies of each type of smile by age. One-year-olds showed significantly more transferring smiles than two-year-olds, χ^2 (1) = 4.89, $p < 0.05$. In these smiles, children looked simply transferring to somewhere without any targets. This kind of walk and crawl can be seen mostly in infants. Walking and crawling is not a commonplace event, but a special event for them. Probably, parents and teachers in nurseries praise them at the beginning of such activities. This mechanism would bring a feeling of satisfaction to children, and they expressed smiles.

Two-year-olds showed significantly more synchronous smiles than one-year-olds, χ^2 (1) = 6.65, $p < 0.01$. In the situations of synchronous smiles, children showed smiles before or after the other person showed them. They shared the attentions to an object and the feelings. The feelings can be not only joy but also embarrassment. It is difficult to presume their feelings from facial expressions. This is a limitation of this study. It is certain, however, that older children have more ability to share their feelings by using smiles.

Table 1. Frequencies of each type of smile by age

Type of Smiles	Frequencies	
	Age	
	1-year-olds	2-year-olds
Solitary	17	28
One-sided	70	81
Synchronous	11	36
Transferring	19	4
Approaching	40	29
Satisfying	5	18
Unsuccessful	2	30

Two-year-olds also made more unsuccessful smiles than one-year-olds significantly, χ^2 (1) = 12.25, $p < 0.001$. These smiles occurred when the target children or other children nearby made some mistakes, and saw them. This suggests that older children show smiles not only in pleasurable situations but also in unpleasant situations.

Sometimes this category of smiles occurred in series. In that case, children looked joyfully and made the unsuccessful situations intentionally. For example, the 32-month-old girl collapsed the tower which she made with blocks. It happened accidentally at first, but she made and collapsed it over and over, and then she smiled. She played the repetition, and it looked as if she made the tower for collapsing.

3.2 Relation between Smiles and Play

There was a difference in total amounts of time for each type of play. Table 2 shows the difference and ratios. Approximately half of play was individual play, and one fifth was play with teachers. This tendency had something in common with the results of Parten [9]. Her participants who were two to two and a half years old devoted much time to solitary play and parallel play (i.e., individual play in this study).

To compare the frequencies of smiles by type of play, the data corrections were made for frequencies of each child's smiles by multiplying one minus the ratios of each playing time. An ANOVA indicated a significant frequency differences in solitary smiles for each type of play, F (3, 42) = 4.15, $p < 0.05$. Figure 2 indicated that there were more solitary smiles in individual play. This tendency was rational that children must keep their gaze at something in solitary smiles, and there were less people around them in individual play. The multiple comparison of the Bonferroni method showed, however, that there was no significant difference in each type of play. This tendency must be confirmed by collecting more data.

Table 2. Total amounts of time and ratios for each type of play

Type of Play	Total Amouts of time (min.)	Ratios
Non-play	85	0.13
Individual	324	0.51
Group	93	0.15
With Teachers	135	0.21

An ANOVA also indicated a significant frequency differences in satisfying smiles for each type of play, F (3, 24) = 3.48, $p < 0.05$. The multiple comparison of the Bonferroni method showed that there was no significant difference in each type of play. There was a tendency, however, that children showed more satisfying smiles in playing with teachers (see Figure 2). Teachers tend to praise children when they achieve or complete something. In fact, teachers praised the target child nine times out of 11 satisfying smiles during playing with teachers. This suggested that teacher's reactions for children increased their playing activities for achievement and their smiling. Teachers in nurseries must have an important role in the development of emotions.

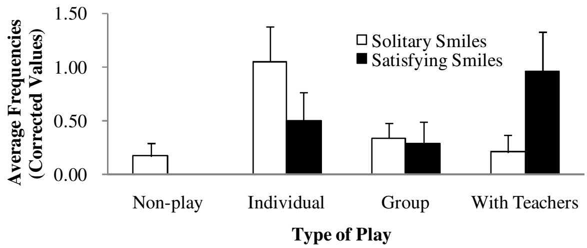

Fig. 2. Average frequencies (corrected values) and SEs of solitary and satisfying smiles in each type of play

3.3 Relation between Smiles and Language Skills

The stage of language development for each child was decided from their utterances. Table 3 shows the numbers of participants for each stage. The numbers varied widely, so the stages were combined into two groups for statistical analyses. Children in the stages from babbling to two-word sentence were integrated into elementary language development group (N = 10) in this study. Children in the stages from three-word sentence and above were also gathered in advanced language development group (N = 12) in this study. The difference in numbers of participants for each group still remained, so the data corrections were made for total frequencies of each type of smiles by multiplying one minus ratios of each number of participants in the group.

A significant difference was found in frequencies of unsuccessful smiles, χ^2 (1) = 5.34, $p < 0.05$. Table 4 indicates that the advanced language development group showed more unsuccessful smiles frequently. This means that higher skill of language usage is necessary for unsuccessful smiles. In some cases of unsuccessful smiles, teachers told the target child that for example, "Ooh! It's collapsed," when they saw it happen. In this case, language skills have some functions for understanding of the failure and for sharing the same emotion with others.

Table 3. Numbers of participants for each stage of language develpment

Stages of Language Development	N
Babbling	2
One-word Sentence	5
Two-word Sentence	3
Three-word Sentence	4
Four-word Sentence	1
Five-word-or-more Sentence	7

Table 4. Frequencies and corrected frequencies of unsuccessful smiles for each stage of language development

Stages of Language Development	Frequencies	Corrected Value
Elementary	2	1.09
Advanced	30	13.64

4 Conclusion

This study establishes a new style of classification in children's smiles. Detailed descriptions of situation and classifications of smiles from them are the core of this study. Four hundred seventeen smiles were obtained from one to two-year-old children, and they were divided into 11 different kinds of smiles.

Younger children showed more smiles when they simply crawled or walked without particular targets. Older children smiled synchronously with others and they smiled even if they were faced with failure situations. The playing situation had also important role for smiles. Children frequently smiled at something and not someone when they played individually, whereas they made satisfying smiles when they achieved or completed something with teachers. Children who had advanced language skills showed more smiles when they were faced with failure situations.

These observational data suggest that smiles develop from individual to social and from simple signs of pleasure to indications of more complex emotions. Judgment of children's social and emotional development can be made by their variations of smiles. It is more important, however, to provide joyful environment for children to see their smiles. Smiles are undoubtedly condensed cognitive-affective responses to the complex realities of life.

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Investigation of Users' Reactions toward Various Kinds of Artificial Agents: Comparison of an Robotic Agent with an On-screen Agent

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Abstract. We experimentally investigated users' reactions toward an on-screen agent appearing on three different types of media: a 42-inch television (120 cm away from participants), 17-inch display (80 cm), and 4.5-inch mobile PC (40 cm). Specifically, we observed whether the users accepted the agent's invitation to a Shiritori game while they were engaged in given tasks. The results showed that most participants who received the invitation from the on-screen agent appearing on a 4.5-inch mobile PC accepted the agent's invitation, while most participants did not accept the invitation from the agent appearing on the other two formats. We then investigated their reactions toward the agent the other situation; that is, appearing on 42-inch television (80 cm away), 17-inch display (40 cm) and 4.5-inch mobile PC (80 cm). The results showed that the participants still significantly accepted the invitation from the on-screen agent appearing on the 4.5-inch mobile PC from 40 cm away, and then clarified that both factors of the shorter distance from the agent and of the appropriate media type affected the participants behaviors whether they accepted or rejected the agents' invitations.

Keywords: On-screen agent, Media Terminals, Shiritori game.

1 Introduction

Various interactive agents such as robotic agents [1] or embedded conversational agents (ECAs) [2,3] have been developed to assist us with our daily tasks. Because of this situation, some researchers have started testing the effects of various agents appearing on different media on users' reactions and impressions. In particular, comparisons of on-screen agents appearing on computer displays with robotic agents have been conducted [4,5,6,7,8,9]. Most of these studies argued that robotic agents were much more comfortable and believable interactive partners than on-screen agents for users [5,6,7]. However, some studies have reported that people reacted toward

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on-screen agents as if they were reacting toward robotic ones [8,9]. Thus, these studies [8,9] showed that on-screen agents could also become comfortable and believable interaction partners for users.

Therefore, an on-screen agent could be utilized specifically in situations where a robotic agent cannot be used, e.g., in mobile situations, and these agents could appear on various media in home or office environments, such as big screen televisions, computer displays, mobile computers, or cell phones. However, the effects of different media on users' reactions during the users' interactions with on-screen agents have not been considered. Therefore, in this study, we focused on three different media terminals that could be generally utilized for the on-screen agents: e.g., a 42-inch big-screen television, a 17-inch LCD PC monitor, and a 4.5-inch mobile PC. We firstly conducted an experiment to investigate the effect of these three types of media placed on appropriate distances on participants' reactions during their interactions with on-screen agents.

2 Experiment 1

2.1 Overview

We utilized a "Shiritori game" environment as an experimental setting to observe the participants' reactions in their interactions with on-screen agents [7,8]. First, the participants were told that the purpose of this experiment was to investigate the computer mouse trajectory while they played a web-based puzzle video game "picross" by Nintendo Co., Ltd. Actually, this puzzle game was a dummy task for the participants. The experimenter then told them that an on-screen agent would conduct the experiment because the presence of a human experimenter would affect the results. One minute after the puzzle game started, an on-screen agent placed diagonally to the left and in front of the participants talked to them, and encouraged them to play a "Shiritori game" together. Shiritori is a Japanese word game where you have to use the last syllable of the word spoken by your opponent for the first syllable of the next word you use (the rule of this game shown in Fig. 1.). Most Japanese have a lot of experience playing this game, especially when they are children.

Japanese Last and First Game (*Shiritori)*

Rule:

- Two or more people take turns to play.
- Only nouns are permitted.
- A player who plays a word ending in the mora "*N*" loses the game, as no word begins with that character.
- Words may not be repeated.

Example:

Sakura (cherry blossom)-> *rajio* (radio)-> *onigiri* (rice ball)-> *risu* (squirrel) -> *sumou* (sumo wrestling) -> *udon* (Japanese noodle)

Note: The player who played the word *udon* lost this game.

Fig. 1. Rules of Shiritori from Wikipedia[1]

[1] http://en.wikipedia.org/wiki/Shiritori

The actual purpose of this experiment was to observe the participants' behavioral reaction when the agent talked to them: specifically, whether the participants accepted or rejected the invitation of the on-screen agents. The Shiritori game is a quite easy, so we assumed that the participants who accepted the invitation of the Shiritori game regarded the on-screen agent as a comfortable interactive partner.

2.2 Participants

30 Japanese university students participated (19–23 years old: 15 men and 15 women). These participants were randomly divided into the following three experimental groups (Fig. 2).

- Group 1 (10 participants): The on-screen agent appeared on a 42-inch LCD flat television (Sony Corporation: FWD-42PX2). The agent on the screen was about 38 cm tall, and the distance between the display and the participants was about 120 cm. The resolution of the on-screen agent on this television was 800 x 600 [pixels].
- Group 2 (10 participants): The on-screen agent appeared on a 17-inch flat display (Eizo Corporation: FlexScan S1701). The agent was about 14.5 cm tall, and the distance was about 80 cm. The resolution on this display was 800 x 600 [pixels].
- Group 3 (10 participants): The on-screen agent appeared on a 4.5-inch mobile PC's wide display (Sony Corporation: VAIO type U VGN-UX90S). The agent was about 4 cm tall, and the distance was about 40 cm. The resolution on this wide display was 1024 x 600 [pixels]

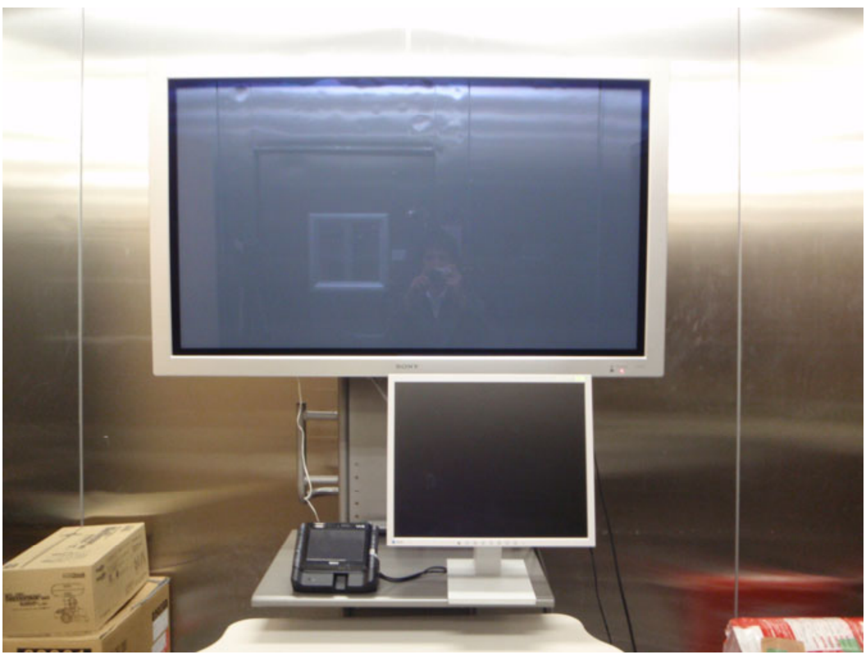

Fig. 2. Three dirrerent media terminals: 42-inch television (center), 4.5-inch mobile PC (left bottom) and 17-inch LCD display (right bottom)

We used NEC's CG robot software "RoboStudio," which is PaPeRo robot (by NEC) simulation software, for the on-screen agent. Before the experiment, we ensured that the participants did not know about RoboStudio or PaPeRo robot. Actually, the agent was placed in front of and to the left of the participants so that they could not look at the agent and the puzzle game simultaneously (Fig. 3 and 4). The distance between each type of media and the participants was decided based on the appropriate distance for each media. The sound pressure of the on-screen agent's voice at the participants' head level was set at about 50 dB (FAST, A). The agents behaviors (announcing the starting and ending signals and playing the Shiritori game) were remotely controlled by the experimenter in the next room using the wizard of oz (WOZ) method.

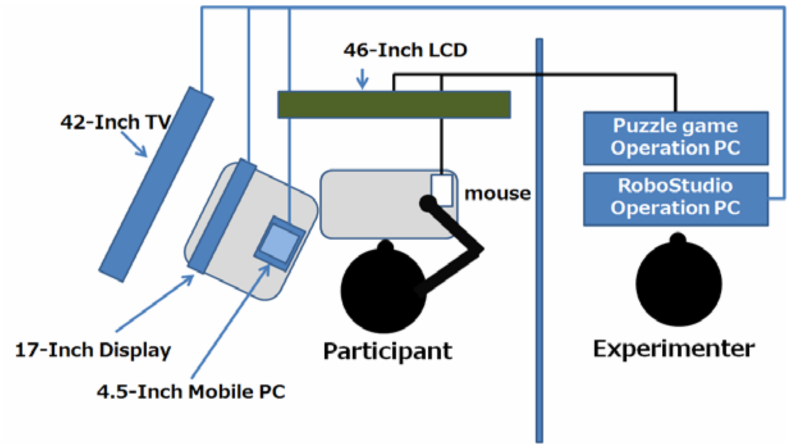

Fig. 3. Experimental Setting

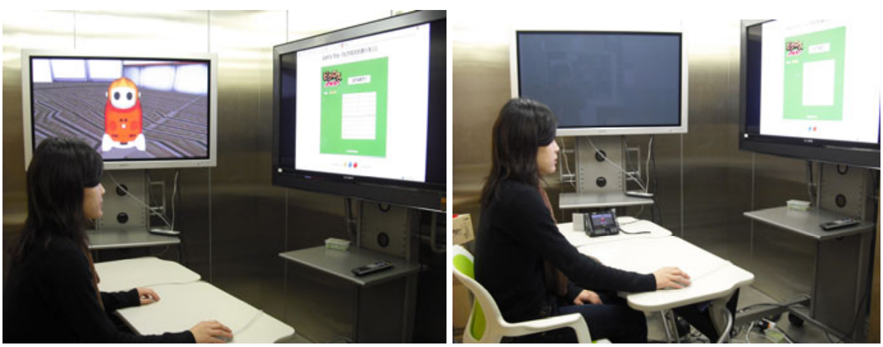

Fig. 4. Actual Experimental Scene: Group 1 (left) and Group 3 (right)

2.3 Results

We investigated how many participants accepted the on-screen agent's invitation in each experimental group (Fig. 5). In Group 1 (42-inch TV), two out of 10 participants

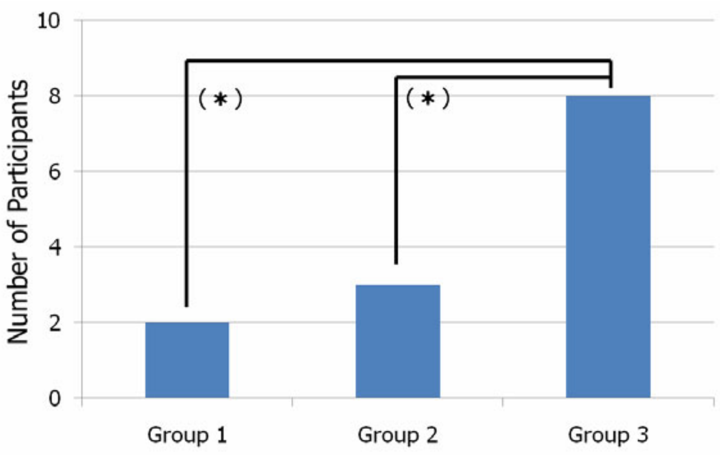

Fig. 5. Number of participants who accepted the agent's invitation in each experimental group

accepted the agent's invitation and actually played the Shiritori game. In Group 2 (17-inch Display), three out of 10 participants accepted the invitation, and in Group 3 (4.5-inch mobile PC), eight participants did so.

A Fisher's exact probability test was used to elucidate the effects of the different media by comparing all three groups. The results were that we found significant differences between Group 1 and 3 (one-sided testing: $p=0.012<0.05$ (*)), and between Group 2 and 3 ($p=0.035<0.05$ (*)). Therefore, the results of this experiment clarified that most participants in Group 3 (on-screen agent appearing on a 4.5-inch mobile PC) accepted the agent's invitation, while most participants in Group 1 (42-inch TV) and Group 2 (17-inch display) did not.

The results of the experiment suggest that a mobile PC is an appropriate media for an on-screen agent that is required for interaction with users. Interestingly, our finding seems to be completely opposite to the findings of Goldstein et al. [10]; that is, "people are NOT polite towards small computers." On the other hand, our finding seems to be in accord with the findings of Hall's proxemics [11]; that is, "the social distance between people is reliably correlated with physical distance." However, whether the media type itself (e.g., mobile PC or large display) or the distance between the agent and the participants affected the participants' reactions is still unclear from this results.

3 Experiment 2

We then conducted a follow-up study to investigate which factor (media type or distance) significantly affects the participants' reactions and to compare the acquired results with the findings of Goldstein [10] and Hall [11].

3.1 Participants

30 Japanese university students participated (19–22 years old: 15 men and 15 women). These participants were randomly divided into the following three experimental groups. In addition, they did not participate the Experiment 1.

- Group 4 (10 participants): The on-screen agent appeared on a 42-inch LCD flat television and the distance between the television and the participants was about 80 cm, which was 40 cm shorter than ones in Group 1. The resolution and the height of the on-screen agent on this television were the same with the ones in Group 1.
- Group 5 (10 participants): The on-screen agent appeared on a 17-inch flat display, and the distance was about 40 cm, which was 40 cm shorter than one in Group 2. The resolution and the height of the agent on this display were the same with the ones in Group 2.
- Group 6 (10 participants): The on-screen agent appeared on a 4.5-inch mobile PC's wide display and the distance was about 80 cm, which was 40 cm longer than . The resolution and the height of the agent were the same with the ones in Group 3.

The investigation of the participants' behaviors whether they accepted the agents' invitations or not in these additional three experimental conditions would clarify which factor (media type or distance) significantly affects the participants' reactions. Specifically, this investigation would clarify the one of the following two claims based on the acquired results.

- Case 1: the factor "distance" significantly affected the participants' reactions.
  1. The number of the participants who accepted the agents' invitations in Group 4 is larger than one in Group 1 (i.e., 80 cm in Group 4 vs. 120 cm in Group 1).
  2. The number of the participants who accepted the invitations in Group 5 is larger than one in Group 2 (i.e., 40 cm in Group 5 vs. 80 cm in Group 2).
  3. The number of the participants who accepted the invitations in Group 6 is smaller than one in Group 3 (i.e., 80 cm in Group 6 vs. 40 cm in Group 3).
- Case 2: the factor "media type" significantly affected the participants' reactions.
  1. The number of the participants who accepted the agents' invitations in Group 4 is the same with the one in Group 1 (i.e., the same media "42-inch TV" is utilized).
  2. The number of the participants who accepted the invitations in Group 5 is the same with the one in Group 2 (i.e., the same media "17-inch display" is utilized).
  3. The number of the participants who accepted the invitations in Group 6 is the same with the ones in Group 3 (i.e., the same media "4.5-inch mobile PC" is utilized).

Here, the procedure and setting of this experiment was the completely same with the ones in Experiment 1 except of the placed distance of each media from the participants.

3.2 Results

We investigated how many participants accepted the on-screen agent's invitation in each experimental group (Fig. 6). In Group 4 (42-inch TV with 40 cm shorter distance), three out of 10 participants accepted the agent's invitation and actually played the Shiritori game. In Group 5 (17-inch Display with 40 cm shorter distance), six out of 10 participants accepted the invitation, and in Group 6 (4.5-inch mobile PC with 40 cm longer distance), five participants did so.

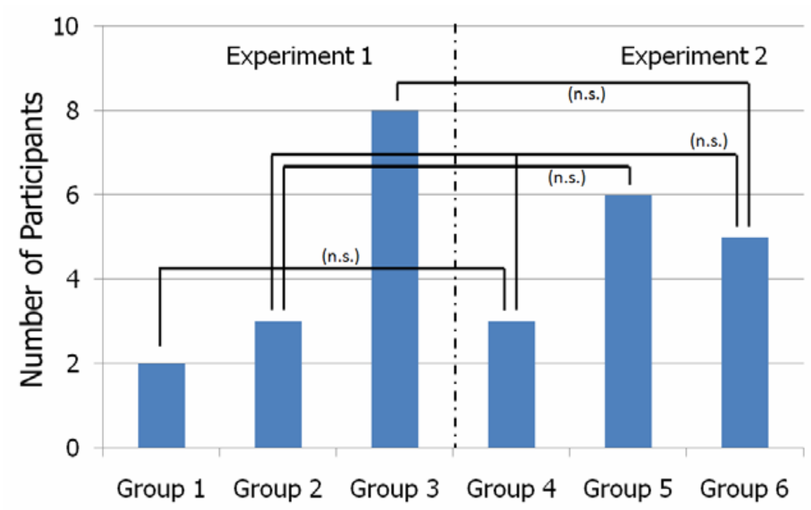

Fig. 6. Number of participants who accepted the agent's invitation in each experimental group

A Fisher's exact probability test was used to elucidate the effects of the different media and different distance by comparing the following four couples; that is, between Group 1 and 4, between Group 2 and 5, between Group 3 and 6, and between 2, 4 and 6. The results were that we found no significant differences in the all four couples (one-sided testing: p=0.50, n.s. (Group 1 and 4), p=0.1849, n.s. (Group 2 and 5), p=0.1749, n.s. (Group 3 and 6), p=0.350 (Group 2, 4 and 6). Therefore, it seemed that this result support the claim "Case 2" mentioned in the above, e.g., the factor "media type" significantly affected the participants' reactions. However, in between Group 3 and 6, the number of the participants who accepted the invitations was getting decreasing as its distance was getting longer (five participants with 80cm vs. eight with 40 cm). Moreover, in between Group 2 and 5, the number of the participants who accepted was getting increasing as its distance was getting shorter (three participants with 80 cm vs. six participants with 40 cm). Although there were no significant differences in these two couples, it would be hard to exclude the effects of the factor "distance" on the participants' reactions, and it would be simultaneously hard to say that the effects of the factor "media type" only affected the participants' reactions.

On the other hand, in between Group 1 and 4, the number of the participants did not change even though the 42-inch TV moved to the shorter distance to the participants (i.e., two participants with 120 cm in Group 1 vs. three participants with 80 cm in Group 4). This results might indicate that it would be uncomfortable for participants to react to the agent appearing on the media with large display regardless of the distance between them.

To sum up, we could confirm the following three phenomena based on the results of the Experiment 1 and 2:

- The number of the participants who accepted the invitations of the agent appearing on 4.5-inch mobile PC was decreasing as its distance between them was increasing.
- The number of the participants who accepted the invitations of the agent appearing on 17-inch display was increasing as its distance between them was decreasing.
- The participants did not react naturally to the agent appearing on 42-inch TV regardless of the distance between them.

Although these three phenomena could not clarify which factor ("media type" or "distance") significantly affects the participants' reactions or not, these would suggest the other interpretation, such as "each media terminal has an each appropriate distance to the users."

4 Conclusions

The purpose of this study was to clarify the effects of the different media terminals where the on-screen agent appears on the participants' behaviors or reactions. Specifically, we focused on the three different media terminals that could be generally utilized for the on-screen agents; that is, 42-inch big-screen TV with 120 cm away from the participants, 17-inch LCD PC monitor with 80 cm away, and 4.5-inch mobile PC with 40 cm away. We then investigated whether these participants accepted the agent's invitation to a Shiritori game while they were engaged in given task. The results showed that most participants who received the invitation from the agent appearing on a 4.5-inch mobile PC accepted the agent's invitation, while most participants did not accept the invitations from the agent appearing on the other two media terminals. However, whether the media type itself (e.g., mobile PC or large display) or the distance between the agent and the participants affected the participants' reactions was still unclear from this results.

We then conduct a follow-up experiment to investigate which factor (media type or distance) significantly affects the participants' reactions. Specifically, we prepared the three additional experimental conditions; that is, 42-inch TV with 40 cm shorter distance, 17-inch display with 40cm shorter distance, and 4.5-inch mobile PC with 40 cm longer distance. The results showed the following three phenomena; 1) The number of the participants who accepted the invitations of the agent appearing on 4.5-inch mobile PC was decreasing as its distance between them was increasing, 2) The number of the participants who accepted the invitations of the agent appearing on 17-inch display was increasing as its distance between them was decreasing, and 3) The participants did not react naturally to the agent appearing on 42-inch TV regardless of the distance between them. It seemed that this result suggest the other interpretation, such as "each media type has an each appropriate distance to the users. " Therefore, we could not clearly confirm which the claims of Goldstein or Hall was an appropriate for interacting between users and on-screen agents.

One of the interesting phenomena observed in the two experiment was that the participants did not look at the on-screen agent when they accepted the invitations to a Shiritori game or even during they were actually playing the game. This phenomenon would indicate that whether they accepted the agents' invitations or not would depend not on the visible existence based on the visual information but on the audible one based on the audio one. Therefore, there would be some possibilities that the participants who listen the agents' invitation from the wearing headphone would accept the invitations and play the game regardless of the types of the media terminals and regardless of the distance between them.

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Sense of Presence in a Robotic Telepresence Domain

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Abstract. Robotic telepresence offers a means to connect to a remote location via traditional telepresence with the added value of moving and actuating in that location. Recently, there has been a growing focus on the use of robotic telepresence to enhance social interaction among elderly. However for such technology to be accepted it is likely that the experienced presence when using such a system will be important. In this paper, we present results obtained from a training session with a robotic telepresence system when used for the first time by healthcare personnel. The study was quantitative and based on two standard questionnaires used for presence namely, the Temple Presence Inventory (TPI) and the Networked Minds Social Presence Intentory. The study showed that overall the sense of social richness as perceived by the users was high. The users also had a realistic feeling regarding their spatial presence.

Keywords: elderly, human-robot interaction, social richness, spatial presence, user-evaluation.

1 Introduction

Many countries today are faced with the problems of an aging society due to a decrease in rates of childbirth, increased life expectancy and the aging baby-boom generation.[1] When people get older, they are more likely to need medical, social and personal care services. In countries like Sweden, which are faced with a large aging segment in the population, a challenge is to provide such services despite a decreasing proportion of people who are active in the work force. Many elderly people prefer living independently in a familiar and residential setting for as long as possible [3]. This implies that there is an increasing need to support independent living of elderly people in their own homes. Research in assistive technologies is therefore aimed at facilitating independent living while also providing an increased sense of safety and security to the elderly. Examples include fall detectors, health monitors, medication reminders and appointment reminders.

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[1] For example, in 2008 17.8 % of the Swedish population was older that 65. In 2020, the projected number is 22.8 % [1]. Further, the demographics are such that the majority of Swedish elderly live either alone or with their spouse [2].

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However, a major concern with many assistive technologies is that they can contribute to an enhanced feeling of isolation as the technology often removes the presence of the human in distributed care. Therefore, finding technological solutions which can promote independent living, safety at home and still enable an enhanced social interaction are of special interest. This is particularly true for the new generation of senior citizens who are expected to be active and productive long after the age of retirement and maintain a diverse social network encompassing family, friends and former colleagues.

Telepresence has long been advocated as a means to enable virtual face-to-face communications for people located at different places, particularly in the context of Telemedicine. Telepresence was coined already in 1980 by Marvin Minsky and it means that an operator receives sufficient information about the teleoperator and task environment, displayed in a sufficiently natural way, that the operator feels physically present at the remote side [4]. Robotic telepresence is a newer variant that proposes to integrate Information and Communication Technologies (ICT) onto robotic platforms and enable actuation in a remote location. With the arrival of video conferencing systems the step to developing social robotic telepresence systems is not long. Such a system allows a remote operator of a system to embody themselves within the shape of a robot in a remote environment. The first system of the kind was PRoP [5,6] and it allowed humans to project their presence into a real remote space and to roam around in that environment.

A number of factors seem to indicate that such systems are well-suited as a tool to enhance distributed care for the elderly. Firstly, an elderly person interacts with the robot in a natural and intuitive manner, and little additional learning is required. Secondly, the healthcare professional connecting to the robot from a remote location gains a greater level of control as they are allowed to move in the environment. This adds an enhanced level of safety and enables the caregiver to better assess potentially dangerous situations. Thirdly, the technology is suitable for a diverse group of elderly people ranging from the very mobile, who want to maintain contact with their local caregiver, to those who are less mobile, who want to gain a greater sense of safety. However, despite this potential, the deployment of social robotic telepresence systems in elderly homes must be backed up by user evaluations on first time experiences as well as long-term experiences to best understand problems and user needs.

It is however important to have all potential users in mind when performing evaluations. For example when developing products for elderly, who in many cases are in frequent contact with alarm services and health care personnel that might very well be future users of the system one should also evaluate them with these user groups. Other studies exist which investigate user perspectives of robotic telepresence, such as [7] where a mobile robot enabled remote workers to live and work with local workers almost as if they were physically present and [8] that showed that a socially expressive robot was found more engaging and likeable than a static one. However, these studies so far have not explicitly dealt with user groups that will work closely with elderly.

The work reported in this paper is a study of the experienced level of presence when using a social robotic telepresence system, the Giraff, with health care personnel and alarm operators. Presence was mounted around the 1990s and can be described as the sensation of "being there" and it is likely an important factor in acceptance of any video conferencing system. The study reported is based on data collected at training sessions with people working with health care in homes of elderly and alarm operators responding to alarms from elderly. We are interested in investigating whether adding the possibility to move in a remote environment in contrast with interacting through a traditional videoconferencing system has positive effects on the perceived presence. We are also interested in whether it is possible to measure spatial presence in a robotic telepresence system domain using a presence questionnaire originally designed for a different medium.

The paper is organized as follows. In Section 2 the Giraff system is described. Section 3 describes the methodology behind the study presented in this paper and includes information about the test subjects, the experiment and the questionnaire used. Section 4 outlines the results obtained in the study. The results are discussed in Section 5. Future work is outlined in Section 6.

2 The Giraff Robot

The robot used in the training sessions was the Giraff. It provides a means for achieving remote communication between two parties. On one end, there is a mobile robotic base equipped with a web camera, a microphone and a screen. A user interacts through the robotic device with a peer who connects through a client interface. The client interface on the other end allows the user to teleoperate the Giraff while speaking through a microphone and a web camera and receiving the real-time video and audio stream from the Giraff. Graphical depictions of the robotic device are given in Fig. 1. (a) and (b). The robot consists of a screen and web camera that are mounted on the mobile base.

Specifically, the camera and screen are mounted on a tilt unit which allows the remote user to control the field of view. A snapshot of the client interface is shown in Fig. 1 (c). This interface is designed to be as easy to use as possible, and does not require any special hardware such as a joystick. A standard computer, its pointing device (such as a mouse) and a web camera is sufficient. By holding down the left mouse button when pointing at any spot in the real-time video image, the robot will go to the place indicated by the cursor. To turn in place, a dragging motion with the mouse on the real-time video image can be made. The Giraff automatically moves

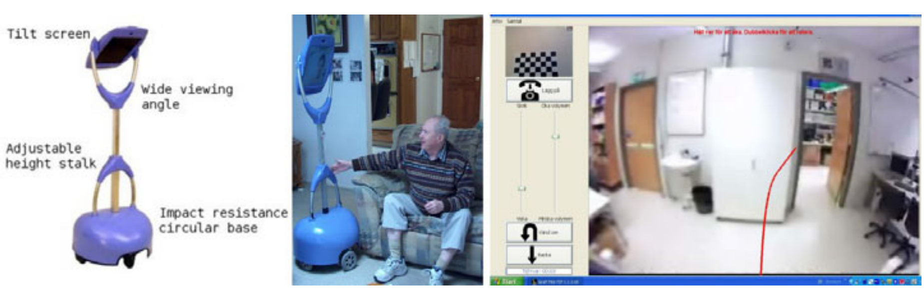

Fig. 1. (a) The Giraff robot (b) A conversation between an embodied teleoperator and an elderly (c) The Giraff client interface

Table 1. Technical Specifications of the Giraff Unit being used in the training sessions

Form Factor
• Low center of gravity, ensuring stable operation even on wheelchair ramps. • 14 kg weight and integrated carrying handle to allow carrying. • 173 cm height
Base
• The base moves using a differential drive movement system. • A patented suspension system allows the 15 cm wheels to climb small obstacles and rugs while maintaining the stalk in an upright position. • Enabling speeds of up to two meters per second, a brisk walking pace. • Both drive motors use encoders for accurate positional feedback.
Wireless
• Capable of supporting 802.11 wireless.
Docking Station
• A remote user can charge the Giraff by driving it onto the docking station. The docking station charges the batteries in under two hours. • A full charge is sufficient to allow the Giraff to wander untethered for • over two hours.

until the camera is centered at the end of the point of the drag. The Giraff is intended to be used in forward motion but it can also move backwards. That movement is used when undocking from its charging station as well as to enable going backwards if being stuck. The technical specifications of the device used in the training session are described in Table 1.

The use of the Giraff platform as outlined in this paper is part of an ongoing study to evaluate social robotic telepresence systems used to promote social interaction for elderly users. This study funded by the Ambient Assisted Living framework (AAL Call 2) is one of many evaluations under the ExCITE project.[2] One use, which is particularly relevant in Sweden, is the Giraff as a remote monitoring device for ”Hemtjänst”. Hemtjänst is a domestic care service provided by the Swedish municipalities. Through this service, elderly citizens receive assistance at home from health care professionals according to their individual needs. These needs can vary greatly, from sporadic visits to several visits a day. The Giraff application could increase the ability of Hemtjänst to provide help and guidance to senior citizens who are difficult to reach. Another use of the Giraff within this context is in conjunction with the currently deployed alarm device: upon receiving an alarm, an operator may monitor the elderly person through the Giraff in order to assess what kind of assistance the user needs. We believe that the Giraff can be used as a complement to Hemtjänst and alarm services.

3 Methodology

In this section we describe the experiment in which we measured experienced social richness and spatial presence. The methodology consisted of inviting the users to a training

[2] The interested reader can find more information about the project ExCITE at http://www.excite-project.org.

session where they were allowed to use the system to make a remote visit to an elderly home. This visit was presented as an opportunity to train on steering and using the Giraff. The training session also served the purpose to collect data via questionnaires.

3.1 Subjects

The users trained in the presented experiment were 11 people working with health care in homes of elderly and 21 alarm operators responding to alarms from elderly. All users are to use the Giraff system in one of the testsites for the ExCITE project. The health care personnel came to the experiment in groups of two or three persons and had not seen any instruction movie or written manual before the training while the alarm operators came one by one and had all seen the instruction movie. This implies there may be a difference in experienced presence based on differences in methodology as well as prior knowledge. The average age of all users was μ=42.45, σ=9.797. The health care personnel and alarm operators had a similar age spread. There were three men and 29 women being trained thus not allowing any gender comparisons in this experiment.

3.2 The Experiment

The training session took place in two smart-home environments that exist at AASS[3]. The locations were chosen to enable the users to make a remote visit with the Giraff to a home similar to a home of an elderly while at the same time allowing data collection with existing smart-home technology. The users were welcomed to feel comfortable in a home-like environment where a laptop connected to a headset and a mouse was placed from which they were to visit another home remotely. A graphical overview of the remotely visited room can be found in Fig 2. The blue cylinder symbolizes the Giraff and the blue office chair symbolizes a wheelchair. As can be seen in the figure, the smart-home has both bedroom, living room and kitchen.

The same test scenario was used for all subjects but as the health care personnel arrived in groups the people not currently driving the robot were allowed to follow the conversation beside the Giraff operator. The session began with informing the participants about the computer and its connected devices and then instructing them to make a visit as realistic as possible to a remote home with the Giraff, namely act as if they visited a real home and an elderly person. They were also asked to be attentive during the training session and to inform the elderly if they noticed strange things in the remote environment such as a fridge door left open and the sound of an alarm. Further, they were informed that they would be asked to fill in a questionnaire after completing the training session.

All users visited a person who pretended to be an elderly person in need of a wheelchair. The users were told to start the Giraff Application, log on to the Giraff server and to connect to a specific Giraff in a list of Giraffs. The 173 cm tall Giraff, the blue cylinder in Fig 2, was being charged. The Giraff is being charged by driving it forward into its dockingstation that needs to be placed against a wall. Thus, once connected remotely, the users were facing a wall. The connection scenario was thus similar to the one that would occur when connecting to a remote Giraff placed in a real

[3] AASS stands for Center of Applied Autonomous Sensor Systems (AASS) at Örebro University.

Fig. 2. A conceptual sketch of the training session environment. The Giraff is symbolized by the blue cylinder and the wheelchair by the blue office chair.

home-setting. Further the placement in the docking station allowed training in docking as well as undocking the Giraff. The users were told to undock the Giraff from the docking station by pushing the buttons **Backward** and **Turn** in the Giraff Application and to find the elderly person who was laying in the bed. Upon finding the elderly, the elderly person would move over to the wheelchair and ask the visitor to follow. The elderly first went to the kitchen where the door to the refrigerator had been left open. To allow some time for the visitor to notify the elderly, the elderly asked the visitor about a medical issue. The elderly then asked for help to find the remote control to the television which in most cases had been forgotten on the floor in between the sofa table and the television[4]. After finding the remote control, there would be a sound from an alarm in the bedroom. The visitors were given some time to notify the elderly about the sound but as some never noticed the sound the elderly would finally say good bye and tell the visitor to go back to the docking station and hang up the phone.

The Questionnaire. The questionnaire used was based on two standard questionnaires, the Temple Presence Inventory (TPI) [9] and the Networked Minds Social Presence Inventory [10]. The questions were asked in Swedish with minor adjustments of the questions. For all questions, a 7-number likert scale was used where "1 = Not at all" and "7 = To a very high degree". Specifically, in the investigation presented within this paper, we are interested in spatial presence when applying the same measures to a robotic telepresence system domain. We are also interested in investigating whether adding the possibility to move in a remote environment in contrast with interacting through a traditional videoconferencing system has positive effects on the perceived presence. Data about age gender and if the users had used Skype or similar systems before was also collected.

4 Results

There was no significant difference between the response from the health care personnel and the alarm operators regarding the presence dimensions social richness and spatial presence when doing a one-way ANOVA-test. For that reason, only one mean and standard deviation value for each question is presented for all questions from here on presented. The values are based on all users at the training sessions.

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[4] As the health care personnel arrived in groups, the remote control would be forgotten in different places for the 2nd and 3rd person driving the Giraff.

4.1 Previous Familiarity with Video Conferencing Systems

None of the participants had previously used Skype or similar systems for videoconferencing (μ=1.66, σ=1.405). This is a low score on a 1-7 likert scale where "1 = not at all" and "7 = to a very high degree". This implies there was a dual novelty of using the proposed system in the videoconferencing technology and in the added mobility of the robot.

4.2 Experienced Social Richness

Social Richness was measured by asking the users to make a circle on a scale 1 to 7 in all opposite couples presented to the left and right respectively in Table 2. The Mean (μ), Standard deviation (σ) and the internal consistency measure Cronbach's α for the dimension were calculated. An α-value higher than 0.8 but lower than 0.95 is generally considered as showing a good reliability. As such the questions regarding this dimension after our training session seem to measure the same variable, in this case social richness.

Table 2. Experienced social richness, α=0.89

	Mean (μ)	Standard deviation (σ)	
Remote	4.35	1.142	**Immediate**
Unemotional	4.23	1.257	**Emotional**
No response	5.60	0.932	**Response**
Static	5.03	1.643	**Lively**
Impersonal	4.61	1.606	**Personal**
Insensitive	4.55	1.480	**Sensitive**
Unsociable	5.00	1.461	**Sociable**

4.3 Experienced Spatial Presence

A number of questions were asked to gain knowledge of the users' experienced spatial presence. For all questions, a 7-number likert scale where "1 = Not at all" and "7 = To a very high degree" was used, The Mean (μ) and Standard deviation (σ) along

Table 3. Experienced spatial presence, α=0.76

	Mean (μ)	Standard deviation (σ)
To what degree did it feel as if… ..the objects you saw were at the same place as you	4.09	1.532
..the person you saw were at the same place as you	4.19	1.512
..you could reach and touch the objects you saw	2.66	1.516
..you could reach and touch the person you met	2.81	1.674
..you were in the environment you met	4.16	1.417
..the sounds came from specific different locations	3.44	1.605
I tried touching the objects I saw	1.56	0.948
I tried touching the person I met	1.56	0.948

with Cronbach's α for the dimension were calculated and are presented in Table 3. The α-value for this dimension was lower but generally α-values between 0.6 and 0.7 are acceptable. As such the response indicates that the questions given regarding this dimension after our training session measure the same variable.

5 Discussion

An overall concern for the study is whether the novelty of using videoconferencing while further adding the possibility to move in the environment could potentially shift focus from interacting with the person visited to a focus on navigation and other technical issues. Subjective questionnaires as the ones used in our study cannot explicitly isolate the effect of this parameter. Nevertheless, overall the sense of social richness in the training session was high when taking in to account the unnatural situation for the users with the use of a new kind of medium for interaction, a new environment and meeting a new person (actor). As can be seen in Table 2, the users gave their preference to the right-side alternative in all opposite-couples. This indicates that the social richness was considered high on a first-time usage of the system.

We were also interested in whether it is possible to measure spatial presence in a robotic telepresence system domain using a presence questionnaire originally designed for a different media. The Cronbach's α-value for this dimension was an acceptable 0.76 and thus indicates it is a valid measurement technique even in this domain. The users also had a realistic feeling of their spatial presence. Users did not feel as if they could reach and touch the objects or the person (μ=2.81, σ=1.674). Nor did they try touching the objects or persons. There were small indications that they still felt as if they were at the same place as the objects (μ=4.09, σ=1.532) and the person (μ=4.19, σ=1.512). The indication of feeling as if they were present in the environment was similarly high (μ=4.16, σ=1.417).

However, the results did indicate a possible need for improving the sound presentation from the system as the users did not perceive whether sounds came from specific locations (e.g. a phone ringing in the background) (μ=3.44, σ=1.605). This is supported by an observation made during the trials that only 75 % of the users notified the elderly about the sound of an alarm. We had also asked a question outside the presence scope regarding if it was easy or difficult to hear what the other person said (μ=5.42, σ=1.43 where "1 = very difficult" and "7 = very easy"). As the Giraff is a communication device, it is important to pay caution to perception of sound with respect to noise, sound representation and volume.

It should be noted that although there was a difference in methodology and prior knowledge between the health care personnel and alarm operators, no significant difference was noted between the groups and their perceived level of presence in any of the dimensions of presence measured.

The study reported in this paper was performed in an artificially created setting in which users interacted with an actor whom they had never met before. While caution should be used in the interpretation of the results, overall it seems as if the questions from the spatial presence dimension on the TPI were adequate to be applied to the robotic telepresence system domain. We plan to regularly prompt the users in this study about their sense of presence throughout ExCITE.

6 Future Work

While measurements of two dimensions of presence were investigated in this paper also most of the other dimensions in the questionnaires presented in Section 3.2 were measured within the presented experiment. Two dimensions in the TPI-questionnaire (parasocial interaction and active interpersonal) were not developed for our sort of medium and were not used in our questionnaire The smart-home environment allowed video recording the training sessions with ten cameras from different angles and positions which will allow comparisons by answers in questionnaires and observations. Also data regarding the ease of use of the user interface was collected using a questionnaire. We plan to further investigate the data and correlations among them and present them in a separate publication.

As the trained users are part of the larger ExCITE project we expect to further question the same users about their experienced presence when using the Giraff on a long-term basis as it is our belief the perception will change when the novelty effect wears off.

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Exploration of the Cultural Image of Chinese Form Using Culture Identity Design

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Abstract. The scope for the development of product design concerns several fields including cognitive meanings, symbolic functions and cultural histories of form. Through effective intervention of the culture identity design, the difference of the nationality will be decreased, the interaction between product and people will be improved, and the opportunities for cultural self-expression will be enhanced. The objective of this study mainly investigates the relationship between Chinese form and implied cultural image. The study applied the knowledge of culture identity design to enrich design semantics of a new product. In regard to develop more strategically culture identity design, a conceptual basis is needed to guide the understanding of traditional culture and support design making. In order to achieve the objective, this study partitions the knowledge into three principles including metaphor coding, traditional frame and decorative pattern. The three principles contain insights regarding how people perceive and think in such a Chinese culture environment. Designers can understand the principles of Chinese culture identity and apply the concept to design cultural creativity product.

Keywords: Culture identity; Cultural image; Chinese style; Metaphor coding; Decorative pattern.

1 Introduction

The cultural creativity industry has listed as Taiwan's national prioritize plan since 2002, and become one of the most important industries. Cultural industries have been defined as systems for controlling innovation through gatekeeping processes [1]. The cultural industry fits the fashion industry, since a new collection is produced through a sequence of gatekeeping activities, which were identified by Blumer [2]. Besides, the cultural creativity industry is the activity of local actions based on the thinking of the globalization. The globalization is the social life striding across space and time by separating out the social situation and resulting in the interactive correlation process among society, culture, system and individual [3][4]. In Taiwan, the government deliberates definitions of various countries regarding the cultural creativity industry and considering the particularity of the development of Taiwan industries. Therefore,

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the cultural creativity industry in Taiwan is defined that is provided with the creation wealth, potential employment opportunity, and promotion of the whole living conditions which are derived from accumulations of the creativity and the culture and utilization of the intellectual property. In addition, applying design to cultural creativity industry is gradually important. For example, Lee [5] extracted cultural elements from the representative landscapes in Kaohsiung, Taiwan, and designed a series of cultural creativity products.

A good design should help users to understand how to use products but also how to understand their cultural image including implied cultural meanings, stories and emotions. The most noteworthy design development maybe concerns about the cognitive meanings, symbolic functions and cultural histories of form. All man-made forms are provided with socio-cultural histories, existing archetypes, and implied cultural meanings that place them in the symbolic context during the use process. An object's form reveals something about its function, usability and quality; sometime, an object's form also reveals which country it is made in. Through culture identity design, designers can demystify nationality, improve the interaction between product and people, and enhance opportunities for cultural self-expression. In this Age we live in needs an emotional revival. It needs culture identity design. It is merely a design activity that keeps the user's emotional, social, cultural needs in mind [6]. This study design activity requires the designers understand the user's lifestyle and cultural background.

China possesses a long cultural history which has generated distinctive Chinese symbols and forms including Chinese writing, Chinese painting, Chinese knot, Chinese architecture and decorative arts. This research mainly investigated the relationship between Chinese forms and cultural meaning. The research applied the knowledge of culture identity design to enrich the design semantics of a new product. This study explored product semantics to create the cultural cognitive models that explain the meaning of form and allows users to understand Chinese origin of product. The Chinese decorative arts always contain some metaphorical poetry, but most of modern Chinese don't understand those cultural meanings, because the western style replaces the Chinese tradition gradually. For example, the dragon is the metaphorical meaning of royal power. The butterfly is the metaphorical meanings of joy. Much of the new design approach embodied by Post-Modernism focuses on metaphor, as powerful a device for design, because it illuminates a new perspective by suggesting connections between the subject and memories from our experience [7]. This study not only affords users to see the aesthetics of the Chinese objects but also enable users recognize the culture meanings of the decoration.

In regard to develop more strategically culture identity design, a conceptual basis is needed to guide the understanding of traditional culture and support design making. In order to achieve the objective, this study partitions the knowledge of the culture identity design into three principles including metaphor coding, traditional frame and decorative pattern. The three principles assume the definition of culture identity design as a dialogue. Good design provides an effective information transfer among the dialogue's participants in which the user can understand the cultural meaning emotionally. The following three principles contain insights about how people perceive and think in such a Chinese culture environment. Results of this study provide valuable references for academic circles and related industrial field. Additionally, the culture identity design model addressed by this study can be extended to develop cultural creativity design for other related fields.

2 Metaphor Coding

Chinese arts always contain some metaphorical poetry that is the culture meanings of the decoration art. This study classifies metaphor coding of the Chinese style into three portions including homonym, metaphor and metonymy.

2.1 Homonym

Most Chinese characters evolved from essential pictures. In comparison, westerners are 'people of the ear' rather than of the eye. Chinese words can't be spelled, and there are not too many phonemes, so the number of homonyms remains very high. Often, the concept of the Chinese word is phonetically close to the symbol itself. For example, we can say shat "fu" represents the culture meaning of good luck, and the pronunciation of the bat is phonetically close to "fu" (Fig.1).Therefore, the pronunciation of the bat symbolizes good fortune. In such homonym cases we can speak of 'phonetic' or ' aural' symbols [8]. The reason for this must be sought in a phonetic parallel: the word for 'vast' (ping) is identical in sound with the word for 'peace' (ping); the word for 'fish' (yu) is identical in sound with the word for 'abundance' (yu), as shown in the Fig. 2; the word for 'orange' (ju) is phonetically very close to the word for 'lucky' (ji).

Fig. 1. Bat (fu) representing the culture meaning of good luck

Fig. 2. Fish (yu) representing the culture meaning of abundance

2.2 Metaphor

The symbolism are often used in ancient China. The Chinese applied symbols to decorate everything in life including clothes, household utensils, furniture, architecture, etc. There are some metaphors of the good wishes hiding those symbols that became the part of the ancient Chinese. We may say that the pictures of those objects contain symbols, or that the symbols take graphic forms. The picture can be read in two ways—as a work of art which is intended to give aesthetic pleasure to the beholder, or as an expression of good wishes concerning the recipient's longevity, progeny, etc. Some of the shapes are indeed pleasing, and remind one of another similar auspicious images, including: the gallant peonies (wealth and status) (Fig. 3), The inside empty of evergreen bamboo (modesty and maturity) (Fig. 4), the tortoise (long life), etc. [9]

Fig. 3. Peonies representing wealth and status

Fig. 4. Bamboo representing modesty and maturity

2.3 Metonymy

The metaphor works by transposing qualities from one plane of reality to another, while the metonymy works by associating meanings within the same plane. The representation of reality inevitably involves a metonymy: we choose a part of reality to stand for the whole. The selection of metonymy is clearly crucial, for from it we construct the unknown remainder of reality [10]. The symbol of yin-yang (i.e. dark and bright) is the part of Tai-Ji (Fig. 5) to stand for the ruling principle of the whole metaphysical world. The sign of eight trigrams (Fig. 6) is the basic form to stand for the all changes of Yi-Jing.

Fig. 5. The symbol of yin-yang (Tai-Ji)

Fig. 6. The symbol of Eight trigrams

3 Traditional Frame

Chinese style frame is one of the characteristics of Chinese art and design. It is interesting to find these frames so widely applied on the painting, furniture, wall and windows. Framing is most often associated with ornate carving and complex shape. We can pick up such characteristics and produce collections based on minimal lines with an oriental feel. In this study, the traditional frame was classified into three portions of the Chinese style including geometric figure, utensil figure and particular figure.

3.1 Geometric Figure

In China, the circle represents the unity, consummation and strength. Besides, the square represents the integrity, regular, and orthodoxy. Therefore, both frames of the geometric shape are usually used on many objects in Chinese culture. There were two circular motifs containing single loop and double loop. The double loop pattern was actually a concentric circle. The internal and external square frames are emphasized as the prevailing motif by the square formed usually in vertical- horizontal relation or X-substitution (Fig. 7). When the small square is in the large circle as a coin (Fig. 8), the circle of heaven and the square of earth symbolize deities that are omnipresent.

Fig. 7. The internal and external square frames

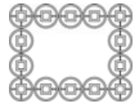

Fig. 8. Circle & square (coin)

3.2 Utensil Figure

Some of the oriental utensils mean to be viewed as symbols, and their characteristics of themes token not only themselves, but also something beyond themselves. Forms of these utensil objects were applied to the frame of the painting, window and vent, or were given on the wall as typical surroundings of elaborate lattice. Shapes of the utensils were usually designed as the frames to make the borders fantastic. The often seen utensil figures include bottle-gourd, fans, vases, knots, the scrolls of Chinese painting and so forth. Figure 9-11 shows three samples of the utensil figure including bottle-gourd, fan, and the scrolls of Chinese painting.

Fig. 9. Appearance of the bottle-gourd

Fig. 10. Appearance of the fan

Fig. 11. Appearance of the scrolls of Chinese painting

3.3 Particular Figure

The Chinese are past masters on modifying or emphasizing corners. They are even more adept at turning corners of frames (Fig. 12). The eye does not readily skirt an acute corner, and it must even be induced to turn a right–angled one. The Chinese have studied this problem for many years and applied in many fields of art. The central frame is supported by the smaller supplementary patterns that add to the beauty of the central primary design. The small patterns with the U-scrolls and T-scrolls (Fig. 13) inlaid on the side of the main frame are typical Chinese style frames [11]. The U-scrolls and T-scrolls were designed around the corner of the frame usually, are symmetrically deployed and balanced in a most pleasing manner.

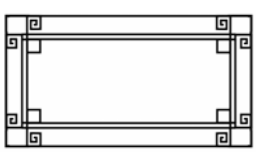

Fig. 12. Turning corners of frame

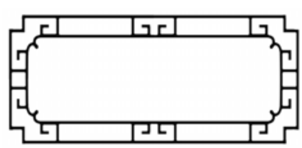

Fig. 13. The T-scrolls of the fram

4 Decorative Pattern

The pattern presents some of the characteristics of the Chinese arts. It is artistic value to maintain that the Chinese have been exploring the possibilities of these patterns for three thousand years. Patterns are used in bronze, stone, jade, woodblock printing, porcelain, wood lattice, and wood carving. Most of the Chinese patterns originate in the inspiration of the animal and plate. Chinese pattern is also an age-old classicism with a sense of balance, order and harmony that appeals to the most modern of minimalists. Particularly, simplification of the repeating pattern design offers a fertile field for variation in the Chinese art. In this study, the decorative pattern is classified into three portions including animal motif, plant motif and particular motif.

4.1 Animal Motif

The Chinese pattern is rooted in the ornamentation of the ancient bronzes, whence the inspiration of much of their design comes. Many of the designs themselves occur on the bronzes, which are often sacrificial objects. Animal's faces were also a popular motif. Sometimes it is impossible to tell if the artist was carving the face of a lion a tiger or a leopard so the carving is simply said the have an animal motif. The Tao Tie motif, which is named for the mythical creature, is currently classified as an animal motif [7]. Animal's faces motifs (Fig. 14) are famed for their greed and savage on early bronze objects. Often times the artist were very fond of carving such dragon and asp motifs onto the objects. The dragon (Fig. 15), a variety of heterogeneous beings, symbols the natural male vigor and also symbols the power of the emperor.

Fig. 14. The motif of the Animal's face

Fig. 15. The motif of the dragon

4.2 Plant Motif

The flower affords pleasing and beautiful patterns and gives a change from the other groups of grille, so there is usually a small unit of plant just within the external one (Fig. 16 & Fig. 17). Grainy pattern actually looked like a grain or seed, and the repeating grainy patters are often simply symmetric construction.

Fig. 16. Flower pattern

Fig. 17. Plant pattern

4.3 Particular Motif

Chinese successfully manage the line of the Ju-I (Fig. 18) with some of methods of upturned ending. The Ju-I scepter-ends tend to bring the attention back and focus it at the center of the pattern; the artistic treatment of the line end is as significant as its meaning: "May things be as you desire". Cloud-band (Fig. 19) is perhaps the oldest designs to be found. Clouds symbolize good fortune and happiness. Stylized clouds, which take the form of the spiral wave, are frequent in many ornamentation things. The clouds make use of symmetric variations and are much softer than other patterns. This meander of strip ornamentation, which is still used a great deal on similar articles with decorated borders, makes its appearance as far back as Neolithic Age, when it was used on pottery. These patterns were designed through repeating, balancing, emphasizing and contrasting, can achieve the goal of unity.

Fig.18. Appearance of the Ju-I

Fig. 19. Cloud-band

5 Experiment

The purpose of this experiment is to explore if the significant difference existed among the three principles to represent the Chinese style.

5.1 Subjects

To attain effective results, this study invites 30 design students, participated in this evaluation experiment, 9 males and 21 females, with ages ranging from 18 to 25 (mean=21.8, SD=1.6), and all possessed a normal or after correction, eyesight of 1.0., and requests the subjects to fill out the evaluation questionnaires.

5.2 Procedure

Subjects were introduced to the experiment procedures. Afterwards, subjects were asked to fill out the evaluation questionnaire. All the evaluating time for a subject is about 15 minutes.

The evaluation questionnaires were made up of 19 sets of Chinese style pictures and questions. The subjects evaluate those pictures representing the Chinese style images, and sign a mark on a 7-point scale of a single adjective pair. At the ending of the experiment, data collected on the reaction of subjects was further statistically analyzed.

6 Results and Discussion

With regard to metaphor coding, the ANOVA results in the Table 1 indicate that the statistical significance ($F (2, 87)=7.52$, $p<0.01$) exists among homonym, metaphor, and metonymy. Consequently, on a further conduction of Scheffe's test [12], results reveal that metonymy more strongly represents the Chinese style than homonym and metaphor (Table 2). Metonymy can use a simple sign to represent the Chinese philosophical thinking; metaphor can use an illustration to signify the meaning of the Chinese literature and culture; homonym can use the same phonetics to represent the form, sound and meaning of the word. For this reason, a part of metonymy image that stands for the whole the Chinese philosophical thinking represents the Chinese style unequivocally.

Table 1. ANOVA for metaphor coding

Source	df	Sum of squares	Mean squares	F	p
Metaphor Coding	2	16.8	8.4	7.52	0.00097**
Error	87	97.2	1.12		
Total	89	114			

**$p<0.01$.

Table 2. Scheffe's test on the metaphor coding factor

	Homonym (mean=4.80)	Metaphor (mean=4.60)	Metonymy (mean=5.60)
Homonym		0.765	0.017*
Metaphor	0.765		0.002**
Metonymy	0.017*	0.002**	

* $p<0.05$; **$p<0.01$

Table 3. ANOVA for traditional frame

Source	df	Sum of squares	Mean squares	F	p
Traditional Frame	2	24.598	12.299	20.02	0.000**
Error	87	53.441	0.614		
Total	89	78.04			

**$p<0.01$.

Table 4. Scheffe's test on the traditional frame factor

	Geometric figure (mean=3.17)	Utensil figure (mean=3.78)	Particular figure (mean=4.45)
Geometric figure		0.0139*	0.0000001**
Utensil figure	0.0139*		0.0055**
Particul figure	0.0000001**	0.0055**	

* $p<0.05$; **$p<0.01$.

With regard to traditional frame, the ANOVA results in the Table 3 indicate that the statistical significance (F (2, 87)= 20.02, $p<0.01$) exists among geometric figure, utensil figure and particular figure. Accordingly, on a further conduction of Scheffe's test, results reveal that particular figure more strongly represents the Chinese style

(Table 4). Especially, utensil figure and particular figure of the traditional frame are strong mode exist in Chinese objects universality. Geometric figure is little distinguishing characteristic from the other country by comparison.

With regard to decorative pattern, the ANOVA results in the Table 5 indicate that the statistical significance (F (2, 87)= 13.498, p<0.01) exists among animal motif, plant motif and particular motif. Accordingly, on a further conduction of Scheffe's test, results reveal that animal motif and particular motif more strongly represent the Chinese style (Table 6). Animal motif and particular motif of the decorative pattern are used to the topical subject to enrich the design, but the plant motif, usually decorative background, is perceived the Chinese style weakly.

Table 5. ANOVA for decorative pattern

Source	df	Sum of squares	Mean squares	F	p
Decorative Pattern	2	17.528	8.764	13.498	0.000**
Error	87	56.489	0.649		
Total	89	74.017			

$^{**}p<0.01$

Table 6. Scheffe's test on the decorative pattern factor

	Animal (mean=4.7)	Plant motif (mean=3.88)	Particul motif (mean=4.90)
Animal motif		0.00079**	0.632
Plant motif	0.00079**		0.00002**
Particular motif	0.632	0.00002**	

$^{**}p<0.01$.

Table 7. ANOVA for three principles

Source	df	Sum of squares	Mean squares	F	p
Principle	2	82.289	41.144	44.148	0.000**
Error	267	248.837	0.932		
Total	269	331.126			

$^{**}p<0.01$.

Table 8. Scheffe's test on the three principles

	Metaphor Coding (mean=5.00)	Traditional Frame (mean=3.40)	Decorative Pattern (mean=4.44)
Metaphor Coding		0.00000**	0.00015**
Traditional Frame	0.00000**		0.00000**
Decorative Pattern	0.00015**	0.00002**	

$^{**}p<0.01$.

Table 7 shows the significance exists among three principles. According to the result of the Scheffe's test, the metaphor coding is the best of three principles to represent the Chinese style (Table 8). Homonym, metaphor, and metonymy explain clearly the meaning of form and allow users to understand Chinese culture, so metaphor coding is well suited to apply on the design of the Chinese theme. Traditional frame and decorative pattern are applicable to the background design for the Chinese style.

7 Conclusion

The ideas developed in this short paper continue to evolve. The principles make up a growing body of knowledge that can help make decisions for the Chinese styles of today's design. All the principles can represent the Chinese style clear and reasonably, specially metaphor coding. The Particular figure of traditional frame, and the animal motif and particular motif of decorative pattern are also well to communicate the meaning of the Chinese form. The results will be become the reference resources provided the conceptual basis of culture identity design, and let Chinese style well merge the western aesthetic with centuries-old idea being reworked into the directions for modern products.

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Museum Exhibit Content Recommendation and Guidance System Focusing on Experience Design

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Abstract. With the growth of economic and the change of consumers' needs, the museum gradually adopts the concept of experiential marketing. The guidance system has played an important experience media. Its development process of services model starts from "one-way standardization" and "passive customization", to "active customization" and "personal adaptability", trying to attract visitors by providing unforgettable and unique experience. This study integrated different scholars' "experience" viewpoints and principles, utilizing design innovation to develop recommendation and guidance systems of content displaying, which consists three man-machine systems, four databases and three core techniques. Furthermore, this study established violin exhibition as an example to descript the "actively customized and recommended displaying content" innovative experience model of "artificial intelligence people" and "invisible encircling".

Keywords: Index Terms—interactive design, guidance system, experiential design, experiential economics.

1 Introduction

Collection, research, exhibition and education are the four main functions for a museum. Gradual diversification of museum types not only reflects the progress of society but also evolutes because of higher demand expectations.

With no doubts, visitors are core for the museum to bring its functions into full play, and exhibit and guidance system is certainly the key factor. In 1907, The US Boston Museum brought in human narrator for the first time, while the mechanical audio guidance system did not appear until 1959 (Lin, 2004). The guiding type of "Man-to-Man" has flexibility to adjust contents and interacting way according to each visitor. "Personnel guidance" approach can be divided into three major categories, which are teaching style, inquiring style, and leading style (Alison L. Grinder & E. Sue McCoy, 1985). Many people believe that personnel guidance can fulfill the function most; however, it also requires the highest labor cost. Now the museum begins to utilize technological media as the guidance tool (Lin, 2004). The development of guidance system evolved from initially "man-to-man" (that is, narrator-to-visitor) to

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"device-to-man". In early period, "audio guidance" mode was extensively adopted. Visitors were required to carry hand-held devices with headphones, and all the hand-held devices provided the same information, which focused on standardized one-way service. In recent years, because of vigorous development of multimedia guidance system and a substantial increase in labor costs, "man-to-man" guidance approach has gradually substituted by "device-to-man" mode. Visitors started to have two-way interaction with devices, and they could select information they need. That is, the devices provided "passive customized services". With the breakthrough of file compression format and wireless networking technology, digitalized exhibition information can be stored in remote server. The devices visitors actually hold or approached are getting smaller and smaller. Currently, every major computer companies devoted to develop gesture controlling technology, which made the characteristic of guidance system shift from "visible", "hold" to "invisible", "enclose". And referring to the development of content recommendation technology, it also changed from "passive" selection to "active" recommendation in accordance with each visitor's characteristics. The narrators started from the "natural person" have evolved into the "artificial intelligence" or "digital virtual human" as well, forming a new service type of "machine to be people".

In order to fulfill various people's demands, the service types and providing method of museums have become diversified. Besides facing competitions from the same profession, the rapid development of other leisure services industry also make museum must find ways to provide more diversified and adaptive services to attract visitors. Under the influence of experiential economy, the experiential marketing strategy introduced into design of museum exhibition will be an inevitable trend. This study conducts experiential design theory to innovate museum guidance mode, of which three core concepts are proposed as follows:

1. Customization: providing proactive customized virtual guides to arouse visitors' self-motivations to learn.
2. Adaptability: recommending personal adaptive guidance content, and strengthening the visitors' self-learning effects.
3. Interaction: creating a unique visit experience through interaction with the exhibition information.

According to the aforementioned design concept, this study takes "Augmented-reality Teller (ArT)" for museum guidance system as an example to descript the "proactively customized and recommended displaying content" innovative experience model of "artificial intelligence people" and "invisible encircling".

2 The Evolution and Current Status Analysis of Museum Guidance System

Nowadays, museum guiding types can be simply divided into "digitalized guidance" and "mobile guidance". Digitalized guidance is scenario-oriented learning model, presenting guidance service information on displaying entities with word, pictures, audio and other multimedia. Mobile guidance is provided by the auxiliary devices, such as personal digital secretary (PDA), Pocket PC (Pocket PC), headphones, label sensors; it downloads information of displayed items through the wireless network, which are not subject to space and time limit for on-demand viewing display information. In 2009, Ron Wakkary et al. developed the hybrid guidance system between the two. This device consisted a tabletop display (touchable monitor table), which can be provided for many people, and multiple sets of personal mobile guidance devices. The guidance system considers small group as their services target (Group Museum Guide), for instance, family. They can use the tabletop display to inquire information of exhibitions, processing social interaction through mobile guidance devices, and getting involved in experiential learning. In comparison with personal guidance, group museum guidance can let the visitors in the same group communicate mutually and share what content they heard, or leading other group members by one of them.

Table 1. Context layer, construct the principle of interactive experience and the key factors influencing learning effect

Context	Principle of interactive experience	Key factors
Personal Context	(1) Each visitor may use different way to learn, according to past knowledge, experience, and believe, interpretation information gaining from the museum. (2) All the visitors use their personal views to interpret museum's information in order to match their own knowledge and experience. (3) Every museum visitor has their plan on the visiting journey and is full of expectation.	(1) Motivation and Expectations (2) Prior knowledge, interests, and beliefs (3) Choice and control
Socio-cultural Context	(4) Most visitors won't go museum alone, and they usually follow a certain social group. What they see, do, and remember is all influenced by other members in the group. (5) The visitors' experience in museum includes narrators, security guards, sellers, and other visitors.	(4)Within-group socio-cultural mediation (5) Facilitated mediation by others
Physical Context	(6) The reasons why visitors are attracted to museum are that they think there are some unusual things they cannot see in daily life, therefore visitors "see" respectively in the museum in their own way. (7) Visitors are impacted strongly by museum, including architecture, atmosphere, flavor, sound, and the "feeling" toward this place. (8) Visitors can only pick a little part in numerous experiences (9) Visitors' attentions are strongly influenced by where they are and the design of museum circulation.	(6) Advance organizers and orientation (7) Design (8)Reinforcing events and experiences outside the museum

"Robot Guidance" is another branch of extension development. In addition to providing multimedia visiting information, there are some advantages of “mobile guidance” to break the space constraints. The research focus in recent years emphasizes on making the robot life-like (humanoid) (D. Matsui et al., 2005). With the evolution of guidance types, a variety of technical methods have emerged, for examples, the so called RFID (Radio Frequency Identification), facial recognition system, and GUI (Graphical User Interface). Users can utilize the “Tangible user interface (TUI)" and “Embodied Interaction" which make entities and digital information interacting, and

"Augmented Reality (AR)" technology which integrates the virtual items into the scene of life, to let them observe displaying items with more intuitions, interact with exhibitions, and create both virtual and physical experiences.

Falk & Dierking (1992) modeled interactive experience (The Interactive Experience Model) as a framework, collated the relative museum visit researches, and analyzed three contexts of visitors (Personal Context, Socio-cultural Context, and Physical Context). This framework rendered the interaction between contexts as the abstraction concept to present museum experiences and it also proposed 9 principles of exhibition experience structure and 8 key factors influencing the effect of museum learning. (Table 1)

The museum visiting experience is an interactive result between "ideal experience" (hope and expectation) and "real experience" (the actual event). The definition of experience is "when a person attains a certain level of emotion, intellect, and even the spirit, the good feeling arises from his consciousness. The essence of experience is individual, it's impossible for any two people to have the same experience (Pine & Gilmore, 1999)". Pine & Gilmore (1999) divided experience into two orientations including the level of participation (active participation and passive participation) and contact (absorption and immersion), which then formed four quadrants, that is, four types of experience: education, entertainment, aesthetic, and escapism. The richest experience will include all the four types, and they pointed out the main procedure of creating experience: setting the theme, building stories, deep impressions, and influencing behavior.

After comparing visitors' experience types and the current state of guidance system, this study found out that experience should include all the visiting process, however, recent system usually focus on "during visit". As a result, the museum guidance system must extend from a single individual to a system and cover the service range to "pre-visit" and "post-visit". In addition to extend the scope of services, this study emphasizes on the depth of experience and learning in each stage as well. Therefore, this study investigates every developable innovative chance in each stage separately from the viewpoint of personal, socio-cultural, and physical contexts. (Figure 1.)

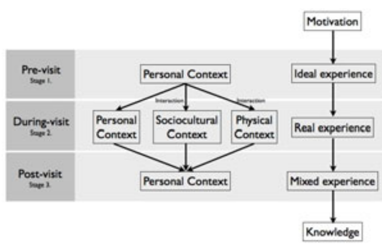

Fig. 1. Developable innovative point in each visiting stage

Referring to personal context, traditional guidance system cannot raise expectation before visitation. The past "ideal experience" construction model is based on a variety of propaganda profiles, websites, blogs, and other sharing channels. Museums did not arouse visiting motivation actively. It depends on whether visitors are interested in exhibition. The educational role museum plays should try to "turning extrinsic motivation into intrinsic motivation (Chang, 1996)", and think how to make the image of "ideal experience" guidance as the key point through the design of guidance system.

In terms of personal and socio-cultural context, services provided by digitalized guidance and mobile guidance are "Man-to-machine" interactive platform, not "Man-to-Man". As a result, "Machine anthropomorphic" concept should be able to make up for this deficiency. As for personal and physical contexts, current guidance system provides "passive" customization than "active". The so called passive customization is that visitors must clarify what they want to see. However, they won't spend too much time to think what they want in a constrained time. The objective of active customization is that systems can previously have certain understanding toward visitors in accordance of visitors' backgrounds. When visitors enjoy in the situation and would like to explore for more knowledge, systems can actively provide adaptable displaying information or passively furnish any other information in accordance to visitors' needs for intensifying "real experience". Moreover, exhibits and guidance system are often considered as individual identities. Exhibition has its theme, so experience should also be themed. For the security reasons of exhibits preservation, exhibits are usually covered with transparent glass. Out of curiosity, many children like to touch glass with hands and forehead to make them closer. Taking this behavior into consideration, suppose transparent glasses are the interaction interface between visitors and exhibits, in addition to achieve the function of preserving, it also helps to activate these cold exhibits. Therefore, design of guidance system should break the barrier, and create a unique experience for the entire visiting process by a variety of sensory stimulations.

3 The Museum Displaying Content Recommendation and Guidance System

Starting from users' demands or wants, then basing on the three contexts of experience models, nine principles, and eight key factors to expand innovative planning provides the experiential content framework and program to establish museum displaying content recommendation and guidance system - Augmented-reality Teller (briefly as "ArT" hereinafter). This study takes museum as the field and sets violin as the target to develop detail design. In accordance with the needs of administer system management, it points out the system framework and technological integration method. The exhibition space could be simply divided into three parts, showroom, exhibition area, and exhibition unit. In this study, exhibition unit would be introduced as the main target to illustrate the significant innovative content of ArT system.

ArT system consists mainly of three human-machine systems, four databases and three core technologies (Figure 2). Among the three main systems, user side (User) consists of ticket-taking system, character-making system, and displaying windows. It's a platform directly contact with visitors. And management side (Server) mainly includes demographic data, lifestyle data, personal narrator database, exhibits database, and story database. These four databases are joined through three core technologies and three main systems, including face recognition, speech recognition and synthesis technology, as well as the content recommended techniques.

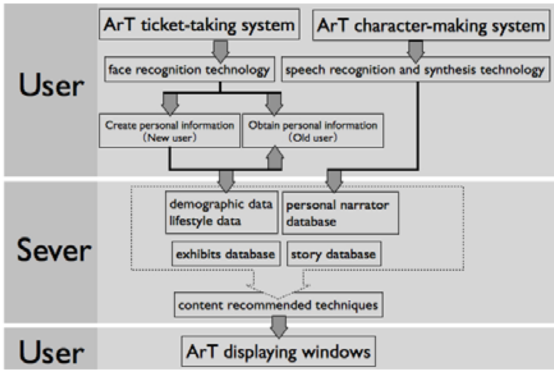

Fig. 2. Framework of ArT system

3.1 Ticket-Taking System

Visitors are allowed to enter the exhibition area by the RFID label tickets which can recognize their identity. In order to provide personal guidance, information, and adaptable services, visitors can operate ticket-taking devices to make system recognize them. This device has convenience, flexibility, and it is equipped with hidden physical IT apparatus. Besides, it's also introduced the concept of universal design to meet different groups' requirements (such as wheelchair users and children). The system utilizes face recognition technology and connects it to demographic database for comparison to see whether it is the initial visit or revisit. Suppose it's the revisit, system will access data comparison with visitors' current and previous appearance, so that it will adjust greetings statement to make visitors surprising and feel friendly. Otherwise, suppose it's the initial visit, visitors will be asked to fill out the demographic and lifestyle questionnaires to let system get familiar with them. The complete data could be obtained gradually through the interaction in visiting. When visitors are completing questionnaires, the system default virtual narrator will have interactive conversation with them, and system will recommend virtual narrators to accompany visitors for visiting as well.

After finishing questionnaires, visitors can choose exhibits which they are interested in. The ticket-taking system will automatically recommend other five exhibits to constitute a series of display units. Or, the system built-in recommendation platform will plan appropriate visiting schedules.

3.2 Character-making System

Visitors can select whether to adopt the recommended narrator or make other choice. Making visitors create their favorite narrators is believed to enhance their learning motivation. There are three main categories for visitors to choose, including "Top ten popular tellers in this week", "Favorite movie stars", "Building personal characters". The former two are voted by visitors and chosen by system as representative characters in accordance with the result of lifestyle questionnaires. And the third is to use the photo shoot taken in that day to create a virtual narrator which make the visitor oneself as a protagonist. In addition, visitors can choose their favorite narrator's voice. System uses synthesis and recognition technology to remix, or it could convert the character database's text content into different voices.

3.3 Displaying Window System

With the appropriate displaying contents and entertainment interaction interface provided on the recommended technology platform, visitors can obtain the "interactive" services through this interface. There are sensor devices on the displaying windows, which can sense visitors around and start to guide served by the exclusive narrators they picked. This system makes use of augmented reality technology to display both physical exhibits and virtual information images on the user site in the same time. The transparent touchable panel in front of the exhibit in the displaying window can offer different auditory and visual feedbacks to have visitors interact with exhibits based on visitors' and exhibits' characteristics. It not only achieves the effect of edutainment but also enhance visitors' experience in innovative way. ArT system recommends based on visitors' lifestyle characteristics. In comparison with the traditional recommendation system of related principle, ArT system can effectively improve the insufficiency of databases, low effectiveness when new exhibit items are added, and offer users displaying content information that are more closer to their preference.

Taking violin as the example to interpret visiting experiential model: when the displaying window senses that there are visitors coming, the preselected and exclusive narrator then appear. This virtual narrator will introduce relative background stories to them and test visitors whether they absorb information or not at times, also, inquire for their opinions. Visitors can interact with virtual narrators through touch panels, and even more they can "remote touch" the violin. When touching certain violin's string, it will sound corresponding to that string. And when someone touch violin's waist, virtual narrators will humorously responded: "wrong touching, it's itching!" Also, visitors can enlarge the virtual violin on the touch panel to see the detail. Besides the themed information provided by virtual narrators, visitors are able to select the information they want. And the offerings of extended information are based on visitors' lifestyle background. After appreciating these exhibits, the displaying window interface will hint visitors the direction toward next exhibit, so that it will delight visitors and keep them watching the exhibition.

4 Test and Assessment

The ArT system proceeded to test after completing establishment. There were 10 testers with various design backgrounds (5 in industrial design, 2 in information management, 2 in engineering science and technology, 1 in visual design) invited to practically operate these three subsystems and give qualitative opinions for improvement. After improving the design, another 197 subjects were invited to test the displaying window recommendation system, comparing whether the lifestyle recommendation system are different from traditional one. The obtained analysis data abstract are listed below: The qualitative opinions are mainly the three:

1. The ticket-taking system: Some testers pointed that the items of lifestyle questionnaire are too much, so that the respondents may lose their patience. In the planning considerations, these questionnaire items can be separated in different exhibits to reduce the bad feeling which is aroused from too much items. Nevertheless, constraining to a single exhibit is hard to provide desired ideal experience.
2. The character-making system: Some testers mentioned that it really interested them to use. Almost all of them agreed on establishment of exclusive narrators.
3. The displaying window systems: Many testers indicated that the personal narrators indeed offered the exhibition information that is much more in line with their preference. However, this system can only serve one visitor at one time; other onlookers must wait in patience, so they may lose their interest. And some testers also indicated that the public way may interrupt other visitors, therefore they suggested that it could be considered to install headphones.

In terms of the performance of recommendation system, the effects and satisfaction between lifestyle recommendation and tradition recommendation by "Recommendation Performance Evaluation Index" and “The Museum Guidance Index” were compared. The former adopted “Maximum Average Error” to analyze gaps between recommendation system’s forecast and the degree of consumers’ adoptability. The smaller the gap is represents the more accurate recommendation systems predict. The latter adopted Bitgood's(1988) principle of evaluation of museum exhibition to measure whether this exhibition is good or not. The main indicators and methods are below:

1. Attraction: using recommendation rating score to analyze whether different recommendation method have difference on the degree of visitors’ adoptability. The higher the rating score, the more attractive this recommendation system is.
2. Sustainability: Analyzing the time a tester focuses on the exhibit can effectively evaluate whether the information provided by recommendation system interests visitors.
3. Simulating power: Using “actively learning motivation” satisfaction survey data to investigate whether different recommendation system have simulating power on visitors or not. Expecting that visitors will be more willing to actively know exhibits and dig for more knowledge.
4. Satisfaction: Investigating tester’s degree of adopting on recommendation by “recommendation satisfaction”.
5. Revisiting ratio: the degree that users are willing to use recommendation system again.

The investigating result showed that, in “Recommendation Performance Evaluation Index ", lifestyle recommendation is truly better than traditional one. “The Museum Guidance Indexes” of attraction, sustainability, and satisfaction are all superior to past recommendation system’s effect, but there are no significant differences in simulating power and revisiting ratio. Finally, based on preliminary test results, the visiting experience mode could be concluded (Figure 7). The design of the ArT System in accordance with three main concepts (customization, adaptability, and interaction) can

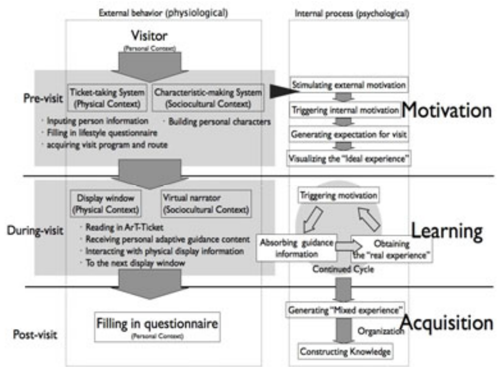

Fig. 7. The visiting experiential mode of ArT system

interpret the "Actively Customized Recommendation System" innovative experience mode of "artificial intelligence people" and "invisible encircling".

5 Conclusion and Suggestion

The future development trend is from "customization" to "community". In addition to offer personal services, there should be interactive mechanism during visiting. This study adopts the point of view of Humanity and Social Science, and also it is learning-oriented. Through the established and demonstration of "Virtual Guidance System", visitors are able to learn by themselves, self-explore, and put museum's educational objective into practice. That is, helping visitors convert "experience" into "knowledge".

"Recommendation Performance evaluation index" showed that, the effect of adoptability displaying content recommendation by lifestyle pattern is better than the pattern of traditional recommendation system. And "The museum guidance index" indicated that lifestyle recommendation system has a better performance in the dimensions of attraction, sustainability and satisfaction, but there are no significant differences in the dimensions of simulating power and revisiting ratio.

Despite the installed displaying window cannot serve many people at one time, it offers tranquil and quality aesthetic experience for individual visitor. Nevertheless, in terms of the trend guidance system develops, when it comes to the importance of sharing with others during the visiting tour, ArT system might be slightly weak in socio-cultural context. It could refer to hybrid system pattern to accommodate both individual and group visitors in near future.

The personal narrators can improve visitors' self-learning motivation. However, the "ideal experiences" arouse before visiting museums are influenced by exhibition propaganda, Internet-based media or other factors. Future research could make more effort on it.

Most of the testers are satisfied with the entire performance of system. How to expand system's services to post-visit so that completing the visiting experience, and how to be further supported by technology, organize experience effectively, then construct knowledge, is a field awaiting to be explored for the follow-up research.

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General Factors That Elicit Human Affect across Countries

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Abstract. People's needs for products that provide *affective experience* have kept growing. Some previous researches have investigated the relationship between product design parameter and human affect, while others concerned about how to design affect-eliciting products. But there is still few researches clearly clarifying the essential elements that may evoke human affects. The purpose of this paper was to find the general factors contributing to the generation of human affects across countries. People's narrative descriptions about things or experiences that elicited their affects were collected and compared to the elements extracted in the previous research to distill general elements across countries. To validate the elements extracted, a questionnaire-based investigation was then conducted in seven regions in the world. As a result, six general factors were derived from elements extracted using factor analysis and named as *affective factors*. The relationships between affect factors and affects were also validated using correlation analysis.

Keywords: affect, design, experience, product, reflection.

1 Introduction

In the last century, both academics and industries made great efforts to improve product functionality, quality and usability. As a result, nowadays, high-reliability and user-friendly products have become common in people's daily life. On the other hand, as those features have been widely recognized as "must-have" product attributes, it becomes more and more difficult to delight users than ever before. To find a breakthrough in this situation has been deemed as a high-priority issue recently.

Providing customers with *affective experience* has been considered as a solution in various research fields. The term *affective* used here was defined as "being capable to evoke affects in people's minds" or "being capable to deliberate affects to be evoked in people's minds" [1]. The origin of *affective* is *affect*, which has been widely used in the field of psychology representing human's emotions, moods and feelings. In the field of human factors, Norman argued that users' emotion should be considered when designing products [2]. Similarly, Jordan proposed his theory about four pleasures evoked by products [3]. Besides, to create superior customer experience has been considered as one of the central objectives in today's marketing environment. Recognizing the economic

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value brought by providing customers with distinctive experience [4], concepts and frameworks have been proposed to detect the formation of such experiences [5].

Though studies on how to provide customers with affective experience have been conducted from both theoretical and practical perspectives, there are still few studies that clarify what elements of the products may have the potential to evoke human's affects. In other words, what are the elements contributing to the generation of human affects has been left ambiguous.

The purpose of this research was to distill general factors across countries. In the previous research, attempt has already been made to extract factors that elicit human affects among Japanese and Chinese [6]. The same methodology was also applied in this research to extract elements and factors that have the potential to evoke human affects. However, in this research, data were collected from seven different regions with different cultural types, while in the previous research participants came only from two countries. More narrative descriptions about things or experiences that elicited or may elicit people's affects were also collected and compared with that collected in the previous research. Data collected in seven regions in the world were then analyzed to validate the general factors extracted. The result of this research is supposed to give useful information on how to elicit human affects for designers of value-added products and services.

2 Extraction of Affective Elements

To extract general elements contributing to the generation of human affects across countries, more narrative descriptions about things and experiences that elicit people's affect were collected and analyzed. The investigation was conducted both in the form of questionnaire and interview. Japanese, Chinese, Korean and Thai undergraduate and graduate students participated in the investigation.

During the investigation, participants were firstly given the explanation of the concepts of *affect* and *affective*. Then they were required to write down their answers to two questions in free-response form. The first question was (1) "Please raise things (either tangible or intangible) that give you any (either positive or negative) affects". The second question was (2) "What kind of affect did these things give you and why?".

After manually checking all the data, keywords that best represented the reasons why something was regarded as "affective" were selected and keywords with similar semantic meanings were grouped together and labeled. These keywords were referred

Table 1. Examples of Affective Elements Extracted

Functionality	Good atmosphere or environmental condition
New high-techs	Thoughtful and deliberate person or behavior
Quality	Sports
Easy to use	Keeping learning or making effort
Satisfying physiological needs	Achievement, success, reward of effort
Natural scenery	Feeling of belonging and acceptance
Comfortable sound, taste, smell and touch	Taking a breath from everyday routine
….	….

to as *affective elements*. The same methodology was also adopted in the previous research [6]. Result obtained in this research was compared with that obtained in the previous research. It was found the 43 affective elements extracted in previous research could cover all the elements extracted in this research. As a result, the 43 keywords were considered as universal elements across countries. The examples of affective elements are shown in Table 1.

3 Extraction of Affective Factors

To confirm that affective elements extracted actually have the potential to evoke affects, a questionnaire survey was administered. Fort-eight participants from China (aged between 20 and 30, *M* = 23.81, *SD* = 2.69), 20 from Germany (aged between 18 and 82, *M* = 27.00, *SD* = 13.15), 17 from Italy (aged between 20 and 34, *M* = 23.47, *SD* = 3.89), 36 from Japan (aged between 21 and 45, *M* = 23.61, *SD* = 3.97), 27 from Korean (aged between 19 and 33, *M* = 25.11, *SD* = 3.26), 20 from Taiwan (aged between 16 and 25, *M* = 19.05, *SD* = 3.02) and 26 from Thailand (aged between 17 and 29, *M* = 22.92, *SD* = 3.37), in total 184 participants, participated in this questionnaire-based investigation. Male participants accounted for 53.33% of all participants.

The questionnaire used in our previous research [6] was also utilized in this study. Fourteen pictures (in some cases, picture with a short paragraph of statement) were used as experiment stimuli to elicit participants' affects. Participants were required to have a look at each of the stimulus picture and read the statement (if there is) and then answer the questionnaires corresponding to the stimulus.

The first section of the questionnaire consisted 55 items designed based on 43 affective elements extracted. For elements that have polarities, such like quality (good quality and poor quality), both sides were employed as items. Participants were asked to rate to what extent each affective element matched the stimulus.

The second section of the questionnaire examined the participants' affects elicited by each stimulus. The two primary dimensions of human affects known as valence and arousal were used to measure affect elicited by stimulus.

A factor analysis was then conducted to explore the factor structure of participants' responses for the 55 questionnaire items. Principal component method and varimax rotation were employed. The numbers of factors extracted was determined by the eigenvalues before rotation. Only factors with eigenvalues greater than 1.0 were accepted. As a result, six general factors were distilled: "social connection", "product satisfaction", "poor design and style", "creativity and challenge", "risky and unpleasant" and "ethic and moral". The extracted factors were named as *affective factors*. The cumulative contribution for the six factors was 46.80%.

4 Validation of Affective Factors

To validate the affective factors, correlation analysis was conduct to examine the relationships between affect variables and affective factor scores. Table 2 shows the relationships between affective factor scores and affect variables. It was observed that all the factors showed significant correlations with at least two affect variables at the 1% significant level.

Table 2. Correlations between Affect Variables and Factor Scores of Affective Factors

	Fac. 1 Social Connection	Fac. 2 Product Satisfaction	Fac. 3 Poor style and design
Positive	0.505**	0.235**	-0.165**
Negative	-0.193**	-0.178	0.312**
Strong	0.238**	0.032	0.028
Calm	0.432**	0.074**	0.014
	Fac. 4 Creativity and challenge	**Fac. 5 Risky and unpleasant**	**Fac. 6 Ethic and Moral**
Positive	0.128**	-0.231**	0.063**
Negative	-0.055**	0.458**	0.118**
Strong	0.152**	0.284**	0.098**
Calm	-0.057**	-0.136**	0.094**

** $p < .01$.

5 Discussion

The purpose of study was to extract and validate the general factors that contribute to the generation of human affects across countries. Forty-three elements that have the potential to evoke human affects were distilled. To validate the elements extracted, a questionnaire-based investigation was conducted in seven regions in the world. A six-factor structure was obtained based on participants' responses to affective elements. The relationship between the affective factors and human affect was also verified.

The general affective factors and elements proposed in this paper offer advice on how to elicit human affects more effectively, which is supposed to serve as references during product design process. New affective features such as "social connection" can be added to products to create added value. Details on how to add such features can also be interpreted as the affective elements distilled.

The result obtained in this research is different from that acquired in the previous research we conducted [6]. As a result, difference was observed in the factor structures. In this research, a six-factorial structure was attained, while in the previous research, an eight-factorial structure was obtained. The "healing and relax" and "physical and active" factors were not observed in this research.

In future, it is necessary to conduct further intercultural comparisons to clarify cultural influences on affective factors and elements. It is also important to develop a practical methodology to fully utilize the result of this study.

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Affective Technology through Affective Management

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Abstract. For the organizations that create technological products and services that provide users with affective experiences, viewpoints to deliberate affects of stakeholders are necessary in their management. Management that emphasizes its potential influences on affective experiences of stakeholders can be called as affective management. This paper argues the concepts, importance, and possible approaches of affective management.

Keywords: affect, affective technology, affective service, management, stakeholder, customers, employee.

1 Introduction

In the last century, significant efforts of human factors and human computer interaction communities have been devoted to quest for usability [1][2]. As the results of their cumulative efforts to enhance usability, most of the products and services that can be seen in markets today have high usability. Usability is now considered as one of the attributes that every product or service must have. Thus it is said that usability alone no longer makes a product or a service attractive and distinguishable from other competitors any more [3].

Among various efforts to seek for the new characteristics beyond usability that may attracts the users, some researchers and practitioners have focused on the importance of providing the users with affective or emotional experiences [4][5][6]. Umemuro [7] named technological products and services that provide users with affective experiences as *affective technology*.

When a company wishes to create and produce such affective technology, the company should have deep insights as well as emphasis on the affective experiences of customers. Marketers must be sensitive for what kind of affective experiences customers demand (consciously or unconsciously) and bring that information back to the company. Designers should be familiar with various ways to realize wanted affective experiences and be capable to implement them in actual design. Acquisition people are responsible for acquiring materials with sufficient quality, and production division should be able to produce the products with intended function and quality. Sales and delivery has to deliver the products and services with the best experiences they can provide to customers.

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However, even if the company has potential to design, produce, and deliver such products and services, affective technologies might not be realized and appear in the market unless the management of the company realizes and appreciate their values. In general, affective values are not easy to be converted to economic values. Thus if the management cannot evaluate affective values of products and services appropriately, it is quite possible that the management may make decision to sacrifice such added values for the purpose of cost reduction.

In this paper, such management that appreciates values of affective experiences of stakeholders will be referred to as *affective management*. This paper argues the definition, significance, and possible approaches of affective management to realize affective technologies.

2 Affective Management

Affective management can be defined as management of an organization that takes into considerations the potential influences of its decision-making onto stakeholders' affects or affective experiences [7]. In other words, affective management should recognize potential factors that might influence on people's affect, assess the possible impacts, and deliberate them as well as the conventional quantitative standards in decision-making.

The concept of affective management is not that all decision-making should be done solely based on affective aspects; it does not mean to neglect or to think little of conventional rational and objective standards. The idea is to emphasize possible influence on affects of stakeholders just equally as rational aspects.

Affective management is not an issue only for top management. As discussed in the previous section, in order to provide affective technology products or services, various divisions throughout the organization have to play their own roles. This idea is common with total quality management (TQM) concept, which claims the involvement of whole organization is important for effective management of product quality. In order for the whole organization to be fully effective to realize affective experiences through technological products and services, the concept of emphasizing affective experiences of stakeholders should be penetrated throughout the organization.

Affective management is not a very new idea. Throughout the history, excellent managements have known what affective effects of their decisions and behaviors might have on whom, and whether they should dare to do them or not, mostly based on their sensibility and experiences. However, this skill has mostly been considered as implicit knowledge of excellent managements, and have not been explicitly claimed or organized.

When the idea of affective management is widely shared as an important concept for management, throughout organizations and across the industries, *affectiveness*, or to what extent the management is capable to deliberate the affective influence on stakeholders, may become one of the important measures to evaluate the quality of management, or the organization as a whole.

3 Whose Affects Should We Care About?

What management has to consider when making decision is not limited to affects of customers. Fig. 1 illustrates possible affects that stakeholders may have on and around a company. For all stakeholders including shareholders, employees, business partners, and society, managements need to consider what impacts on affects their managerial decisions may give, what affective experience they should provide with, and what priority they should give to these issues comparing with other criteria.

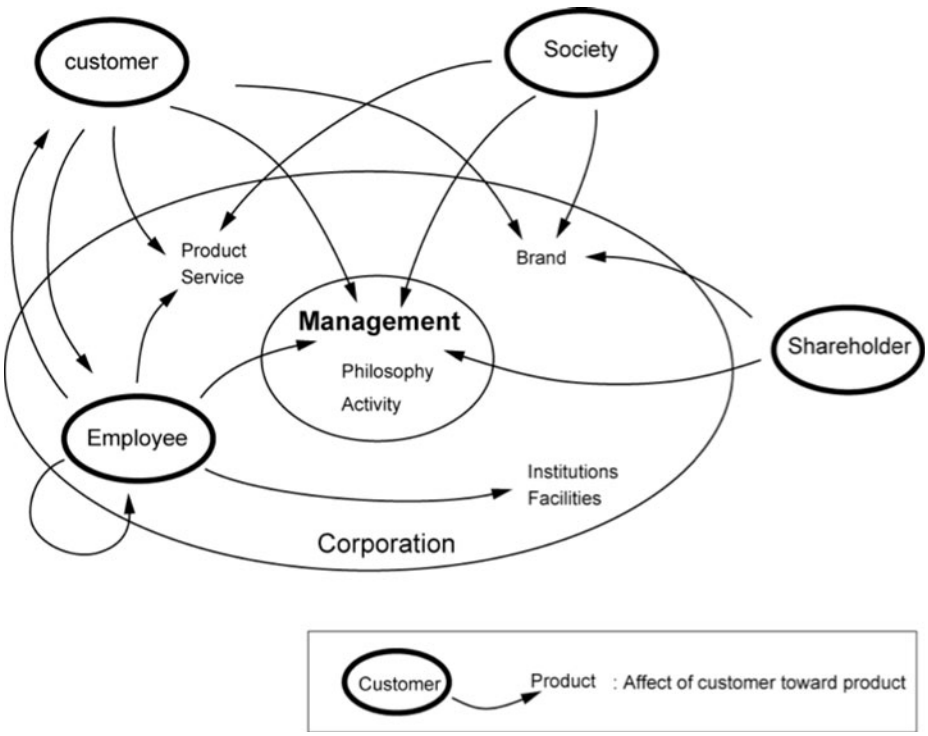

Fig. 1. Various affects that stakeholders of a corporation might have on its management, assets, and activities

Potential affects in various situations in Fig. 1 suggests that, in other words, management has a number of opportunities to effectively provide many of stakeholders with affective experiences through various approaches. Table 1 shows examples of possible approaches for affective experiences of stakeholders. Table 1 is based on the discussion sessions with our colleagues and thus it is not definitive. However, it is noteworthy that management has, and actually should take advantage of, various channels the can approach stakeholders.

Table 1. Possible opportunities for managements to approach affective experiences of stakeholders

	Customer	Shareholder	Society	Employee
Product / service	X	X	X	X
Price	X		X	
Brand management	X	X	X	X
Marketing	X		X	
Customer communication	X			
Publication / CSR	X	X	X	X
Management philosophy, direction, strategy	X	X	X	X
Management performance		X		X
Dividend policy / stock option		X		X
Business process	X			X
Organizational design		X		X
Team / project management				X
Personnel / HRM		X	X	X
Training / human capital development				X
Employee healthcare				X
Welfare				X
Wedge				X
Equipment / Facility / Site	X	X	X	X
Office design				X

4 What Makes Technology Affective?

As mentioned above, in order to provide customers with affective experiences through technology, knowing what affective experiences customers really want, knowing possible ways to provide such affective experiences through products and services, and being capable to design technological implementations are essential capabilities needed for the organization. Sales and marketing divisions are responsible for effective communications with current and potential customers to probe what they want. Especially for affective features, people are very often unconscious about what they really wish. Thus high skills to probe possible customers' affective experiences as well as deep insights into human characteristics of affects should be required.

In order to design technologies that provide affective experiences, designers have to be familiar with the factors that have potential to elicit affects on users. Most of the design efforts have focused on aesthetics and quality of materials, as well as usability and functionality. However, some researchers have emphasized the importance of high revels of mental processes [5][8], that may lead to high level of pleasure, or *eudaimonic* well-being. This viewpoint is especially important when considering the long-term experiences with technology for years, not only for the moment of purchase. Designers should be familiar with what factors may lead to such high levels of affective experiences, in addition to conventional aesthetics and usability factors. There have been some efforts to find out such general factors [9], though further investigation should be necessary to reveal a big picture of such universal as well as culture-dependent factors for affective experiences.

5 Affective Organization

Besides customer, another important stakeholder whom management should take care of in terms of affective experience might be employee. In order to practice the organization's philosophy, principles, and strategies of affective management, these concepts should be shared throughout the organization. Furthermore, if management wishes to take best advantage of employees, their motivations and satisfaction are also important issues.

Conventional concepts of productivity in workplace have been based on rational and objective measures of output per unit time. It started from motion study practices in factory lines, and still remains even in office work environment as amount of output per unit time. On the other hand, issues such as workplace climate or atmosphere have generally got little attention.

Recently, however, there have been a number of scientific evidences suggesting that affective factors in workplaces have significant influences on productivity and creativity (e.g. [10], [11]). There are also psychological evidences that affect have impact on cognitive information processing and creativity. Thus affective climate in workplace is attracting more importance as evaluation criteria of workplaces, in addition to conventional efficiency and productivity measures.

In workplace context, "good" climate does not necessarily mean simple joy and coziness. Office full of instant joy may provide workers with happiness, but they may not produce much output. On the other hand, in office environment with high motivation, sense of support, respect, and self-actualization, workers may feel higher level of satisfaction. According to Norman [5], environment with appropriate level of stress may be better for productivity, while calm and relaxed environment is essential for creativity. Managers may be required to dynamically maintain appropriate environment, culture, and climate according to the types of tasks his/her team is doing now.

6 Challenges

In order to practice the concept of affective management, it is essential to have means to evaluate its effectiveness. Especially, when one wants to make decisions considering affective aspects along with other rational and objective aspects, numerical measures of affectiveness, or significance of emphasizing affective aspects, should help comparing and balancing among the factors to be considered. In practice, however, it is not always easy to convert affectiveness into numerical measures such as economic values.

There have been some efforts to propose evaluation method of the affectiveness of products or services. Nagao [12] proposed a checklist method to evaluate to what extent services or products are providing affective experiences from the viewpoint of Japanese traditional hospitality *omotenashi*. However, what the checklist measured is limited to the affective experience of customers only, and intention of management behind the products and services are still left unrevealed. In order to validate the effectiveness of affective management, it is urgently needed to research and develop quantitative measurements to evaluate affectiveness of management.

As discussed in section 3, management may have a number of opportunities and means to approach better affective experiences of stakeholders. Effectiveness of opportunities and methods are not yet well investigated. Comparative studies on effectiveness of various opportunities and approaches for affective management should also be conducted.

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Do Hedonic and Eudaimonic Well-Being of Online Shopping Come from Daily Life Experience?

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Abstract. The present article examined whether people's experience of hedonic well-being and eudaimonic well-being in online shopping has been connected with their feeling in real life shopping activity. A questionnaire was used to assess hedonic and eudaimonic well-being of participants in online shopping and in its real life corresponding activity. The results indicated that there were two different types of participants along with their perceived usefulness towards online shopping. For those, who believed online shopping is more useful, well-being in online shopping and real life shopping were positively correlated. On the other hand, for people who considered real life shopping is more useful, well-being of online shopping and real life shopping were negatively correlated.

Keywords: well-being; hedonic well-being; eudaimonic well-being; shopping; online shopping.

1 Introduction

Some researchers suggest that in social activity, computers are unlikely to reduce people's isolation by themselves but rather will act as an additional tool for those with existing social networks to stay in touch with them [1]. Similarly, computer and the Internet should also affect on people's other daily life activities in the same way. In this research, we are going to answer the question whether people's online shopping experience, especially in positive aspect, comes from ones' real life shopping experience.

Well-being research is focused on positive psychological functioning and positive subjective experience, emerged in 90's last century [2]. A significant number of studies of well-being have been thought to be falling into two traditions [3]. One is hedonic well-being, and the other is eudaimonic well-being. Hedonic well-being is defined as the presence of positive affect and the absence of negative affect, while eudaimonic well-being is focuses on living life in a full and deeply satisfying way [4].

The purpose of this study was to investigate the relationships among hedonic well-being, eudaimonic well-being in real life shopping and online shopping, aiming to clarify the connection of well-being between the Internet activity and its daily life counterpart. Then, the differences in hedonic well-being and eudaimonic well-being

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in online shopping were also examined, for probing the distinct characteristics of two types well-being constructs.

2 Methods

2.1 Participants

Eighty-four Japanese adults aged between 61 and 86 years (M =73.0, SD=5.3) participated voluntarily in this study. Of the 84 participants, 45 were male and 39 were female. Participants applied to participate in this study in our subject pool in response to advertisements on regional newspapers.

2.2 Measurements

The questionnaires used in this study to investigate hedonic well-being and eudaimonic well-being were adapted from those developed by Waterman [5]. The Personally Expressive Activities Questionnaire (PEAQ) was constructed aiming to investigate the hedonic well-being and eudaimonic well-being in activity level, which would identify the convergent and divergent aspects of these constructs. According to the purpose of this study, the statement of each item was changed from positive to neutral, because this study focused on the degree to which participants could feel hedonic well-being and eudaimonic well-being. Participants responded to each item by a seven-point Likert scale between 1 (strongly disagree) and 7 (strongly agree). The Cronbach's alpha reliability of hedonic well-being in shopping and online were .97and .97, while the Cronbach's alpha of eudaimonic well-being were .93 and .95, respectably.

Participants' perceived usefulness was measured by perceived usefulness scales, developed by Davis [6]. Participants responded to this 6-item scale by a seven-point Likert scale between 1 (strongly disagree) and 7 (strongly agree). In this study, the Cronbach's alpha of perceived usefulness in shopping and in online shopping were .91and .95, respectably.

3 Results

3.1 Gender Differences

When asked to indicate to what extent they feel hedonic well-being in their real life shopping, females (M = 5.59, SD = 1.08) on average rated their hedonic well-being significantly higher than males (M = 4.76, SD = 1.06; t(df = 78) = -3.46, p=.001). When respondents were asked to rate their eudaimonic well-being in their real life activity, females also rated significantly higher than males (female: M = 4.77, SD = 1.04; male: M = 4.12, SD = 1.00, t(df = 78) = -2.86, p=.005).

3.2 Well-Being between Real Life Shopping and Online Shopping

To investigate the relationships of hedonic well-being and eudaimonic well-being between shopping and online shopping, the Pearson's correlation coefficients were

Table 1. Correlation among hedonic well-being, eudaimonic well-being in shopping and online shopping (n = 38)

	Shopping HWB	Shopping EWB	Online shopping HWB	Online shopping EWB
Shopping EWB	.78**	-		
Online shopping HWB	.10	.25	-	
Online shopping EWB	.03	.22	.83**	-

Note: HWB = hedonic well-being; EWB = eudaimonic well-being;
**p < .01.

calculated and reported in Table 1. Hedonic well-being and eudaimonic well-being were significantly correlated separately in shopping and online shopping. Meanwhile, there were no significant correlations of hedonic well-being between shopping and online shopping, as well as eudaimonic well-being between shopping and online shopping.

Then, participants were divided into two groups according to their perceived usefulness towards shopping and online shopping. The first group was defined as the participants who consider that online shopping is more useful than shopping in real life, and will be referred to as the Useful group (n=19); the other group was defined as the participants who preferred shopping in real life being more useful than online shopping, they will be referred to as the Useless group (n=19). Pearson's correlation coefficients were calculated again and reported in Table 2.

Table 2. Correlation among hedonic well-being, eudaimonic well-being in shopping and online shopping in(n = 38)

		Shopping HWB	Shopping EWB	Online shopping HWB	Online shopping EWB
Useful Group (n=19)	Shopping EWB	.77**	-		
	Online shopping HWB	.54*	.76**	-	
	Online shopping EWB	.35	.61**	.77**	-
Useless Group (n=19)	Shopping EWB	.78**	-		
	Online shopping HWB	-.57*	-.47*	-	
	Online shopping EWB	-.38	-.20	.82**	-

Note: HWB = hedonic well-being; EWB = eudaimonic well-being;
*p< .05, **p < .01.

Being consistent with previous research claiming that in participants' favorite activities there may be high correlation between hedonic well-being and eudaimonic well-being [7], the result of this study repeatedly verified this point. The results showed that with all participants, hedonic well-being and eudaimonic well-being are highly correlated with each other in real life shopping, as well as in online shopping. In useful group, shopping hedonic and eudaimonic well-being is significantly related to online shopping hedonic well-being; shopping eudaimonic well-being is significantly related to online shopping eudaimonic well-being. On the other hand, in useless group, shopping hedonic well-being and shopping eudaimonic well-being showed significantly negative correlation with online shopping hedonic well-being. There was no significant relationship founded between shopping eudaimonic well-being and online shopping eudaimonic well-being in useless group. This result showed that, for those who perceived online shopping is more useful than real life shopping, their well-being in online shopping, in this occasion, was enhanced by their real life shopping well-being. For those people who considered online shopping is not as useful as shopping in real life, if they felt more eudaimonic well-being in shopping, they would feel less eudaimonic well-being in their online shopping experience.

4 Discussion

The objective of this research was to investigate whether people's well-being experience of shopping was correlated to the well-being of online shopping, and whether hedonic well-being and eudaimonic well-being of one specified activity can be experimentally proved as two distinguishable concepts of happiness. A questionnaire was utilized to assess participants' well-being in shopping and its counterpart.

In this research, it was empirically proved that people's online experience is connected with their real life activity either positively or negatively according to people's perceived usefulness. However, if we'd like to generalize the results into other aspects of our Internet activities and their counterparts, caution must be applied. Different activities and the natures of those activities should be carefully studied.

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Part V

Eye Tracking, Gestures and Brain Interfaces

Eye Tracking and Universal Access: Three Applications and Practical Examples

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Abstract. The human eye is an essential component in the communication between computers and their operators. For this reason, eye tracking technology provides a valuable perspective into HCI. This paper discusses three applications of eye tracking technology to the challenge of universal access. The first is the use of gaze-controlled systems that allow disabled users to operate computers and other modern technology. The second is the use of eye tracking as a research methodology to be used in designing interfaces that help to bridge the digital divide. The third is the use of eye data to examine cognitive attributes (i.e., workload, fatigue, etc.) of operators of complex systems as they complete critical tasks. Practical examples of each of the three applications are provided.

Keywords: eye tracking, HCI, Universal access.

1 The "Eye" in HCI

Most standard computers send information to their operators visually. Data is rendered on a display, perceived by the human eye and then transmitted to the brain for processing. Obvious though it may seem, this elegant communication between screen and sight has shaped the field of human-computer interaction (HCI) since its inception. Think about modern day PCs, tablets, mobile devices, workstations and simulators. The vast majority of these standard user systems would be rendered inoperative if not for this optical link.

Given the importance of the eye in HCI, one can easily see how eye tracking technology might be of great value. The ability to record and interpret visual behavior provides unparalleled insight at the most basic point of contact between user and system. Such information can be utilized by developers to adjust the interface and enhance the overall efficiency of interaction. Alternatively, the eye data can be directed back into the computer as real-time input to be used in system operation. Researchers have long recognized the essential connection between eye tracking and HCI [16]. One of the more fruitful areas of research has been in the pursuit of universal access. The following sections describe three groups for which this technological synergy has been most successful: disabled persons, inexperienced users and operators of complex systems.

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2 Access for the Disabled

Over the past twenty years one highly publicized contribution of eye tracking to universal access has been its role as an assistive technology. Disabled users have benefited greatly from the use of gaze-controlled systems as a means of clicking and typing [8]. In such interfaces, the eye is used as a pointing modality. The eye tracker interprets the visual behavior of the user in real-time and communicates the pixel coordinates of the point-of-gaze to the computer. In this way, users can select links, press buttons, type words and operate navigation using their eyes instead of hands or voice.

Recent advances in technology have improved both effectiveness and affordability. The latest eye tracking systems for the disabled are non-invasive, easy to calibrate, and robust with respect to lighting changes [7]. The list of specific disabilities that currently benefit from the use of gaze-controlled interfaces includes cerebral palsy, spinal cord injury, brain injury, ALS, multiple sclerosis, brainstem stroke and muscular dystrophy among others [21]. For many disabled persons, eye tracking is the only feasible means of accessing computers and other modern technology.

2.1 Obstacles and Challenges

While this application may seem quite intuitive, there have been several major obstacles in the history of gaze-controlled systems. Among the most persistent of these obstacles is the “Midas Touch” problem [17]. In general, people are not accustomed to controlling an interface with their eyes. Eye movement is more typically used to gather information. Thus, there is the need to distinguish between gaze intended to gather information and gaze intended to activate a specific command. Otherwise the user finds that everywhere he or she looks, voluntarily or involuntarily, a new function is activated. For this reason the eye cannot efficiently be used as if it were simply a computer mouse. Solutions to this problem have included blink, wink and dwell time activation, but further development is still needed [25].

Another obstacle to the performance of gaze-controlled systems is the accuracy of the eye tracker. Although the quality of hardware has improved dramatically over the past several years, these systems are still far from perfect. Almost all eye trackers calibrate the gaze of the user in some manner. However, gaze accuracy has a tendency to drift from the actual point of gaze over time [9]. This can be a source of errors and frustration for the user, who is forced to correct for the imprecise gaze data by focusing slightly off target. Drift correction is an issue that will no doubt be addressed in future generations of eye trackers.

The anatomy and behavior of the eye itself can also be problematic. The area to which a person can pay attention is smaller than the entire fovea. Attention can be shifted within the fovea without making any eye movements. Thus, no matter how accurately an eye tracker measures the position of the eyeball, we can infer one’s attention only to within the one-degree width of the fovea [18]. Saccadic activity has been known to further complicate the interaction. These quick and often involuntary eye movements can result in discontinuous or jittery motion of the pointer. Additionally, the severity of the disability can impact the ability of the system to support a particular user.

Despite these obstacles, eye tracking as an assistive technology continues to positively affect the lives of thousands in the information age. As usability and accuracy improve so too will the ability of these systems to serve a wider range of users who cannot interact with standard computers. The following section provides an example of one such gaze-controlled system designed to provide computer access to the disabled.

2.2 A Practical Application: *The Eyegaze Edge* Gaze-Controlled System

Over the past quarter of a century, gaze-controlled systems have evolved from relatively limited assistive capacity [15] to become an indispensible resource for many thousands of disabled persons around the world. One such example is the *Eyegaze Edge* from LC Technologies (shown in figure 1). This system accurately and effectively processes eye movements and fixations in real-time as a means of navigation and activation of commands [5]. Capabilities include typing, speaking, reading, using software and the internet, environmental control (lights and appliances) and more.


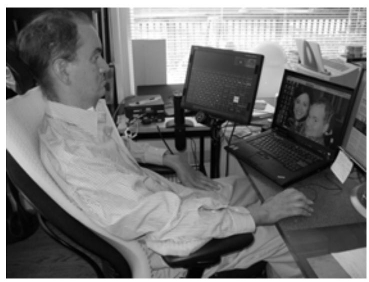

Fig. 1. A programmer (left) and an author (right) using Eyegaze Edge systems. Images used with permission of LC technologies.

The *Eyegaze Edge* utilizes the pupil-center/corneal-reflection method to determine where the user is looking on the screen. Relative position of these two features is calculated within a video image of the eye and then the point of gaze is extrapolated onto the screen. Accuracy of this system is within a quarter inch or better. The orientation of the eye determines cursor placement, and dwell time is used in typing and selection of links or buttons. One of the primary advantages of *Eyegaze Edge* over other models is that it can be accurately calibrated with the head of the user at any angle. When working with disabled populations this is an important consideration.

There are, however, limitations with any assistive eye tracking system. Bright and text-heavy screens can be difficult to navigate due to user fatigue. *Eyegaze Edge* provides an option for a secondary screen with a black background to ameliorate this effect. Additionally, the type and severity of disability may impact the capacity of the user to control his eyes. Brain injury and other cognitive impairments add yet more barriers to successful use. While such challenges persist, *Eyegaze Edge* demonstrates the increasing value of eye tracking as an assistive technology.

3 Access for Inexperienced Users

The ability to use a computer – and, more specifically, the internet – grows more important every day. As our "information society" continues the process of digitizing employment, education, retail, healthcare, government and any number of other components of modern life, it becomes essential that everyone be granted access. This includes all of the roughly two billion internet users in the world, the fastest growing segment of which is in developing countries [2]. It also includes an increasing number of elderly people, a demographic that traditionally has struggled to adopt new technology [19]. Add to that list users at or below the poverty line, most of whom do not have a computer in their home [10]. The task of granting universal access to all of these disparate groups is formidable to say the least.

The 'digital divide' refers to the systematic inequity of access to information technology across different groups. Contributing factors to this inequity include age, education, geography and economic status [13]. Given the growing importance of access to the internet and other computer platforms, bridging the divide has become more critical than ever before. In pursuit of this goal, eye tracking can be employed to help underserved segments use the internet and other software applications. The following section describes the analysis of visual behavior as a usability engineering tool to create better platforms for inexperienced users.

3.1 Eye Tracking and Usability

The burden of bridging the digital divide does not rest solely on inexperienced users themselves. In order for these users to achieve proficiency on a particular website or software application, developers must create programs that effectively support them. Testing real people as they interact with real programs or sites is an important step in this process. Usability research is the field of study devoted to evaluating effectiveness, efficiency and user satisfaction with a particular interface [1]. It traditionally includes analysis of errors, speed and success of task performance, click streams and qualitative feedback.

In recent years, eye tracking has gained prominence as a methodology within this field. By measuring visual behavior directly, the researcher gains access to a wealth of information about an interface that is not available by any other means [6]. For example, consider the typical usability research scenario in which a user takes longer than expected to locate information on a webpage. Without eye tracking, there is no discreet means of determining the impetus of his or her hesitation. Is the information hard to locate? Is it easily located but difficult to interpret? Is the user looking for a link to a more appropriate page? Is some other design element distracting from the task objective [20]? The only way to know the answer to these questions is to examine the interaction between human and computer at the primary point of contact: where the eye meets the screen. This principle has been applied to virtually every facet of software and website design, from how we search the internet [12], to how we process digital content [29], to how we navigate within a site [23].

The challenge of bridging the digital divide is one that eye tracking is uniquely suited to address. A standard website or software application must visually communicate with its users, regardless of age, ethnicity or previous experience. Because of this, an analysis of visual behavior is apt to detect differences between groups and areas in which an interface could be improved to allow access to a broader range of users. By identifying cultural and generational barriers to successful use, eye tracking provides developers with the tools required to eliminate these barriers. The ideal outcome is to facilitate the interactions of inexperienced users without compromising the interactions of more sophisticated users.

3.2 A Practical Application: Eye Tracking Evaluation of a Pharmacy Website

Nowhere is it more essential to optimize websites for older users than in the healthcare industry. The internet offers vast resources to simplify and expedite medical care, but the elderly (who are more often in need of such care) are much less likely to take advantage of these resources [24]. A study conducted by EyeTracking, Inc. in 2008 sought to explore the usability of a pharmacy website for both younger and older users. While specifics cannot be published here for confidentiality reasons, in general this study provides a useful example of the application of eye tracking to provide a more accessible website for an underrepresented group of users.

The study was conducted at the EyeTracking, Inc. research offices in San Diego, CA. A sample of participants was eye tracked while interacting with the targeted pharmacy website. Those chosen for participation represented a wide age range and included a mix of gender, education, income level and self-reported computer proficiency. The study materials were comprised of functional prototypes of a pharmaceutical homepage and several subpages related to ordering prescriptions and managing contact with the pharmacy. Project objectives included evaluation of the layout, visibility of important text and features, understanding of complex tables of information, and overall satisfaction with the site.

Eye tracking data plus traditional usability metrics and qualitative feedback were effective in identifying aspects of the site that were difficult for less savvy users to understand and operate. Specifically, older users of the site struggled with the meaning of certain icons, the placement of relevant information, the size of text, and the organization of tables which included important details about their prescriptions. While some of these findings were evident from navigational data and post-testing interviews alone*, the majority of actionable recommendations could not have been made without the eye tracking component.*

For example, it was observed that participants who struggled to complete certain tasks focused their visual attention heavily on a particular section of navigation. The recommendation to include all relevant site functions within this menu was supported by the eye tracking data. Another recommendation pertained to a particular icon within the site that was rarely clicked when appropriate. Without an analysis of visual behavior it would not have been possible to conclusively and unobtrusively determine that this icon was, in fact, viewed extensively. Participants failed to click it because they failed to understand its meaning. A further example is illustrated in figure 2.

Such findings demonstrate the value of eye tracking as a tool for improving accessibility of websites and software for inexperienced users. By examining the reaction of the eye to the interface in a realistic context it is possible to isolate the components that obstruct usability for a given population. Eliminating these obstructions is one of

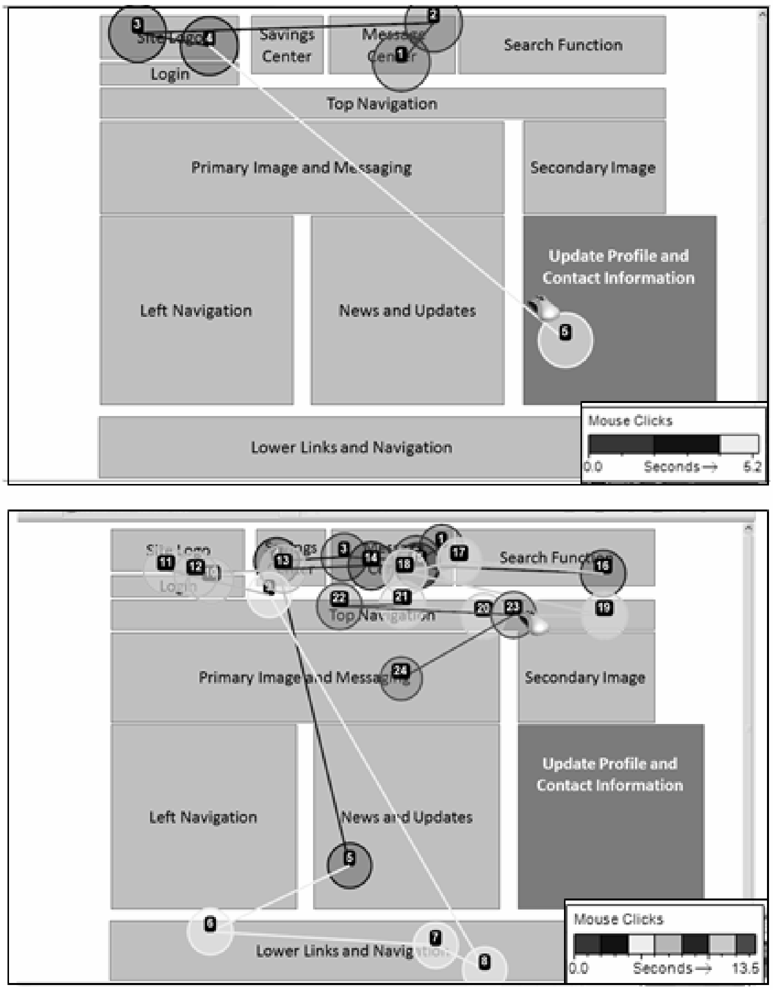

Fig. 2. The figure presents two representative examples of site interaction. A 35 year old user (upper image) located the appropriate link quickly (5.4 seconds) without significant scanning of unrelated page areas. A 61 year old user (lower image) searched the page extensively (13.5 seconds) and failed to locate the appropriate link.

the keys to bridging the digital divide. As the popularity of eye tracking in usability research grows, this technology will play an increasingly large role in guiding the development of digital spaces.

4 Access for Operators of Complex Systems

The previous sections have described the application of eye tracking to improve access for disadvantaged computer users. On the other end of the spectrum, this technology can be used to aid the interaction of highly trained specialists working with complex systems. Consider air traffic controllers, command and control officers, and trainees using sophisticated simulators. The efficacy of the human-computer interaction is extremely important in these environments. Through eye tracking it is possible to assess not only the position of the eyes on a complex interface [3], but also the cognitive state and workload of the operator [26].

There are two ways in which eye tracking can be applied to this scenario. The first is in usability engineering research. By assessing the visual behavior of operators of complex systems during critical events, it is possible to identify features of the interface that could be adapted to facilitate a smoother interaction. This application of eye tracking is quite intuitive and has been in practice since Fitts' research with aircraft pilots over sixty years ago [11].The second way in which eye data is used to enhance the interaction between system and operator is in the analysis of cognitive attributes during operation. Pupil, blink, vergence and other eye data can be analyzed to make inferences about fatigue and workload [14,26]. This information can be used as real-time input for modifying the interface or in evaluation of the operator after the interaction. One such eye metric for measuring cognitive state is discussed in detail below.

4.1 The Index of Cognitive Activity

Researchers have known for decades that the pupil reflects cognitive activity in the brain [4]. Early research suggested that simple changes in pupil size correlated with cognitive effort, but the situation is more complicated than that because of the influence of light on pupil size. Any change in light, no matter how small, influences pupil size. Thus, the challenge has been to find a means of measuring changes in pupil size while holding constant or removing the impact of light. One such metric is the Index of Cognitive Activity (ICA), which uses the signal processing techniques of wavelet analysis to detect small but reliable increases in pupil size. The ICA has shown statistical differences in a number of important contrasts including task difficulty (higher ICA found in difficult than in easy tasks), proficiency (higher ICA observed in novices than in experts), and alertness (higher ICA seen in fatigued individuals than in alert individuals) [22,27,28].

4.2 A Practical Application: The Eye of the Surgeon

Surgery is an excellent example of a field in which skilled operators must perform at a high level in critical situations. In recent years, computers have come to serve an important function in the training of surgeons. Sophisticated digital simulators provide surgical trainees with the opportunity to complete realistic laparoscopic procedures in a safe and controlled environment. EyeTracking, Inc., in collaboration with surgeons at the Smith Institute of Urology, conducted an eye tracking assessment of experts and non-experts as they completed simulated and live surgeries [28].

One of the primary goals of this research was to identify an objective method for assessing surgical skill. In other words, based on eye tracking data alone, can we determine the proficiency with which a surgeon completes a given simulation or procedure? A sample of ten surgeons was tested while completing forty-six simulated tasks on a LapMentor virtual surgical simulator. Data were collected using an Eyelink

II head-mounted eye tracker from SR Research. The features analyzed included blink rate, fixation rate, vergence and ICA.

Based on these eye metrics, linear discriminant function (LDA) models and neural network analysis (NNA) models were used to predict both surgical skill and task difficulty. Surgical-skill results found that expert surgeons were differentiated from non-experts with 91.9% (LDA) and 92.9% (NNA) accuracy in the simulations. These results were replicated with slightly lower accuracy in the live surgical environment (81.0% LDA and 90.7% NNA). The models also successfully identified the difficulty level for each surgeon on each simulator task. Figure 3 shows the results of the task-difficulty analysis.

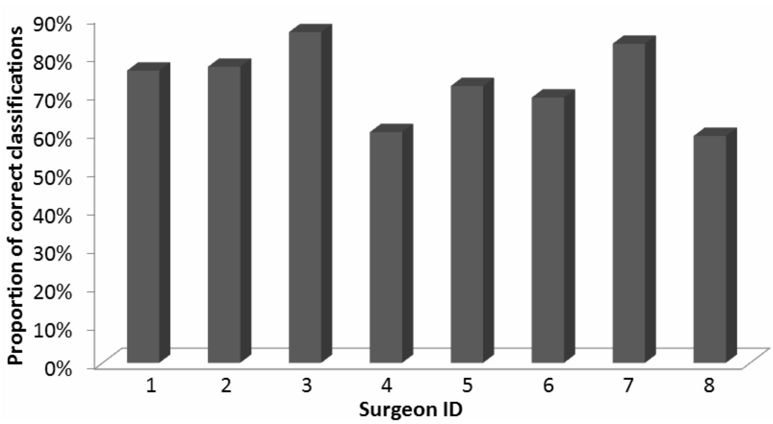

Fig. 3. Success in predicting task difficulty level using eye metrics on surgical simulations. Every 4 seconds of data was examined separately and classified as coming from one of three difficulty levels. Average success rate is 73%.

While the principal application of this research is to the field of surgery, the implications for HCI are noteworthy as well. In the study described above, eye tracking provided a previously unattainable method of evaluating the skill with which an operator uses a system. There is, of course, performance data generated by the task, but it does not capture cognitive functioning, only physical behavior. The simulator's evaluation of operator performance is incomplete without a means of assessing the visual and mental activity of the user. Such information was used in this case to classify the user as "expert" or "non-expert." In broader terms, however, the study can be seen as an example of the diagnostic precision with which eye data can be used to evaluate the interaction between the user and the interface.

5 Conclusions

The quest for universal access to computers is daunting to say the least. Because there are so many different obstacles to overcome, so many different groups to accommodate, and so many different programs to optimize, no simple solution exists for streamlining HCI. There is, however, one commonality among the vast majority of people and systems: communication between the eye and the screen. The use of visual behavior as both a real-time input and a research methodology has provided an extremely effective approach to universal access. By understanding how the user sees and thinks we gain unique insight into HCI at the primary point of interface.

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Interpreting 3D Faces for Augmented Human-Computer Interaction

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Abstract. Human-machine interaction requires the ability to analyze and discern human faces. Due to the nature of the 3D to 2D projection, the recognition of human faces from 2D images, in presence of pose and illumination variations, is intrinsically an ill-posed problem. The direct measurement of the shape for the face surface is now a feasible solution to overcome this problem and make it well-posed. This paper proposes a completely automatic algorithm for 3D face registration and matching based on the extraction of stable 3D facial features characterizing the face and the subsequent construction of a signature manifold. The facial features are extracted by performing a continuous-to-discrete scale-space analysis. Registration is driven from the matching of triplets of feature points and the registration error is computed as shape matching score. A major advantage of the proposed method is that no data pre-processing is required. Despite of the high dimensionality of the data (sets of 3D points, possibly with the associate texture), the signature and hence the template generated is very small. Therefore, the management of the biometric data associated to the user data, not only is very robust to environmental changes, but it is also very compact. The method has been tested against the Bosphorus 3D face database and the performances compared to the ICP baseline algorithm. Even in presence of noise in the data, the algorithm proved to be very robust and reported identification performances in line with the current state of the art.

Keywords: Face recognition, 3D faces, Pattern recognition, Scale-space theory, Geometric invariants.

1 Introduction

The interaction among humans is always driven by direct visual perception which conveys several information including the identity, gender, age and emotional state. As such, the analysis and recognition of human faces is of paramount importance to devise a proper interaction of a computer system with humans. The management of identities implies the construction of compact biometric templates, requiring a limited storage and minimal computational resources. This may seem unfeasible when dealing with high dimensional data, such as dense

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3D face shape representations. The geometric approach proposed in this paper is aimed at minimizing the required storage for the face template by extracting and processing a limited number of characteristic 3D points. The resulting template requires only a few KBytes of data. The information contained in the 3D face shape is exploited to devise a robust and accurate identification system through the alignment of the shapes and the computation of their similarity. The Iterative Closest Point (ICP) algorithm [1] has proven to be very effective to accurately register (or match) 3D face scans, but an approximate initial alignment of the two point sets is required to bootstrap the algorithm. For this reason, an accurate and efficient face registration is always mandatory to perform face recognition. Therefore, in this paper 3D face recognition is tackled as a by product of the registration of 3D point sets. The algorithm is based on the extraction of facial features characterizing the face and the subsequent construction of a signature manifold. Registration is driven from the matching of triplets of feature points. After registration two different processes are performed: the registration error is computed first as shape matching score, secondly the coarse registration is refined by using the Iterative Closest Point (ICP) technique [1]. The final match score is determined by the registration error computed after the last iteration.

The proposed algorithm was tested on the Bosphorus database [2], particularly with faces under different poses. Previous works on this database have concentrated on landmarks detection robust to occlusions and noise. The algorithm proposed in this paper significantly outperform the benchmarks algorithms based on automatic features extraction. To demonstrate the efficiency of the algorithm in real application scenarios, several experimental tests are performed and the results compared to those obtained with the ICP baseline algorithm. Even in presence of noise in the data, the algorithm proved to be very robust and reported identification performances in line with the current state of the art.

2 Extraction of 3D Facial Features

2.1 Scale-Space Theory and 3D Face Analysis

Human faces can be characterized from 3D information just by registering the data from two individuals and measuring the goodness of fit. This process requires to identify anchor points on the faces which are similar for all faces but also to locate 3D features which may be highly distinguishing. Considering a 3D face scan as a smooth surface, both kind of points are either local maxima or minima of the Gaussian curvature. Our aim is then to find an algorithm to extract local maxima and minima of curvature, with a given approximation.

The scale-space theory [6], originally proposed to describe the gray level variations in 2D intensity images, can be applied to 3D face scan to optimally select all "common" points, namely 3D features, to be extracted from a set of 3D faces. Given a scale-space representation of the face, we can characterize the face at each scale by means of the Gaussian curvature at each point. Due to computational time and memory limits, the scale can not be varied continuously, nor can the cloud of points be model with a parametrized surface [7] . This problem is overcome by extracting, for each 3D scanned point p_i, an approximation of the Gaussian curvature computed on the set of spherical neighbors $N_{p_i}(r_j)$, centered at the point p_i and of increasing radius r_j. The scale step, i.e. the difference between the radii of two consecutive neighbors is chosen on the basis of the sampling density of the scan. In the performed experiments the scale step was determined by constraining, on average, the difference between two neighbors to be equal to 10 points. Given a 3D point p_i and the 3D neighbors $N_{p_i}(r_j)$, an approximation of the Gaussian curvature can be obtained by computing the Principal Components of $N_{p_i}(r_j)$. The eigenvalues $\lambda_0 \leq \lambda_1 \leq \lambda_2$ and the respective eigevectors v_0, v_1, v_2 corresponding to the principal directions, are computed. The absolute value of the curvature is then defined as $\mathcal{C}(p_i, r_j) = \dfrac{2|(p_i - p_g) \cdot v_0|}{d_m^2}$, where p_g is the center of gravity of the neighbor $N_{p_i}(r_j)$ and d_m^2 is the mean of distances $|p_i - p_j|,\ p_j \in N_{p_i}(r_j)$. The surface normal $\nu(p_i, r_j)$ at the point p_i at scale r_j is computed as the principal direction corresponding to the smallest eigenvalue λ_0.

2.2 Extraction of Features at Multiple Scales

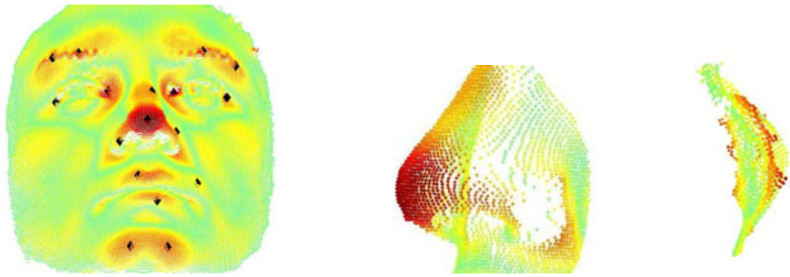
The scale-space 3D feature extraction is based on the following steps:

- Two extreme values for the search radius are set $(r_s\ ,\ r_e)$, determined on the basis of anthropometric facial measures. In all experiments the two radii were set empirically to 6mm and 22mm.
- The scale step σ_s is defined to partition the interval (r_s, r_e) into a set of $n_\sigma = \dfrac{r_s - r_e}{\sigma_s} + 1$ intervals of equal length.
- For each point p_i of a face scan, the curvature $\mathcal{C}(p_i, r_j)$ is computed for $j = s, s + \sigma_s, s + 2\sigma_s, \ldots, e$. The curvature values are then interpolated to produce a function $\mathcal{C}(p_i) : [s, e] \rightarrow \mathbb{R}$. A median filter is applied to smooth the curve, and the scale $\sigma_m(p_i)$ for which the curvature $\mathcal{C}(i) = \mathcal{C}(p_i, \sigma_m(p_i))$ reaches a maximum is computed. The normal ν_i at point p_i is determined as $\nu(p_i, \sigma_m(p_i))$.

For each point p_i of the face scan an optimal curvature value $\mathcal{C}_i$ and an optimal normal vector $\nu(i)$ are obtained. The face edges are first detected and marked to be excluded from the successive processing. Given $r = (r_e - r_s)/2$, and for each p_i in the face scan, p_i is defined to be a local maxima or minima of the curvature if $|\mathcal{C}_i|$ is the largest of all $|\mathcal{C}_k|$ for $p_k \neq p_i \in N_{p_i}(r)$.

While the number of features is naturally bounded by the radius r, up to 12 points of highest curvature are selected amongst them. In figure 1 (a), the projected surface of a sample 3D face scan is shown. The surface color encodes the curvature values computed at the fixed scale $(r_e - r_s)/2$. The marked points on the surface represent the extracted 3D features.

In most 3D acquisition devices the sampling density of the face scan is lower exactly in those areas where curvature variation occurs. This non-uniform sampling often leads to occlusions and may impair the extraction of feature points. Despite the occlusions and noise in the data, preprocessing of the data has been



(a) (b) (c)

Fig. 1. (a) Feature points extracted from a sample face scan from the Bosphorus database, (b) Subsampled nose area, (c) Noisy eye area

carefully avoided. It is worth stressing that all results presented in the experimental section were obtained without applying any kind of data preprocessing. This allows to better evaluate the performance on face registration and matching as related to the raw data only and not to the quality of any pre-processing step.

3 Registration of 3D Facial Scans

The registration algorithm is based on the Moving Frame Theory [9]. The procedure that leads to the generation of the invariants and the signature are discussed in full detail in [10]. Only the fundamental issues are discussed here.

Given a surface F, the Moving Frame Theory defines a framework (and an algorithm) to calculate a set of invariants, say $\{I_1, \ldots I_n\}$, where each I_i is a real valued function that depends on one or more points of the surface. By construction, this set contains the minimum number of invariants that are necessary and sufficient to parametrize a "signature" $S(I_1, \ldots, I_n)$ that characterizes the surface up to Euclidean motion. The framework offers the possibility of choosing the number of points the invariants depend on, and this determines both the number n of invariants we get and their differential order. The more the points the invariants depend on the lower the differential order. For instance, invariants that are functions of only one point varying on the surface ($I = I(p)$, $p \in F$) have differential order equal to 2. These are the classical Gaussian and Mean curvatures. In order to trade the computational time with robustness to noise the invariants are built depending on three points at one time. The result is a set of nine invariants, three of differential order zero, and six of order one.

3.1 3-Points Invariants

Let $p_1, p_2, p_3 \in F$ and ν_i be the normal vector at p_i. The directional vector v of the line between p_1 and p_2 and the normal vector ν_t to the plane through p_1, p_2, p_3, are defined as:

$$v = \frac{p_2 - p_1}{\|p_2 - p_1\|} \qquad \text{and} \qquad \nu_t = \frac{(p_2 - p_1) \wedge (p_3 - p_1)}{\|(p_2 - p_1) \wedge (p_3 - p_1)\|}.$$

The zero order invariants are the inter-point distances $I_1 = \|p_2 - p_1\|$, $I_2 = \|p_3 - p_2\|$ and $I_3 = \|p_3 - p_1\|$ whereas the first order invariants are

$$J_k(p_1, p_2, p_3) = \frac{(\nu_t \wedge v) \cdot \nu_k}{\nu_t \cdot \nu_k} \quad \text{and} \quad \tilde{J}_k(p_1, p_2, p_3) = \frac{v \cdot \nu_k}{\nu_t \cdot \nu_k} \quad \text{for } k = 1, 2, 3.$$

Each triplet (p_1, p_2, p_3) on the surface can now be linked with a point of the signature in 9-dimensional space whose coordinates are given by
$(I_1, I_2, I_3, J_1, J_2, J_3, \tilde{J}_1, \tilde{J}_2, \tilde{J}_3)$.

3.2 Matching 3D Face Scans

For each triplet of feature points extracted from a sample face scan F the invariants are computed and stored into a signature S that characterizes F. Two face scans F and F' can be compared by computing the intersection between the two signatures S and S'. If the intersection between S and S' is not null, then exists a subset of feature points belonging to the two scans holding the same properties, i.e. the same inter-point distances and normal vectors (up to Euclidean motion). The signature points are compared by computing the Euclidean distance: given a threshold ϵ, if $s \in S$, $s' \in S'$ and $|s - s'| \leq \epsilon$, then the triplets that generated the signature points are matched. From the triplets the roto-translation $(\mathbf{R}, \mathbf{t})$ that takes the second into the first can be computed. Given $\{t_1, \ldots, t_m\}$ the set of triplets of the face scan F that are matched to the triplets in S', each matched triplet generates a roto-translation $(\mathbf{R}_i, \mathbf{t}_i)$. To select the best registration parameters among those computed, each $(\mathbf{R}_i, \mathbf{t}_i)$ is applied to F', so that $F'' = \mathbf{R}F' + \mathbf{t}$ and the registration error is computed according to the following procedure.

For each point $q_i \in F'$ the closest point p_i in F is computed together with the corresponding Euclidean distance $d_i = \|q_i - p_i\|$. A set of distances $D = \{d_i\}_{i \in I}$ is obtained where I is the cardinality of F'. The registration error is defined to be the median of $D = \{d_i\}_{i \in I}$. The pair $(\mathbf{R}_m, \mathbf{t}_m)$ corresponding to the minimum registration error d_m is chosen as the best registration between the two faces. Whenever the registration step fails (there are no matching points in the signature space and so triplets) the result is accounted as a negative match.

3.3 3D Face Identification

The registration error is used as matching score between two faces F and F'. Due to noise and occlusions, the computed registration score can be still inaccurate. Another algorithm, such as ICP, is applied to refine the registration. In the first iteration, ICP takes as input the two scans aligned through the invariant matching. The registration error after the last iteration is the final matching score. After registration, two scans will be considered a match, i.e. belonging to the same individual, id the matching score is below a fixed threshold σ. After a successful registration of two fairly neutral scans of the same subject, the median distance d_m can be assumed to be $\delta/2 < d_m < \delta$ where δ is the average resolution of the scans.

4 Experimental Results

The proposed algorithm was tested on the Bosphorus database [2]. The database contains about 50 scans of 105 individuals, with 61 male and 44 female subjects. 31 out of the total male subjects have a beard and mustaches. Each scan either presents a different facial expression (anger, happiness, disgust), corresponding to a "Face Action Unit", or a head rotation along different axes. Since the subjects to be identified can be assumed to be cooperative, we will simulate an authentication scenario using the sets of faces that are fairly neutral and only slightly rotated sideways, upwards and downwards. Examples of the scans for two subjects are shown in figure 2. The picture shows (in a clockwise direction): a neutral pose, a slight downwards rotation, a slight upwards rotation, a 10° head rotation on the right.

Fig. 2. Sample 3D scans of four subjects in the Bosphorus database

This database has been chosen because it contains a large number of subjects and an excellent variety of poses. Furthermore, despite only geometric information (3D points) is used for identificaiton, the availability of landmark points constitutes a ground truth which makes it possible to compare the methodology with a baseline algorithm.

The database was divided into a gallery set G and two probe sets P_1, P_2. The gallery G consists of one neutral face scan for each individual (named N-N in the database). The neutral scan could be stored in a smart card or ID card of an individual in the form of text file, whereas the poses in P_i, $i = 1, 2$ can be assumed to be the scans taken from the acquisition device when the subject undergoes authentication.

Three authentication tests were run. In all of them, the gallery consisted of the neutral poses, such as the first sample of each subject in figure 2.

1. $\mathbf{P_1}$ **vs G**. The probe set P_1 consists of the scans labeled PR-SU in the database (105 scans in total, one for each subject). The pose is a slight rotation of the face upwards as shown in the second image of each subject in figure 2. Each scan of P_1 was compared to all scans of the neutral gallery G using the methodology described in section 3.3.

2. **P_2 vs G**. The probe set P_2 consists of the scans labeled YR-R10 in the database (105 scans in total, one for each subject). The pose is a rotation of the face of about 10 deg on one side, as shown in the third image of each subject in 2. Again, each scan of P_2 was compared to all scans of the neutral gallery G as in 3.3.
3. **Manual P_1 vs G**. This is the baseline algorithm. Each scan in P_1 was roughly aligned with each scan of G using three of the manually selected landmarks provided by the database (the two inner eye corners and nose tip) and the alignment refined with ICP.

All algorithms were implemented in MatLab. On a consumer PC, the computational time to extract the features from a face scan of 30.000 points was on average 2 min. The signature generation took about 3 sec. For the registration of two scans, times varied from 2 sec for scans of different subjects to 20 sec for those of the same subject. The results of the tests are summarized in table 1. The failed registrations (*F.R.*) is the number of subjects for which no triples were matched in the signature space. These numbers are indicative of the robustness of the method. In fact, if a registration fails there is no later chance of refinement. No registration failures occurred in experiment 1 and 2.

Table 1. Matching scores

Experiment	F.R.	A.R.	T.P.	F.P.	F.N.	T.N.	Acc
1	0	0.981	103	0	2	10920	0.9998
2	0	0.924	97	0	8	10920	0.9992
3	0	0.99	104	0	1	10920	0.9999

In the third column of table 1, *A.R.* indicates the authentication rate (number of correctly identified subjects over the total of 105) obtained using as matching score the registration error that follows from the automatic feature extraction and the registration through invariants refined by ICP. *T.P.* is the number of true positives, *F.P.* the number of false positives, *F.N.* that of false negatives, and *T.N.* that of true negatives. In the last column, *Acc* stands for accuracy and it is defined by $Acc = \dfrac{TP + TN}{P + N}$, where $P = 105$ is the number of positives and $N = 10920$ is the number of negatives. The noise associated to some of the scans accounts for the false negative, therefore preprocessing the data or acquiring them with a lower noise system would reduce the number significatively. In figure 3, the matching scores after registration of the probe scans to the gallery scans are shown. The cases of registration failure between different subjects are omitted. Each number from 1 to 105 along the x-axis refers to the gallery scan of a subject. For each subject i, the matching scores after registration of the gallery scan with all probe scans are represented along the column (i, y). The scores are marked by gray circles if the probe subject is different from the i subject and with a black star if the probe scan is of subject i. As we can see from figure 3, the threshold (horizontal line, set to be equal to 0.65 for this database), separates

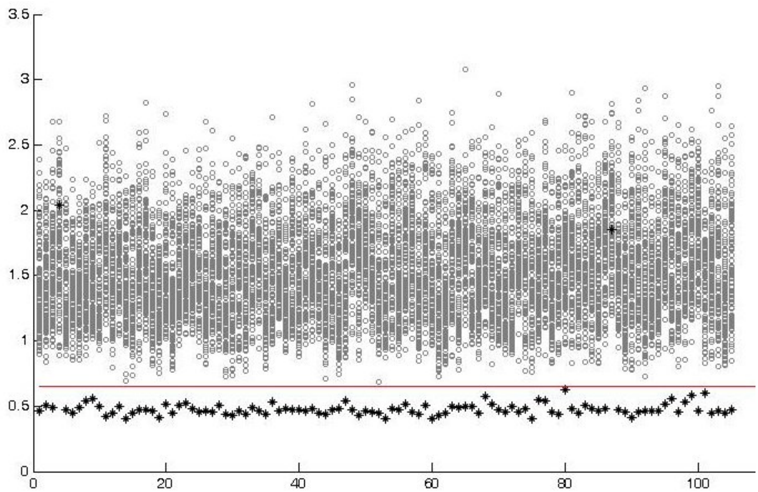


Fig. 3. Distribution of scores from experiment 1

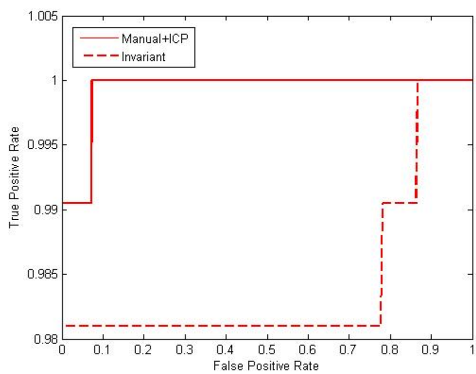


Fig. 4. ROC curves for experiments 1 (red) and 3 (blue)

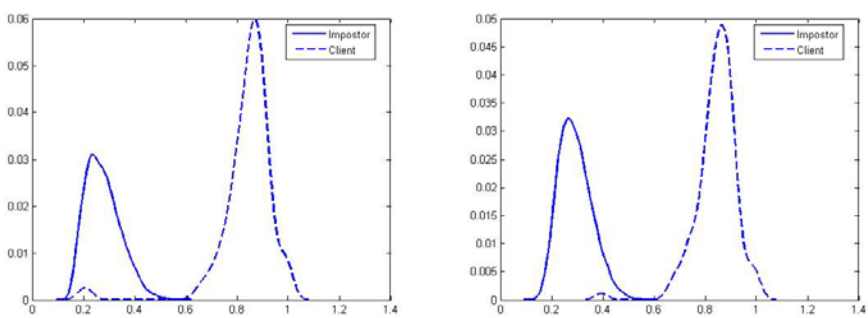


Fig. 5. Impostor and client distribution for experiment 1 (left), and 3 (right)

the two classes client and impostor very well. The performance as the threshold varies is shown by the two ROC curves in figure 4. The images in figure 5 show the separation of the client and impostor classes in experiment 1 and 3. On the x-axis a similarity measure of two faces is given as the inverse of the registration error. It can be seen that the baseline algorithm does not significantly improve the separation of classes obtained with the automatic one, although it manages to identify one of the two subjects on which the proposed method fails.

5 Conclusions

The identification of individuals on the basis of 3D shape information only has been addressed. This is a very promising and challenging biometric technology at the same time, because of the difficulties in processing three-dimensional data and of the advantages such as the relative insensitivity to illumination changes. The proposed method, based on the scale-space theory for the extraction of stable 3D feature points and on the generation of an invariant signature to characterize the face shape, proved to be very robust at identifying subjects, providing very good performances in terms of matching accuracy avoiding any data pre-processing to either fill-in holes or smooth the face surface to remove spikes within the points cloud. Moreover, the procedure is highly flexible regarding the storage and on-line processing: by storing the 3D points only more on-line processing is required, whereas by storing the feature points or the signature of the face shape, on-line processing is increasingly reduced.

Even though changes in facial expression were not addressed, these can be very important in building a proper man-machine interface [11]. Facial expressions play a central role in understanding the mood, emotions and even intentions of the counter-part. As such, further work will be devoted to properly understand and model the deformation of key face areas. The scale-space analysis presented in this paper can be further enhanced to extract and build 3D invariants which are robust to such deformations, but also to define a dynamic facial signature which encompasses the identity as well as the emotional state of the subject.

Further performance improvements are expected with a light data pre-processing, e.g. cropping the central part of the face to remove spikes due to hair or acquisition artifacts, or by consolidating the extraction the feature points of the gallery image with the aid of texture information.

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Social Environments, Mixed Communication and Goal-Oriented Control Application Using a Brain-Computer Interface

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Abstract. For this study a P300 BCI speller application framework served as a base to explore the operation for three different applications. Subjects exchanged messages in the networks of (i) Twitter (Twitter Inc.) and socialized with other residents in Second Life (Linden Lab) and (ii) controlled a virtual smart home. Although the complexity of the various applications varied greatly, all three applications yielded similar results which are interesting for the general application of BCI for communication and control: (a) icons can be used together with characters in the interface masks and (b) more crucially, the BCI system does not need to be trained on each individual symbol and allows the use of icons for many different tasks without prior time consuming and boring training for each individual icon. Hence such a type of BCI system is more optimally suited for goal oriented control amongst currently available BCI systems.

Keywords: Brain-Computer Interface, P300 evoked potential, EEG, BCI.

1 Introduction

Since the early 1990s the BCI research field started growing constantly driven by relatively high performance and low cost computer power and as well as EEG instrumentation capable to be used in real-time and closed loop data processing. However, a first systematic discussion of possible brain-computer communications based on EEG can be found already in J. Vidal [1] in early 1970s; Farwell and Donchin described in another pioneering work the usage of evoked potentials for communication [2]. Since then, performance and usability of BCI systems have advanced dramatically over the last several years. Only about ten years ago, one of the pioneering laboratories in BCI research in Europe published the first BCI that could provide communication for disabled users in their homes. However, the system was only validated with two users, required months of training, and was still slow and inaccurate [3]. Thereafter research laboratories in the USA and Europe were among the first to describe BCIs that could provide real benefit to handicapped people without extensive training [4-6]. Still the BCI users needed a training of several weeks to operate the system with acceptable accuracy [7]. Recently, training time of BCI systems dropped down to only minutes and some BCI systems even do not need any training

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[8;9]. However, BCIs require the user to engage in some conscious, intentional activity to convey information. Work has shown that immersive feedback, which may include virtual reality, can reduce training time and improve accuracy [10;11]. The confluence of ICT techniques (Brain/Neuronal-Computer Interfaces, affective computing, Virtual Reality, ambient intelligence) and neuropsychology allows to integrate them into an advanced platform which will improve quality of life of people by providing not only means for communication but by performing advanced and user orientated analysis of deficits and providing individual training scenarios. A popular BCI approach is based on the P300 evoked potential. It is elicited when an unlikely event occurs randomly between events with high probability. In the EEG signal the P300 appears as a positive wave about 300 ms after stimulus onset. Its main usage in BCIs is for spelling devices, but one can also use it for control tasks for example in gaming [12] or navigation (e.g. to move a computer-mouse [13]). Krusienski et al. [14] evaluated different classification techniques for the P300 speller, wherein the stepwise linear discriminant analysis (SWLDA) and the Fisher's linear discriminant analysis provided the best overall performance and implementation characteristics. A recent study [15], performed on 100 subjects, revealed an average accuracy level of 91.1%, with a spelling time of 28.8 s for one single character. Each character was selected out of a matrix of 36 characters.

This paper discusses case study applications for human computer interaction scenarios all based on the P300 evoked potential for virtual smart home control, and speller like interfaces to operate Twitter and to interact virtually with other participants via Second Life.

2 Methods and P300 Base System

2.1 P300 Base System

A P300 spelling device can be based on a 6 x 6 matrix of different characters displayed on a computer screen. The row/column speller flashes a whole row or a whole column of characters at once in a random order as shown in Fig. 1A and 1B. The single character speller flashes only one single character at an instant in time. The underlying phenomenon of a P300 speller is the P300 component of the EEG, which is seen if an attended and relatively uncommon event occurs. The subject must concentrate on a specific letter he/she wants to write. When the character flashes on, the P300 is induced and the maximum in the EEG amplitude is reached typically 300 ms after the flash onset and the P300 signal response is more pronounced in the single character speller than in the row/column speller and therefore easier to detect [16].

For BCI system training, EEG data are acquired from the subject while the subject focuses on the appearance of specific letters in the copy spelling mode. In this mode, an arbitrary word like LUCAS is presented on the monitor. First, the subject counts whenever the L flashes. Each row, column, or character flashes for e.g.100ms per flash. Then the subject counts the U until it flashes 15 times, and so on. EEG data are then evaluated with respect to the flashing event within a specific interval length, segmented and sent to an LDA to separate the target characters from all non targets. This yields a subject specific weight vector WV for the real-time experiments. It is very interesting for this approach that the LDA is trained only on 5 characters representing 5 classes and not on all 36 characters.

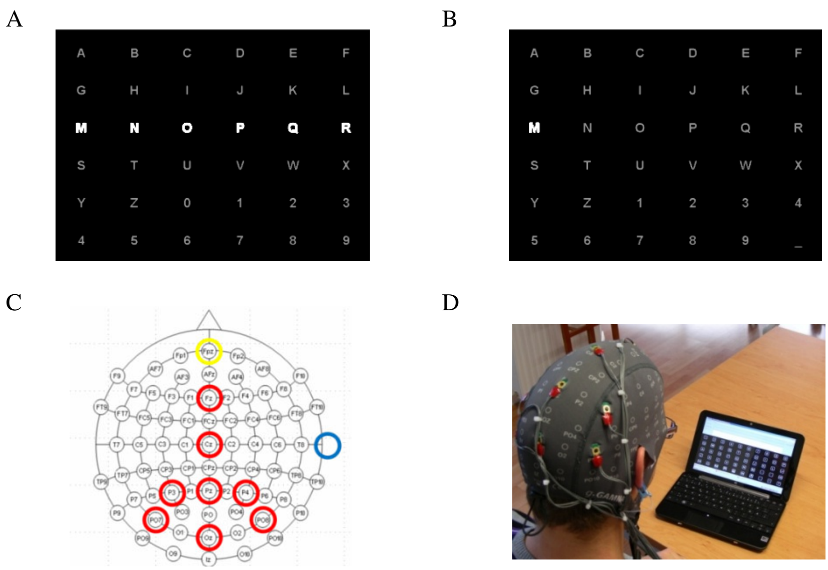


Fig. 1. A and B display the screen layout of the 36 character speller. Either all characters of one row or column are highlighted at the same time in the row/column speller or only one single character is highlighted for a certain time in the single character speller. C displays the electrode layout according to [17]. A total of eight electrodes positions distributed mostly over occipital and parietal regions are used. Red circles indicate the used electrode positions Fz, Cz, P3, Pz, P4, PO7, Oz, PO8. The yellow ring indicates the ground electrode mounted on the forehead at Fpz and the blue ring indicates the reference electrode attached to the right ear lobe. D displays a versatile system setup with the portable wireless EEG device g.MOBIlab+, an active electrode system g.GAMMAsys and a P300 speller application intendiX (courtesy of g.tec medical engineering GmbH, Austria).

Furthermore subjects might utilize averaged WV across several subjects. However, the accuracy of the spelling system increases also with the number of training characters. After the setup of the WV the real-time experiments can be conducted. The device driver ‘g.USBamp’ reads again the EEG data from the amplifier. Then the data are band pass filtered (‘Filter’) to remove drifts and artifacts and down sampled to 64 Hz ('Downsample 4:1’). The ‘RowCol Character Speller’ block generates the flashing sequence and the trigger signals for each flashing event and sends the ‘ID’ to the ‘Signal Processing’ block. The ‘Signal Processing’ block creates a buffer for each character. After all the characters flashed, the EEG data is used as input for the LDA and the system decides which letter was most likely attended by the subject. Then this character is displayed on the computer screen. Hence such a P300 base concept allows very reliable results with high information transfer rates [14;16;18].

In Guger et al. [16] it has been demonstrated that more than 70% of the sample population could use such a spelling setup with an accuracy of 100%. Based on this findings the experiments described in the manuscript are based on a variant of the Simulink model shown in Fig. 2.

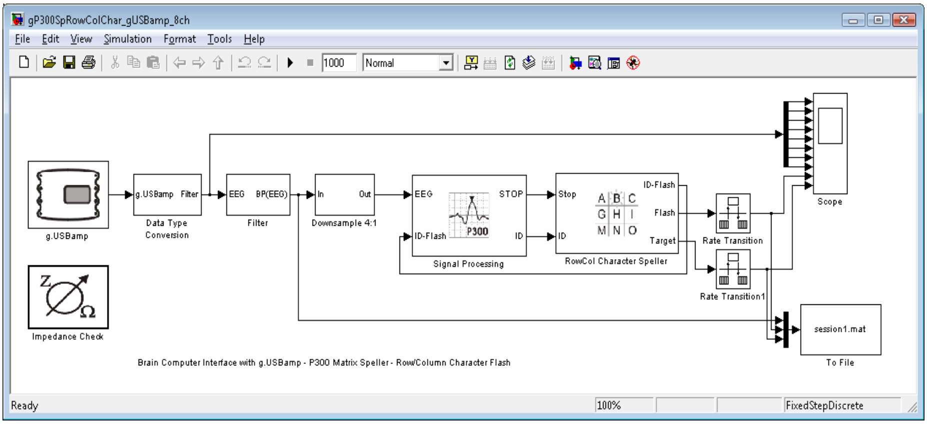


Fig. 2. Real-time Simulink model for P300 speller experiment

3 P300 Applications

3.1 Virtual Smart Home Study

An appropriate interface for controlling a virtual smart home environment was designed. In contrast to the spelling application the subjects were positioned in standing position in front of a control computer and were instructed to avoid unnecessary movements. Next to the subjects a 3D power wall was installed for projecting the virtual smart home. Brain signals were measured from 8 scalp locations similar to the speller study. In order to allow some mobility of the subjects EEG data were acquired with the wireless g.MOBIlab+ (biosignal amplification unit, g.tec medical engineering GmbH, Austria). In the experiment it should be possible for a subject to switch on and off the light, to open and close the doors and windows, to control the TV set, to use the phone, to play music, to operate a video camera at the entrance, to walk around in the house and to move him/herself to a specific place in the smart home. Hence the Simulink model from Fig. 2 was modified and appropriate Simulink blocks for the wireless g.MOBIlab+, the interface masks for smart home control allowing the usage of icons and symbols in addition to letters and a UDP communication block were inserted for controlling the virtual environment by BCI commands. One example of the main interface mask is given in Fig. 3A. A total of 12 subjects participated in the case study. The first task was to train the system on 42 selected icons. In the operation mode the classification result was then sent via a network connection to the control unit of a virtual 3D representation of a smart home (developed by Chris Groenegress and Mel Slater, ICREA-Universitat de Barcelona, Spain). A total of 7 different control masks were operated by the subjects. All subjects needed between 3 and 10 flashes (mean 5.2) per character to reach an accuracy of 95 % for the single character speller. This resulted in a maximum information transfer rate of 84 bits/s for the single character speller (further details of the setup and results can be found in [19]).

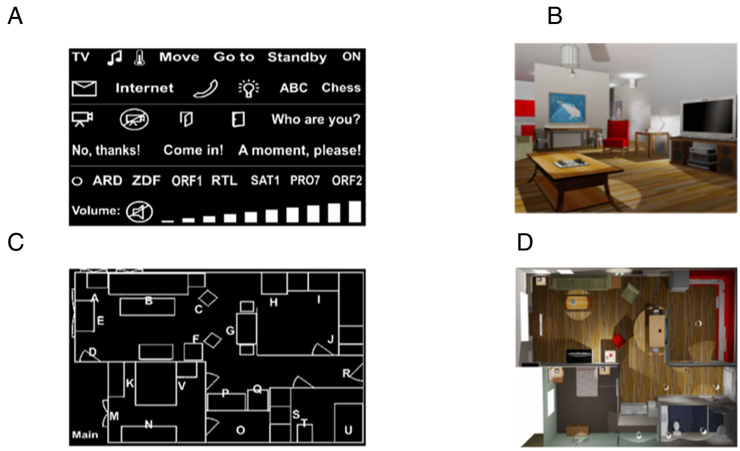


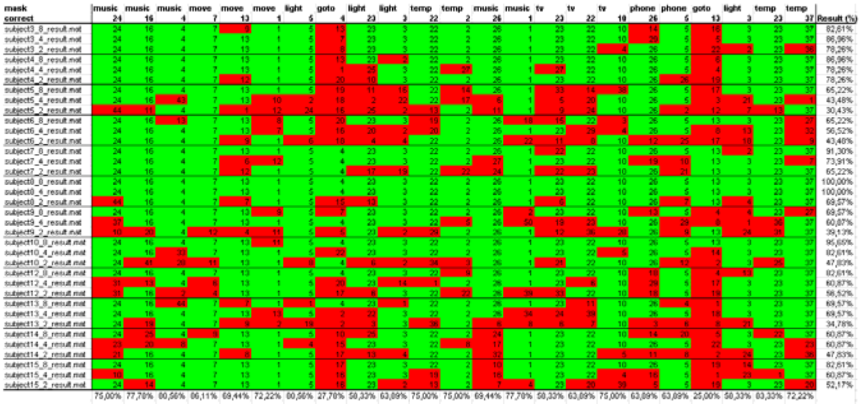
Fig. 3. Panel A displays the main interface mask consisting of 41 different icons arranged in a rectangular grid. Panel B displays a 3D view of the living room including some of the devices that can be controlled via the BCI like the TV set, room light or telephone. Panel C represents the control mask to be 'beamed' to 21 different locations in the apartment. Here 21 characters represent all user selectable positions. In the top left corner in panel D the living room can be found, the top right corner represents the kitchen, bottom left corner represents the sleeping room and on the bottom right corner the bathroom as well as the entrance door of the apartment is located.

In order to measure the performance and accuracy of the control, the subjects had to perform specific tasks e.g. opening the front door, moving to the specific places in the apartment or manipulating the light source or the room temperature. Interestingly the performance varied greatly between the interface masks. Fig. 4 indicates an overview over the accuracies for the different interface masks. For some masks subjects performed consistently worse compared to other masks. Only about 30% of the decisions were correct for the Goto mask.

3.2 P300 Twitter and Second Life Control

Twitter (Twitter Inc.) is a social network that enables the user to send and read messages. The messages are limited to 140 characters and are displayed in the authors profile page. Messages can be sent via the Twitter website or via smart phones or SMS (Short Message Service). Twitter provides also an application programming interface to send and receive SMS. Second Life is a free 3D online virtual world developed by the American company Linden Lab. It was launched on June 23, 2003 and already 5 years later the platform had 15 million registered accounts whereas on average 60 000 users were online at the same time. Only a free client software "Second Life Viewer" and an account are necessary to participate.

One of the main activities in Second Life is socializing with other so-called residents whereas every resident represents a person of the real world (see Fig. 5B). Furthermore it is possible to perform different actions like holding business meetings, to take pictures or make movies, to attend courses, etc. Communication takes place via



mask	music	music	music	move	move	move	light	goto	light	light	temp	temp	music	music	tv	tv	tv	phone	phone	goto	light	temp	temp	
correct	24	16	4	7	13	1	5	4	23	3	22	2	26	1	23	22	10	26	5	13	3	23	37	Result (%)
subject3_8_result.mat	24	16	4	7	9	1	5	13	23	3	22	2	26	1	23	22	10	14	5	16	3	23	37	82,61%
subject3_4_result.mat	24	16	4	7	13	1	5	7	23	3	22	2	26	1	23	22	10	29	5	5	3	23	37	86,96%
subject3_2_result.mat	24	16	4	7	13	1	5	8	23	3	22	2	26	1	23	22	4	26	5	22	2	23	36	78,26%
subject4_8_result.mat	24	16	4	7	13	1	5	13	23	2	22	2	26	1	23	22	10	26	5	6	3	23	37	86,96%
subject4_4_result.mat	24	16	4	7	13	1	5	1	25	3	22	27	26	1	27	22	10	26	5	4	3	23	37	78,26%
subject4_2_result.mat	24	16	4	7	12	1	5	20	10	3	22	2	26	1	23	22	10	26	26	19	3	23	37	78,26%
subject5_8_result.mat	24	16	4	7	13	1	5	19	11	16	22	14	26	1	33	14	38	26	5	17	3	23	37	65,22%
subject5_4_result.mat	24	16	43	7	13	10	2	18	2	22	22	17	6	1	5	20	10	26	5	3	21	23	1	43,48%
subject5_2_result.mat	44	11	4	7	1	12	24	16	25	2	13	2	11	1	9	24	10	26	2	12	7	13	37	30,43%
subject6_8_result.mat	24	16	13	7	13	8	5	20	23	3	19	2	26	18	15	22	3	26	5	13	3	23	27	65,22%
subject6_4_result.mat	24	16	4	7	13	7	5	16	20	2	20	2	26	1	23	29	4	26	5	8	13	23	32	56,52%
subject6_2_result.mat	24	16	4	7	9	1	6	18	4	4	22	2	26	22	11	8	10	12	25	17	18	23	9	43,48%
subject7_8_result.mat	24	16	4	7	13	1	5	4	23	3	22	2	26	1	22	22	10	26	5	13	2	23	37	91,30%
subject7_4_result.mat	24	16	4	7	6	12	5	4	23	3	22	2	27	1	23	22	10	19	10	13	3	23	7	73,91%
subject7_2_result.mat	24	16	4	7	12	1	5	4	17	19	22	22	24	1	22	23	10	26	21	13	3	23	37	65,22%
subject8_8_result.mat	24	16	4	7	13	1	5	4	23	3	22	2	26	1	23	22	10	26	5	13	3	23	37	100,00%
subject8_4_result.mat	24	16	4	7	13	1	5	4	23	3	22	2	26	1	23	22	10	26	5	13	3	23	37	100,00%
subject8_2_result.mat	44	16	4	7	7	1	5	15	13	3	22	2	26	1	6	22	10	26	7	13	4	23	37	69,57%
subject9_8_result.mat	24	16	4	7	13	9	5	7	23	3	22	2	26	2	23	22	10	13	5	4	4	23	27	69,57%
subject9_4_result.mat	37	16	4	7	13	1	5	4	23	3	22	5	26	50	19	23	10	26	29	8	1	36	37	60,87%
subject9_2_result.mat	10	20	4	12	4	11	5	5	23	2	29	2	26	1	12	36	20	26	9	13	24	31	37	39,13%
subject10_8_result.mat	24	16	4	7	13	11	5	4	23	3	22	2	26	1	23	22	10	26	5	13	3	23	37	95,65%
subject10_4_result.mat	24	16	33	7	13	1	5	22	23	3	22	2	26	1	23	22	5	26	5	14	3	23	37	82,61%
subject10_2_result.mat	24	41	20	11	13	1	8	4	6	2	34	3	26	1	21	22	10	26	12	2	3	25	37	47,83%
subject12_8_result.mat	24	16	4	7	13	1	5	4	23	3	22	9	26	1	23	22	10	18	5	4	13	23	37	82,61%
subject12_4_result.mat	31	13	4	6	13	1	5	20	23	14	1	2	26	1	23	6	10	29	5	17	3	23	37	60,87%
subject12_2_result.mat	31	16	2	4	13	1	5	17	8	3	22	22	26	39	33	22	10	18	5	19	3	23	37	56,52%
subject13_8_result.mat	24	16	44	7	7	1	1	4	23	1	22	2	26	1	23	11	10	26	4	1	3	23	37	69,57%
subject13_4_result.mat	24	16	4	7	13	13	5	2	22	3	22	2	26	34	24	39	10	26	5	18	3	23	37	69,57%
subject13_2_result.mat	24	19	4	7	9	2	19	2	3	3	36	2	6	8	6	7	10	3	6	8	21	23	37	34,78%
subject14_8_result.mat	24	25	4	9	13	1	5	10	25	3	22	2	24	1	23	22	10	14	20	5	3	22	37	60,87%
subject14_4_result.mat	23	20	8	7	13	1	4	15	23	3	22	8	17	1	23	22	10	26	5	22	3	23	23	60,87%
subject14_2_result.mat	21	16	4	7	8	1	5	17	13	4	22	2	32	1	23	22	5	11	8	2	24	23	36	47,83%
subject15_8_result.mat	24	16	4	7	13	1	5	17	23	3	22	2	10	1	23	22	10	26	5	19	14	23	37	82,61%
subject15_4_result.mat	10	16	4	7	13	1	5	16	23	3	19	2	16	1	23	22	4	16	5	1	23	1	37	60,87%
subject15_2_result.mat	24	14	4	7	13	1	5	18	23	2	13	2	7	4	23	20	39	5	5	19	3	23	20	52,17%
	75,00%	77,78%	80,56%	86,11%	69,44%	72,22%	80,56%	27,78%	58,33%	63,89%	75,00%	75,00%	69,44%	77,78%	58,33%	63,89%	75,00%	63,89%	63,89%	25,00%	58,33%	83,33%	72,22%	

Fig. 4. Control accuracy results for 12 different subjects and all interface masks. A green color (light gray) coded cell represents a control accuracy of 100%. All other accuracies are indicated in red color (dark grey). The numbers presented in the cells represent the actual correct decisions. The top most rows indicate the total number of decisions per mask. The right most column indicates the total accuracy for the individual subject for all tasks. The last row indicates the accuracy of one specific interface mask over all subjects.

text chats, voice chats and gestures. Hence also handicapped people could participate in Second Life like any other user if an appropriate interface were available. Therefore a P300 controller was interfaced using a Second Life (SL) controller in C++ Simulink S-functions.

In order to participate in sending tweeds and Second Life appropriate interface masks were designed and the P300 base system from Fig. 2 was modified accordingly. The upper panel in Fig. 5A shows an UML diagram of the actions required to use e.g. the service Twitter. Hence the standard P300 spelling matrix based on a 6 x 6 characters matrix was enhanced to provide the necessary commands. Therefore the first two lines contain now the symbols representing corresponding Twitter services and the remaining characters are used for spelling purpose. The matrix contains now a total of 54 characters. Initial training of the system was done for 10 characters. Then another user was asking questions via Twitter and the BCI User had to answer different questions on every other day. Therefore in total the BCI User had to use the interface on 9 different days and selected between 6 and 36 characters every day. Interesting is to compare the beginning with the end of the study. The first session lasted 11:09 min and the user spelled 13 characters, but made 3 mistakes. The user had the instruction to correct any mistake and this yielded to an average of 51 seconds selection time per character. In comparison to the last session the user spelled 27 characters in 6:38 min with only 1 mistake and an average selection time of 15 seconds per character. Also the number of flashes per character was reduced from 8 to only 3 flashes to increase the speed.

For the control of Second Life and similarly to the virtual smart home control three different interface masks were developed. The lower panel in Fig. 5B displays a screenshot of a Second Life scene and the main mask as shown having 31 different classes to select from. Other masks for control like 'chatting' (55 classes) and 'searching'

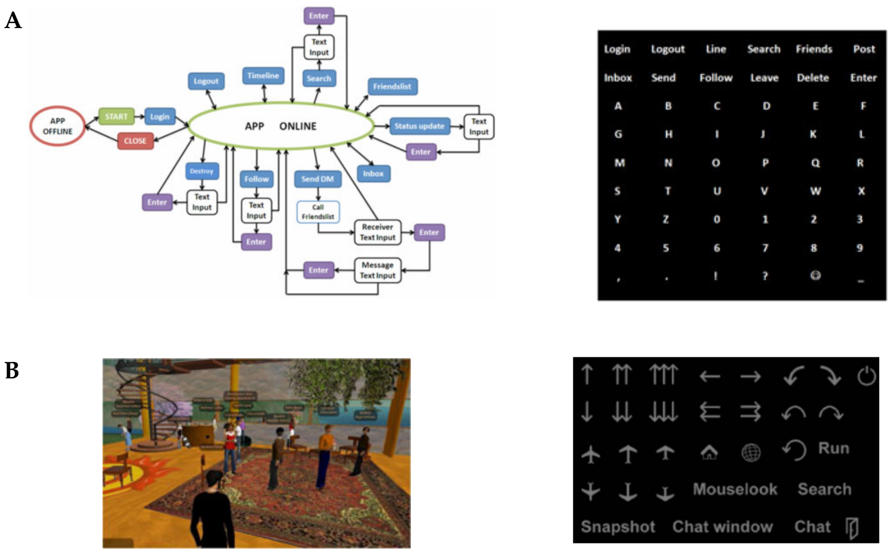


Fig. 5. Upper panel A: UML diagram of service Twitter and P300 - Twitter interface mask for control. Lower Panel B: Screenshot of Second life situation and Second Life interface main mask to walk forward/backward, turn left/right, slide left/right, climb, teleport home, show map, turn around, activate/deactivate running mode, start/stop flying, decline, activate/deactivate mouselook view, enter search mask, take snapshot, start chat, quit and stand-by.

(40 classes) were developed. Each of the icons represent an actual command associated with it. If a certain icon is selected, Second Life is notified to execute this individual action with actually using keyboard events. The Second life control and performance has been tested in first setups and preliminary results indicate a very similar performance to the virtual smart home scenario.

4 Conclusion and Outlook

BCI enabled control and communication is a new skill a subject has to learn. In an initial adaptation phase the BCI system is trained to the specific subject's brain activity. In addition the subjects have to get used and adapt to the BCI system as well. The time needed for a subject to adapt to the system is by far shorter in exogenous BCIs like P300 approaches. Such BCI systems yield higher accuracies in a higher number of subjects and give therefore for control purposes more reliable results. However, subjects have to look at flashing or flickering light sources or pay attention to tactile stimulations. Hence external stimulations might interfere to daily life situations and may distract subjects from other ongoing activities.

Table 1. Questions and text input with the TWITTER BCI system.

Tweets	No. Char	Duration [mm:ss]	Errors	No. Flashes	Time per character [s]
Friend: Which kind of Brain-Computer Interface do you use?					
BCI: P300 GTEC BCI	13	11:09	3	8	51
Friend: Are you using the g.GAMMAsys?					
BCI: Exactly!	7	06:18	1	8	54
Friend: Active or passive electrodes? For explanation: the active system avoids or reduces artifacts and signal noise.					
BCI: Active electrodes	17	06:10	0	5	22
Friend: The mounting of the active system is very comfortable. You do not need to prepare the skin first, do you?					
BCI: you are absolutely right	24	08:55	1	5	22
Friend: How many electrodes are needed to run the BCI?					
BCI: For P300 we usually use 8 electrodes	36	14:21	2	5	24
Friend: What amplifier are you using for the Brain-Computer Interface?					
BCI: g.MOBIlab+	10	04:42	1	5	28
Friend: How long does it take to code the software for the BCI for **TWITTER?**					
BCI: 3 Weeks	7	03:13	1	4	28
Friend: How many characters are you able to write within a minute?					
BCI: 3 TO 4	6	03:15	0	5	33
Friend: Did you get faster in writing during this period?					
BCI: Yes, from 2 to 4 characters	27	06:38	1	3	15

One of the most consistent observations in BCI literature is the fact that a certain percentage of the population cannot operate a specific type of BCI due to various reasons. Inter-subject as well as intra-subject variability often leads to a so-called BCI illiteracy [10;15;20;21]. Across the different BCI approaches around 20%-25% of subject are unable to control one type of BCI in a satisfactory way. Therefore, the usage of 'hybrid' BCIs has been introduced using the output of somato-sensory rhythm BCI as well as P300 or steady state visually evoked potentials based BCIs [22;23] enabling subjects to choose between these different approaches for optimal BCI control. A study of Hong et al. [24] recently did a comparison of an N200 and a P300 speller (tested on the same subjects) and found similar accuracy levels for both of them. This gives evidence that a closer look to the N200 component could be promising, at least for some subjects. Hence BCI illiteracy could be overcome or maybe minimized by investigating more thoroughly subject specific preferences. Designing the interface masks in a more proper way can improve the usability and success rate in BCI. Hence the quite bad control results for all subjects for the specific Goto control mask in the virtual environment can be explained rather by the layout and contrasts used in the mask than the number of icons. The group of Kansaku reported about the improvement of BCI P300 operation using an appropriate color set for the flashing letters or icons [25]. The different applications discussed in the manuscript yielded consistent results: (i) characters and icons/symbols can be used in a similar way to setup and operate different interface having quite different complexity; (ii) an average classifier can be utilized for many subjects right from the beginning to operate a BCI minimizing system calibration and training time and (iii) the experience from the virtual environment can be utilized in real world applications.

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Tactile Hand Gesture Recognition through Haptic Feedback for Affective Online Communication

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Abstract. Our study explores how individuals communicate emotions using tactile hand gestures and provides evidence supporting the link between emotions and gestures to investigate the usability of tactile hand gestures for emotional online communication. Tactile hand gestures are used as the source of information to get to emotions. In this study, behavioral aspects of tactile hand gestures being used for emotional interaction are observed through a sensory input device and analyzed using analysis of variance (ANOVA). In user experiments, subjects perform tactile hand gestures on the sensory input device in the response of a list of distinct emotions (i.e. excited, happy, relaxed, sleepy, tired, lonely, angry and alarmed). An analytical method is used to recognize gestures in terms of signal parameters such as intensity, temporal frequency, spatial frequency and pattern correlation. We found that different emotions are statistically associated with different tactile hand gestures. This research introduces a new way of creating online emotional communication devices that approximate the use of natural tactile hand gestures in face-to-face communication.

Keywords: Tactile hand gesture recognition, affective communication, haptic interface, and tactile stimulation.

1 Introduction

Touch, central to emotional communication, is the simplest and the most straightforward of all sensory systems [1] and it has been described as the most fundamental means for people in contact with the world [2]. It is also capable of communicating and eliciting emotions [3]. Tactile gestures exhibit the natural capability and tendency of humans to move their hands to express and communicate emotions. In particular, in emotional communication, tactile hand gestures arouse human emotions through touch. In face-to-face communication, gestures cover a wide range of non-verbal communication including body language, facial expressions, hand gestures, and sign language. Among these various types of gestures, tactile hand gestures are one form of communication using the sensory modality for touch.

Tactile hand gestures are a natural social tool of expressive behavior that describes emotions and situations in human social life. A gesture is a motion of the body that contains information [4]. For example, soothing someone's arm is a tactile gesture. We can communicate the emotion through the 'soothing act'. Such tactile hand

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gestures are commonly used in face-to-face communication. Their use, however, is limited in the era of online communication environment.

To enable on-line communication that approximates a face-to-face interaction, human computer interaction (HCI) and affective computing researchers have converted emotional messages into the form of text, voice, and video [5], [6]. In these studies, the authors have discussed an integrated physical, intellectual and social experience to incorporate the aspect in design for emotional interaction. Other researchers have designed and developed a mobile emotional messaging system named eMoto to enable affective loop experiences [7]. The previous studies of affective computing indicate that the aim of communication should be to design embodied interaction that harmonizes with our everyday practices and everyday bodily experiences.

Method of expressing emotions through hand gesture: expressive gestures are used as a method of expressing emotions through hand gesture to control a device. Literatures focus tactile interface and haptic device. 'pin alarm' by Hellman and Ypma allows for setting the waking up time with meaningful expressive actions. By pushing as many pins as possible you indicate that you want a lot of sleep and by pushing them one by one you indicate a more urgent situation. Yet the design needs additional feedback to communicate understanding. Other designs have snooze buttons with pressure sensors that elicit pushing, stroking or slamming. Yet these expressive actions offer no feedback to a person [8].

Recently, researchers have also employed various sensory modalities that enable affective online communication through interactive media. Especially, researchers have developed a wearable tactile interface that attempts to encourage humans to share their emotions seamlessly through online digital communication methods. These emotional communication techniques, however, require an explicit process of conversion from emotions to predefined formats such as human/computer languages and symbols. In contrast, tactile hand gestures are a natural and intuitive way to express personal emotions and situations [9].

Our research focuses on the study of tactile hand gestures for the use in affective online communication. We are interested in determining how emotions affect the motion of tactile hand gestures and how we can code different emotions with tactile hand gestures in devices for online communication. The aim of this study is to better understand the relationship between hand gestures and emotions. In addition, from this research we expect that the relationships between touch hand gestures and emotions are determined. Finally, we suggest applying this research to prototype called emotion communication device in future work section. We expect prototype validations show that the gesture-to-emotion conversion can be used to enable the emotional interaction between humans in distance through a new media. The authors argue that emotions and actions are closely intertwined and provide an answer to the following question: can we communicate and decode distinct emotions with tactile hand gestures through on-line communication devices in a similar way that we do in face-to-face communication?

2 Approach

The aim of this study is to analyze the relationship between human emotions and corresponding tactile hand gestures, especially those performed with the fingers. To analyze this relationship, we obtain tactile hand gesture signals by asking participants to express their emotions while they are holding and interacting with a wearable tactile user interface device shown in Fig. 1. The device imitates the shape of a human arm so that subjects in the experiment perform their hand gestures as they express their emotions on human arm such as dragging, shaking and squeezing.

The participants are asked to perform tactile hand gestures on the interface device in response to distinct emotions (i.e. excited, happy, relaxed, sleepy, tired, lonely, angry and alarmed) requested by the researchers. The list of distinct emotions is defined by Russell's *dimensional model of emotions* to be described in Section 2.1 [9]. Russell's model is widely used as the means of emotion classification in the fields of emotional research and affective science. The tactile interface device records hand gestures exerted on the device in terms of signal parameters such as intensity, temporal frequency, spatial frequency and pattern correlation. Distinct tactile hand gestures are determined by a combination of these four signal properties to be described in Section 2.2.

Fig. 1. Proposed wearable tactile interface device facilitating touch sensor arrays

We analyze the recoded hand gestures and their corresponding emotions using a statistical analysis method called multivariate analysis of variance (MANOVA) to find the statistical relationship between the participants' emotions and their tactile hand gestures. The study results showing the relationship between the two are summarized in terms of a look-up table to be used in potential applications such as online emotional communication.

2.1 Type of Emotions

Theory of emotion is mostly based on cognitive psychology but with contributions from learning theory, physiological psychology, and other disciplines including philosophy [10]. Among many proposed models of emotion, the emotional states of the subjects in our research are defined based on Russell's dimensional model, named the *circumflex model of affect*, as shown in Fig 2. In this model, Russell provides the mental map of how emotions are distributed in a two-dimensional system of coordinates where the y-axis is the degree of arousal and the x-axis is the valence and categorizes emotions in terms of pleasure and arousal.

- *Pleasure*: mental state of being positive.
- *Arousal*: mental state of being awake or reactive to stimuli.

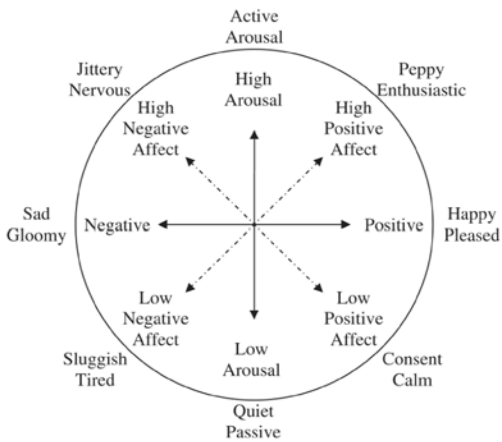


Fig. 2. Russell's dimensional model of emotions

2.2 Model of Tactile Hand Gestures

Gestures are defined as nonverbal phrases of actions [11], describing explicit, symbolic or representational cues revealing cognitive properties [12]. Gestures involve a wide range of nonverbal human communication, which include body language, facial expressions, hand gestures, and sign language. To define the types of tactile hand gesture, we propose a new model that consists of four tactile signal properties as summarized below.

- *Intensity*: the degree of contact pressure.
- *Temporal frequency*: the number of occurrences of contact per unit time.
- *Spatial frequency*: the number of occurrences of contact per unit distance.
- *Pattern correlation*: the vector correlation between input gestures and pattern symbols such as circle, cross, line, etc.

2.3 Mapping between Emotion and Tactile Hand Gesture

This study is to observe which type of hand gestures the participants perform in a particular emotional situation and to obtain statistically significant data that prove a possibility of tactile hand gestures' communication in online environment. Participants' tactile hand gesture inputs in experiments are critical for the analysis of human emotions and furthermore for developing our tactile communication device. In Section 2.1 and Section 2.2, the model parameters of emotions and gestures are provided. Based on these models, the statistical relationship between emotional parameters and corresponding gestures is found by using the collection of statistical models, analysis of variance (ANOVA). The resultant data are applied to finding the model-based statistical parametric mapping between the emotional domain and the hand touch gesture domain.

3 Experiments

Behavioral aspects of tactile hand gestures being used for emotional interaction are observed and analyzed using a wearable tactile interface device shown in Fig. 1. In the response of a list of distinct emotions (i.e. excited, happy, relaxed, sleepy, tired, lonely and angry), subjects perform tactile hand gestures are performed on the tactile interface device. As we aim to make the subjects emotionally involved in a physical sense, it is important that the gestures we pick are not singular, iconic or symbolic gestures, but gestures that give rise to a physical experience that harmonizes with what the user is trying to express.

The wearable tactile interface device is designed to recognize gestures in terms of various sensory parameters such as intensity, temporal frequency, spatial frequency, and pattern correlation. The device facilitates a multi-touch panel (touch area dimension: 52 x 35 mm^2) and its associated electronics (controller board), which are shown

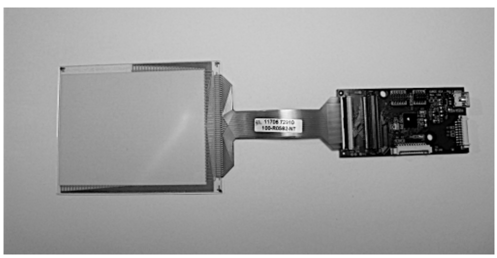


Fig. 3. Multi-Touch demonstration and evaluation kit

Fig. 4. Eight distinct emotions indicated in the Russell's emotion chart

in Fig. 3. The controller board is used to transfer the x-y axis and intensity data of contact points to analysis software. The obtained pressure data is analyzed for the correlation between emotions and gestures using the analysis software. The groups in the gesture domain are mapped to those in the emotional domain.

3.1 Setup

The research sample set consists of 70 participants, who range in age from 20 to 40 years old (23.15 years old in average), from libraries at Georgia Institute of Technology and public libraries in Georgia. 35 are female and 35 are male out of 70 participants. Participants are selected from those who actively use hand gestures to express their emotions. 10 seconds are given for each gestural expression and participants are asked to express the eight types of emotion. The experiment takes 10 minutes per participant.

The wearable tactile sensor interface with pressure sensor arrays implemented on its surface is used as a sensory input device. The researcher introduces to participants the Russell's dimensional model of emotions. Eight distinct states of emotion indicated on the Russell's emotion chart shown in Fig. 4 are expressed by applying finger gestures to the tactile interface device. Each emotion: (1) excited; (2) happy; (3) relaxed; (4) sleepy; (5) tired; (6) lonely; (7) angry and (8) alarmed, leads participants to express the emotions which are analyzed by parameters in Russell's dimensional model (Participants may perform tactile hand gestures such as soothing, pummel, hitting, and squeezing). The obtained pressure data from participants' gestures are then analyzed using ANOVA. Fig. 5 shows finger pressure points detected by the tactile interface device that measures pressure by detecting contact area. Based on the pressed area, the sensor calculates the pressure data in 256 levels. The tactile interface device is also available to monitor the position of finger contact points. Multi-finger movements are tracked with cursors.

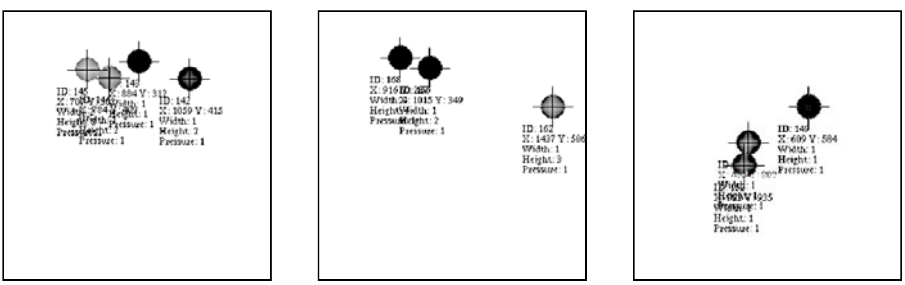
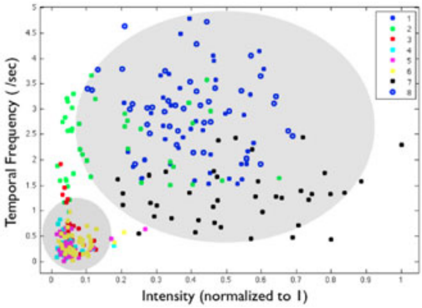


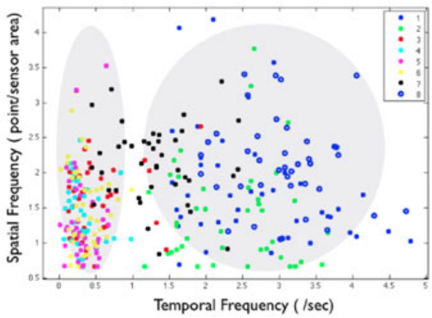
Fig. 5. Contact area based pressure detection of the touch sensor panel

3.2 Results

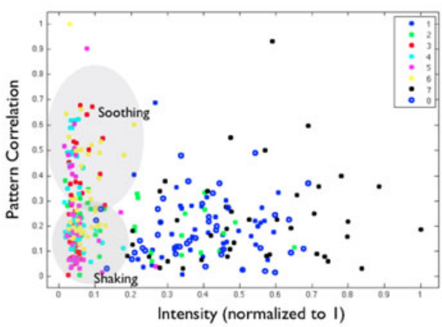
The user research using the wearable tactile sensor device provides us evidence of the relationship between tactile hand gestures and emotions. To assess the relationship, we determined the correlation between the signal properties of tactile gestures and the emotional states by performing ANOVA for recorded tactile data.



(a) Contact area based pressure detection of the touch sensor panel.



(b) Tactile gesture scatter plot: temporal frequency vs. spatial frequency.



(c) Tactile gesture scatter plot: intensity vs. pattern correlation.

Fig. 6. Tactile gesture scatter plot: (1) excited; (2) happy; (3) relaxed; (4) sleepy; (5) tired; (6) lonely; (7) angry; and (8) alarmed

The balanced one-way ANOVA of the obtained tactile gesture sample data was performed for the signal properties: (a) intensity; (b) temporal frequency; (c) spatial frequency; and (d) pattern correlation. Very small *p* values for all the four signal properties that are obtained from ANOVA ($p_{(a)}$ = 2.08e-82, $p_{(b)}$ = 1.76e-111, $p_{(c)}$ = 4.88e-13, $p_{(d)}$ = 3.99e-4) indicate that at least one emotional sample mean is significantly different from the other emotional sample means. The type of emotion whose sample mean is significantly different from the other can be statistically distinguished and decoded from the other emotional states by observing the corresponding property of tactile gesture sample data. As shown in Table 1, the tactile gesture corresponding to angry emotion contains the mean value of intensity significantly higher than that of the other emotions. The mean value of temporal frequency corresponding to alarmed emotion is higher than that of the other emotions. However, spatial frequency and pattern correlation show less significant distinction in their mean values among the various emotions.

Each 2-dimensional scatter plot shown in Fig. 7 displays the gesture sample data in two tactile signal properties out of eight. As shown in Fig. 7(a), the emotion group of (1) excited, (2) happy, (7) angry and (8) alarmed, which corresponds to high arousal according to Russell's dimensional model, are related with gestures with high intensity and high temporal frequency. In Fig. 7(b), the distributions of gesture samples in spatial frequency do not vary much among various emotions. However, gesture samples associated with happy emotion are placed low in spatial frequency as compared to those with excited, angry and alarmed. Fig. 7(c) shows that the emotion group of relaxed, sleep, tired and lonely is associated with patterned gestures such as drawing circles and lines. By observing pattern correlation values, this emotion group can be distinguished from the others. However, this procedure requires detailed pattern analysis for accurate decoding, which is the future work of this study.

The emotional state of anger, which corresponds to high arousal and displeasure according to Russell's dimensional model, is related to tactile signals of high strength and low temporal frequency. The results also show that the emotional state of happiness, which contains high arousal and pleasure, corresponds to tactile signals of high spatial frequency and high temporal frequency. In addition, the duration of hand gestures is extended when people express amplified emotional states compared to subtle emotional states.

Table 1. Mean and standard deviation of tactile gesture samples

	Intensity		Temporal Freq.		Spatial Freq.		Pattern Correlation	
	μ	σ	μ	σ	μ	σ	μ	σ
Excited	0.41	0.11	2.7	0.90	1.8	0.81	0.19	0.13
Happy	0.17	0.16	2.3	0.69	1.4	0.72	0.21	0.12
Relaxed	0.052	0.024	0.50	0.40	1.7	0.58	0.26	0.19
Sleepy	0.049	0.030	0.31	0.20	1.4	0.44	0.29	0.18
Tired	0.054	0.044	0.31	0.17	1.3	0.62	0.24	0.19
Lonely	0.074	0.040	0.37	0.21	1.5	0.54	0.34	0.19
Angry	0.53	0.21	1.3	0.55	2.1	0.55	0.23	0.18
Alarmed	0.39	0.15	3.1	0.67	2.2	0.69	0.19	0.12

3 Conclusion

In this research, the types of tactile hand gestures are categorized in terms of tactile signal properties and related to distinct emotions that the gestures originate from. The findings from this investigation show opportunities and promises to use tactile hand gestures for the communication of emotions among people using online digital communication devices at a distance. From user experiments, we found that different emotions are statistically associated with different tactile hand gestures. However, the aspect of pattern correlation as one of tactile gesture properties needs to be further investigated to uncover more gesture information and to better define gesture-emotion relation. In future study, the relationship between touch hand gestures and emotions will be applied to emotional online communication devices, and a prototype design of wearable online tactile communication devices will be demonstrated.

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Gesture-Based User Interfaces for Public Spaces

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Abstract. Gesture-based approaches are becoming an increasingly popular technique in Human Computer Interaction. Recent developments in the hardware field have made it more affordable and more reliable to use gesture-based interfaces and they are becoming more of a standard way for human users to interact with computers. Most of the research has been investigating the usage of gestures in personal and limited access situations. But gesture interfaces are promising great benefits to usage scenarios in public spaces or general access environments. This paper will summarize and evaluate the particular aspects of using gesture-based interfaces in application contexts in public and semi-public spaces.

Keywords: Gesture-based Interfaces, Alternative reality environments, Human Computer Interaction, Wearable interfaces, Proxemic interaction

1 Introduction

The field of Human Computer Interaction has seen a paradigm shift towards so called "natural interfaces" in the recent years moving away from the standard of keyboard and mouse-based interfaces towards alternative interaction approaches. The term "natural" in this context refers to interfaces that replace the input of commands into a command line interface or the usage of interface devices such as pointing devices and keyboards by communication means that are more close to the ways human beings communicate in general and thus feel more natural [1], [2]. A common area to look for naturalness is interpersonal communication and the means people use to communicate with each other. The ideal for natural communication is direct, device-free communication, which means speech and gestures, while device-mediated forms of communication are regarded as less natural [3], [4]. Reliable speech recognition is a complicated problem stemming from the difficulty of mapping the sound phenomenon to linguistic elements and the extraction of meaning from those elements. This problem field has been researched for more than 50 years and it still remains difficult to resolve ambiguities in spoken language [5]. Compared to the advances made in speech recognition-based interface technologies, gesture processing has seen a number of recent breakthroughs that made gesture-based interfaces significantly more powerful and popular. The successful launch of the *Kinect* controller was just one of the inventions that started a widespread attention towards gesture interfaces. The *Kinect* game controller is a computer-vision-based controller that allows to capture

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and interpret body movements and gestures from users with a depth camera enabling gesture recognition with a degree of reliability and precision that has been so far not been achieved with solely computer-vision-based approaches. Integrated into a game console, this controller became a successful mass-product making gesture recognition a widespread and affordable technology. Since its launch the *Kinect* was sold 8 million times [6] and it was compared to the legendary gestural interface that made its appearance in the 2002 movie “Minority Report” [7]. Before the *Kinect* another gesture-oriented game controller had a very successful release: The *Wii Remote* was released in 2005 and sold 6.29 million only in the year 2007 [8]. Other popular devices were the *iPhone* and *iPad* with their gesture-oriented touch screen controls allowing to “flick” tough pages, “pinch to zoom” etc. Compared to the *Kinect* the other interface systems do not operate device free – the user has to hold or touch the controller – but they are part of a strong movement towards so called natural human interfaces, which Steve Ballmer, the CEO of Microsoft characterized as a key part of the fifth revolution in computing technology in his 2008 keynote of the consumer electronics show CeBIT 2008 [9].

With this strong emphasis on gesture interfaces as a successful approach to natural user interfaces, this paper will look at the implications and possibilities of implementing gesture interfaces in public spaces and in particular in museum or gallery spaces, which we consider semi-public spaces. If we understand public space as a space that is accessible to everybody without any restriction such as access control, fees etc. we would normally think of public streets, squares and the like. In the scope of this text we will include places that are accessible to a large public without requirements such as the membership in a specific group, race or similar criteria. We will consider this valid for public museums, shopping areas etc. While this definition will not be able to qualify public space from a sociological point of view, it allows us to analyze certain usage patterns that are addressed by human computer interaction. What we will exclude from this study are non-geographic public spaces that solely exist in a form mediated through interfaces such as shared online spaces.

Human computer interaction that takes place in public spaces can benefit significantly from gestural interfaces, specifically because they allow unencumbered, device-free interaction. In this regard gesture oriented interface technologies seem more suitable than other techniques [10]. It is it promising to investigate them for several reasons:

1. As a key technology of natural user interfaces they are suitable to implement intuitive interface solutions that are easy to understand and do not require complex skills to be used successfully.
2. An increased familiarity of the audience thanks to those recent successes mentioned above will support the ease of use.
3. There is a potential to reduce maintenance cost due to less or no mechanical parts exposed to the public.
4. With the mass-market introduction of gesture interface technologies the price of deployment is significantly reduced, which formerly was prohibitively high [11].
5. Gesture interfaces – in particular computer-vision-based implementations – allow for seamless engagement: The user can walk into the active range of

> the interface and start interacting before he even realizes and from there start to explore gradually deeper levels of engagement.

The paper will review existing implementations of gesture-based interfaces in public and semi-public spaces and examine their benefits and problems compared to other implementations. It will close with a set of research agenda and evaluation criteria to improve the performance and accessibility of future implementations.

2 Evaluation Criteria

The design of interface technologies for the public space has a number of specific requirements that differ from other task-oriented applications in private usage scenarios. Most interface design criteria are formulated for single-user, non-public settings supported by interface devices such as keyboard, mouse, or even *Wii Remote*. It is in the nature of the control-device that it can only be handled by one user at a time. And even though gesture interfaces lend themselves inherently to more open interaction scenarios, a lot of research still focuses on single-user applications and non-public environments [12], [13]. Some research also targets multi-user systems, in particular with the depth camera technology that is part of the *Kinect* controller, which was explicitly developed to have multi-user capabilities and thus allow for collaborative gaming experiences [14]. This research has generated several guidelines for successful interface design in the domain of gesture-based interfaces as exemplary outlined by Nielsen et al. [15]:

- Easy to perform and remember
- Intuitive
- Metaphorically and iconically logical towards functionality
- Ergonomic; not physically stressing when used often

These criteria hold true also for situations in public space, but need to be extended in order to address some of the specific requirements. In public space it is essential for interfaces to have a steep learning curve. The development of engagement with an application or experience (we will refer to the task that is experienced by the user through the gesture interface as *application*, even though this term implies a task orientation, which might be questionable terminology in an educational or entertainment oriented experience) is different than in most task-oriented applications experienced in non-public environments. While in the latter users generally approach the application with the intention to engage and use it to solve the task at hand (such as write a text with a word processing application or play a game on a game console), in public environments that engagement is often spontaneous as the user encounters the application. Between engagement and non-engagement may be only a very short time of examining the application. In this sense it is vital that the first approach already enables the user to successfully engage into controlling the application and require an easy interface approach that can be grasped very quickly to not deter the user from engaging. Over the time of engagement – once the user made the decision to stay with the application for some time – a certain amount of practice and newly learned skills will establish. In general, though, the learning curve should be steep and then plateau with only little new information learned in terms of operating the application [16]. This kind of phase-staggered engagement can be supported by an appropriate design of the interface complexity allowing the user to ease-into the experience, through the aesthetic appearance that is attractive and accessible to the user, by making the application responsive so that it can sense and respond to the presence of a user, as well as through an appropriate spatial set-up. The spatial characteristics should make the user feel comfortable to spend time in this space, it should be easy to find or enter, and it should make it easy for the user to identify potential tools and positions etc [17]. This can mean different things depending on the application and where it is set up. It is important to mark the space that belongs to the application, i.e. the area that is tracked and thus registering input versus the areas that are not. We often see installations that use projected images set up in "black boxes" in order to keep ambient light controlled and improve the quality of a projection. The light traps that are used with those installations force the user to walk through a dark corridor and constitute a high threshold potentially inhibiting engagement with the application. The user has to go through this corridor and decide to engage before even knowing much about the application at the interior.

Several studies (i.e. Nielsen et al. as mentioned above) have investigated aspects of appropriateness of gestures, such as the relationship of the gesture and the meaning that it stands for (arbitrary versus iconic relationship etc.). A particular criterion arising in public spaces is appropriateness whether a user feels comfortable enacting a certain gesture. As the users are potentially seen by other users, they should not feel embarrassed or uncomfortable carrying out the gestures. Also, gestures can be disruptive in a space shared with other users [18].

3 Example Interfaces

In a short review of some interface systems we will examine exemplary implementations in respect to how they address the above-mentioned criteria. The list of implementations will at the same time revisit several historic steps, but given the scope of the text, it does not claim to be exhaustive. Only applications that use device-free interaction are included.

3.1 Responsive Environments

One of the early implementation of an application that responds to the presence of a user in order to engage him into an interaction is the so-called "responsive environment" *Glowflow*, created by the American artist Myron Krüger. *Glowflow* originated in 1969 as the first application of a series of works that respond to the presence of a user and change their states accordingly. The interaction is carried out by entering the environment deeper and exploring it. In the installation the user steps on sensitive mats that communicate his location to the controlling computer, which then triggers changes in the illumination of the room and the sound created in real-time by a synthesizer. A successor to this work was the installation *Metaplay*, which used instead of the phosphorescent tube lighting of *Glowflow* a video projection of the user in conjunction with a superimposed computer-generated image [19]. Krüger describes as his main focus in these environments as "the only aesthetic concern is the quality of interaction" [19]. Both installations are examples of responsive environments that sense the user and respond to his presence to invite him and draw him into further interaction. The level of complexity of triggering these first state changes of the application system is extremely easy and is done without the user even noticing it. Only based on the response from the system he realizes that he already interacts and is motivated to find out more. We can call such an interface approach "explorative" as the user is invited to explore the system and through this kind of engagement the system reveals its content as well as its interaction methodology.

The notion of a responsive environment has been taken up in later applications. We find a similar approach in a much more recent application by the French artist Marie Sester called *Access* [20]. In the *Access* installation users walk into the range of an overhead computer-vision camera and get tracked by the system. As they get tracked, a spotlight follows them around in the space along with a focused sound projection. The system is construed again in such a way that the interaction starts without the user noticing it, simply by walking into the range of the tracking system the user starts to interact and then realizes the response of the system. The tracking system receives input also from remote users through a web interface where they have access to the imagery captured by the tracking system and are able to select the target to track.

The responsive environments from Krüger were all installed in a gallery space – a semi-public space. Due to the intensive technological preparation of the space it is almost impossible to show these applications in an openly accessible space. Pressure sensors have to be mounted on the floor, the video capturing requires a neutral background, and the interaction system can only present meaningful feedback to a limited amount of users in the system because in case there are too many users the readability of the feedback becomes difficult and state changes are hard to attribute to specific interactions. The *Access* system is more suitable to be presented in an open access public space and is referred to as an installation traveling from "one public space to another" [20], as it provides a seamless entry and exit from the experience and the bounds of the sensitive area are marked by the spotlight.

The type of application described with the help of the above mentioned examples provides a good solution towards the question of seamless development of user engagement with the application and provides a certain possibility to explore the application through continued interaction. While the learning requirements for the user to be able to successfully control this type of application are small, the range of possible interactions is limited to triggering changes in illumination of installed light sources or attracting the spotlight.

3.2 User Representation

A different approach has been followed in a type of application that provides a more complex representation of the user and his interactions with the system. A later application developed by Myron Krüger in 1970 is the *Videoplace* system. Here the image of the user is captured by a camera and shown as a silhouette in a projection [21]. The silhouette image is combined with superimposed computer graphics images of small objects as well as a representation of remote users. The silhouette image and the superimposed images of small objects etc. interact, the objects for example can bounce off of the contour line of the user's silhouette. The system reflects a representation of the user like a mirror and there is an easily understandable mapping of interactions to state changes of the system. With this very direct representation of the user and his influence on the application it is possible to realize a potentially more nuanced set of interactions while preserving the ease of engagement and the possibility to explore the application's functionality through continued engagement.

This approach has also been picked up in a range of applications installed in gallery settings as well as shopping malls and other semi-public spaces. An example for a later implementation is the installation *Bubbles* by Wolfgang Münch and Kiyoshi Furukawa made in 2005, where users see their silhouette interacting with virtual soap bubbles that bounce off of the silhouette outline [22]. Similar installations can be found in science centers (e.g. TELUS World of Science, Vancouver, Canada) or shopping malls (e.g. Glendale Galleria, Glendale, CA, USA). The ability of this type of applications involving a representation of the user in form of a reflection or a shadow to convey more complex and layered content has been observed in several test cases described by Snibbe and Raffle [17].

Most of these applications have been installed in semi public-spaces, as they require a clean projection surface that provides enough contrast and visibility of the projected image, mounting, power, and protection for the tracking equipment and some way to channel users in and out and control the amount of users at a time.

3.3 Ubiquitous Gesture Interfaces

From the previous examples it becomes clear that it is a challenge to deploy gesture-based interfaces in public space for technical reasons as outlined above. Also it seems that interaction sequences in public spaces are significantly different, shorter, and less complex than we know it from other task oriented interfaces in non-public spaces. A lot of the research that spurred the development of technologies like *Kinect* or *Wii Remote* comes from computer gaming. The focus here is on individualized long-term interaction of a comparatively high degree of complexity [23], [24], [25]. There are few examples of gesture interfaces deployed in public space that provide a complex sequence of interactions. Besides the large scale tracking interface of *Access* which is suitable for the public space we can observe the opposite movement towards small mobile mechanisms that provide gesture interface capabilities for the public space. One example is the *Traces* application that consists of a rugged integrated display and tracking device that is "left" in public space so that random passers-by can pick it up and use it. The device captures gestures and colors created by a user and responds by outputting color and motion on a flexible display. The device is intended for "transient public spaces" and presents an instance of a movement towards portable, ubiquitous gestural interfaces [26].

Another application along similar lines is the *PyGmI* interface consisting of an entirely wearable system that integrates a gesture tracker and a micro projector to generate the output of the system [27]. The tracker allows the user to communicate with the system through gestures carried out in proximity to his body. It is thus a system for individuals and not encouraging any multi-user scenarios as the tracker is targeting only the proximity around the user carrying the system.

4 Conclusion and Future Work

The examples discussed in this paper indicate that even though device-free gesture-based interfaces for the public space have great promises there are few implementations of them. The current mainstay of this interface technology is in semi-public and private spaces. We can observe two tendencies in the deployment of gestural interfaces in shared public environments: One tends to make the entire environment responsive with sensing systems covering a larger space, which can be entered, explored and exited by users in a seamless way. Examples for this are mentioned above and further comprise implementations of intelligent spaces [28] and inhabitable interfaces [29].

Several technical implications are responsible for the current distribution of gesture interfaces and the recent development in more reliable tracking methods such as the depth camera technology suggest that future development will break up the current separation between public and semi-public environments for gestural interfaces.

The discussed examples further suggest that users do not tend to engage into interaction of high complexity and spend less time with applications in public space compared to private spaces, while the semi-public spaces are probably in the middle-ground between public and private. These issues of the complexity of applications can potentially be addressed by a meaningful staggering of different levels of engagement. User who do not want to engage simply pass by, others just have a fast glimpse at the application, while those who are ready to engage in a more extended fashion can spend time and proceed to more complex layers of the application. The notion of *proxemic* interactions [30], where this staggering of engagement is based on the distance between the user and the system is a promising approach for future applications.

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Towards Standardized User and Application Interfaces for the Brain Computer Interface

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Abstract. In this paper, we consider two obstacles preventing widespread deployment of Brain Computer Interface (BCI) technology: the lack of standardization for the user interface and the applications interface. We suggest a structure for an intuitive graphical user interface (IGUI) and propose a methodology for usability testing. A universal application interface (UAI) based on Universal Plug and Play and deployed by Open Services Gateway initiative is proposed. This issues user commands and receives device status; and communicates to the IGUI using an eXtensible Mark-up Language file containing menu definitions. Using this approach we have achieved control of simple domestic devices, using 'plug and play' technology, interaction with a set top box and media player for entertainment applications.

Keywords: Brain computer interface, graphical user interface, accessibility, universal application interface, applications.

1 Introduction

For individuals with a neuro-muscular degenerative disorder, the need for a degree of control is paramount in their lives. Neumann and Kubler [1] commented on the distress of people who could no longer participate in a BCI research programme, therefore losing the potential to communicate and interact with their environment. Much of the BCI research to date has been for a communication channel for people with significant physical disabilities, where there are limited usable assistive technologies available. Here there is a significant dilemma, as in such circumstances BCI technology is relevant to only a very limited patient population. Schalk *et al* [2] commented on this aspect:

"*BCI research up to the present has consisted mainly of demonstrations that certain brain signals recorded and measured in a certain way, and translated into control commands by a certain algorithm, can control a certain device for one or a few users*."

Systems lack flexibility and hence have few areas of application. Can we envisage a scenario where BCI can become a 'plug and sense' technology linking with applications that can be deployed as 'plug and play'? What challenges face BCI technology

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in becoming a more competitive choice of assistive technology? Table 1 illustrates current challenges in BCI, as suggested by Allison [3].

Table 1. Challenges to the deployment of BCI

BCI Challenges	**Discussion**
Recording: electrodes, use of an EEG cap, amplifier and computer	Setup requires about 20 minutes by an electrophysiological technician. The dependence on expert assistance could be reduced by more accessible recording technology.
Paradigm and parameter selection suited to the individual	Automatic tools are needed to identify the best BCI approach and parameters for each subject and develop a customized BCI accordingly.
Signal Processing	Tools are needed to identify and extract relevant features, and set operating parameters. This could further improve reliability and usability in noisy settings.
User Interface	BCIs use a simple, conventional interface that is identical for all users. An intuitive user interface is required that is much easier to learn and use, account for assistive design principles, and be customized for user.
Application Interface	BCIs are developed around only one application. Communication and entertainment tools will further enhance flexibility and usability by offering access to a much wider variety of applications
Cost	BCI hardware currently costs over $15,000 which inhibits wide scale deployment.

Within BRAIN [4], research is ongoing to address these scientific and technical challenges, which could potentially lower cost, enhance operation and promote wider uptake. In this paper, we restrict our discussion to challenges which aim to provide some degree of standardization for the User Interface and Application Interface.

In section 2, we outline the architecture of the Intuitive Graphical User Interface (IGUI) developed for BCI, and provide a human computer interaction (HCI) accessibility testing methodology. In Section 3, we provide a description of the technical details for implementing an application interface based on current standards, referred to as the Universal Application Interface (UAI). Figure 1 gives a visual overview of the interaction between the BCI, IGUI, UAI and applications. It illustrates a modular architecture in which BCI2000 provides the BCI interface supplying Universal Data Packets (UDP), the content of which can be specified by the signal processing being performed. The architecture given can support different BCI technologies and is depicted in operation with Steady State Visually Evoked Potentials (SSVEP) [5]. Light emitting diodes placed around the screen provide the visual stimulus for the protocol. Section 4 summarizes the communication between IGUI, UAI and the devices and illustrates some initial applications. In Section 5 we draw some tentative conclusions on wider application.

2 IGUI Interface Design

The intuitive graphical user interface (IGUI) offers a device control mechanism to the user that can support multiple BCI paradigms, namely SSVEP and the intended movement paradigm. It is designed to provide a framework, similar to Mason *et al* [6]. The interface acts upon a menu definition contained in an XML file which lists available domotic devices and their associated menu structures. This interface operates in conjunction with BCI actuated peripherals (see Figure 1). It is applicable to all devices in the device controller module, called the Universal Application Interface (UAI). The IGUI is also capable of handling modifications in display or operation according to user defined preferences. The UAI acts as wrapper for multiple device interaction protocols; it provides a single control interface to the IGUI, hiding the complexity of interaction.

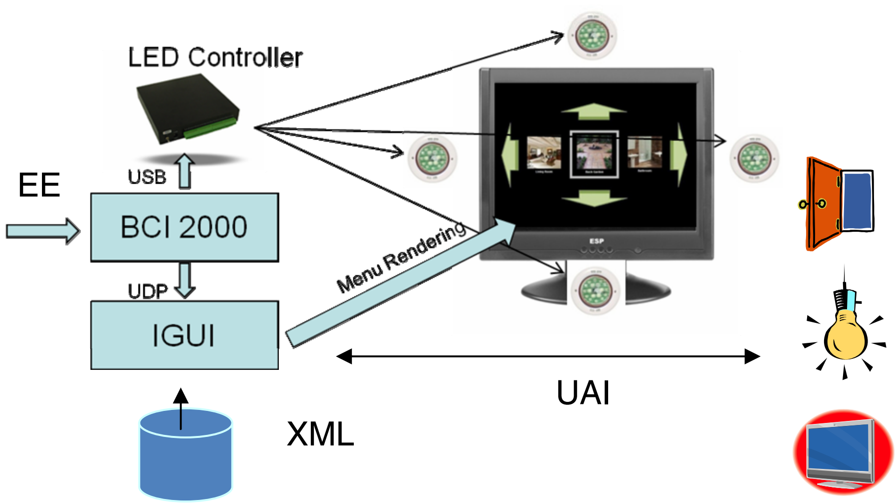

Fig. 1. System for SSVEP mediated BCI control showing Intelligent Graphical User Interface and Universal Application Interface components

BCI suffers from very low data communication rates. This presents a problem with regard to usability and hence acceptability. In Figure 1 a 4 way command choice (up, down, right, left) is illustrated but the user interface can support a 2 or 3 way command structure if this is more suitable to the chosen BCI paradigm and the user.

Navigation of a menu structure using a 4 way command is potentially faster than for 3 or 2 commands due to the reduction in overall steps to perform a task. However a paradox presents; errors may increase with the number of command choices provided by the interface if it becomes more difficult to differentiate the user's intention via the BCI. Furthermore, the cognitive load to the user must also be considered and for some users a more simplistic yet less powerful interface may provide them with a more robust and usable system overall. Finding the correct balance of interface complexity and system robustness is a multidimensional and multidisciplinary problem.

An accessibility test was designed to determine the level of tolerated accuracy in the command interface, for a user when using a four-way command interface. A 'Wizard of Oz' observation technique [7] was used. The testing determines: a) minimum desirable level of accuracy in a command mechanism; b) acceptable level of accuracy in a command interface when used by a motivated and informed user. The BCI accessibility assessment uses a mouse-controlled interface to provide input to the IGUI. The user is asked to navigate, for example, '*Go to the living room and turn on the light*'. The tool issues incorrect user commands to the IGUI on an increasing scale, resulting in incorrect navigation and feedback. Initially the user is unaware that inaccuracies have been generated. The test measures ability to tolerate inaccuracies prior to disengagement. The user is asked to repeat the test on a number of days, tolerating and accommodating the inaccurate interface until they judge that any meaningful navigation becomes impossible. Ware *et al* [8] have tested the approach with three healthy volunteer users. They found for these users that desirable accuracy and acceptable accuracy were greater than or equal to 77%. Users were subsequently asked to use the interface (Figure 1 with SSVEP BCI interaction), and were able to achieve accuracy in excess of 80%. This small initial test indicates that a figure of merit for the IGUI can be obtained, and reassuringly shows that the interface designed can accommodate that degree of user interaction. As there are many parameters that may be varied, it is useful to have a user acceptance figure. For example, IGUI was operated using the SSVEP paradigm with four selected frequencies. For a set menu navigation task lasting 4 minutes a single healthy user demonstrated accuracies in excess of 90%, with an optimal choice of mid range stimulation (26, 28, 30, 32Hz). This can be envisaged as a method used to assess appropriate operating parameters for a user.

3 UAI Interface Design

The main objective of the Universal Application Interface is to make various applications available to the user that can be controlled through the IGUI. The UAI is also responsible for the execution of the commands. It has two key principles:

1. All applications must implement the same Java interface, a single method.
2. All devices are controlled in a uniform way by using the standard UPnP protocol [9]. Non UPnP devices are controlled via a UPnP wrapper; a 'proxy' component that provides a UPnP interface while encapsulating the device's native Application Programmer Interface (API).

The UAI has been implemented using the Open Services Gateway initiative (OSGi) framework [10], which conditions the interaction of the UAI with other parts of the system, and overcomes the limitations of the Java language facilitating a component oriented system. A component is a piece of code that provides some functionality through a well defined interface. The coupling between components must be minimal to allow for easy installation, update and removal. Applications and device drivers are easily managed, implemented as OSGi bundles that can be dynamically installed, started and stopped without the need of restarting the whole UAI. Component management and monitoring can be done remotely, which is very convenient when dealing with community based installations. OSGi provides standard mechanisms for the discovery and control of UPnP devices. Development of UPnP based applications are facilitated by available libraries. OSGi is designed for use in embedded environments. This means that the UAI could be installed, for example, in a residential gateway, away from the rest of modules of the components (BCI, IGUI). Communication between the UAI and the rest of system is achieved through the local home network. This segregation provides the advantage of removing the computing load of the UAI from the CPU dedicated to the BCI and user interface, thereby enhancing portability and battery life of the mobile system. Furthermore, it represents the system independence of the BCI from the application technology. De-coupling the IGUI from the UAI means that the each element can be tested separately, before integration testing. To support this, the UAI – IGUI interface is based on Web Services (WS). UPnP technology allows for a further degree of physical system distribution as devices and control points can communicate through the local network, Figure 2.

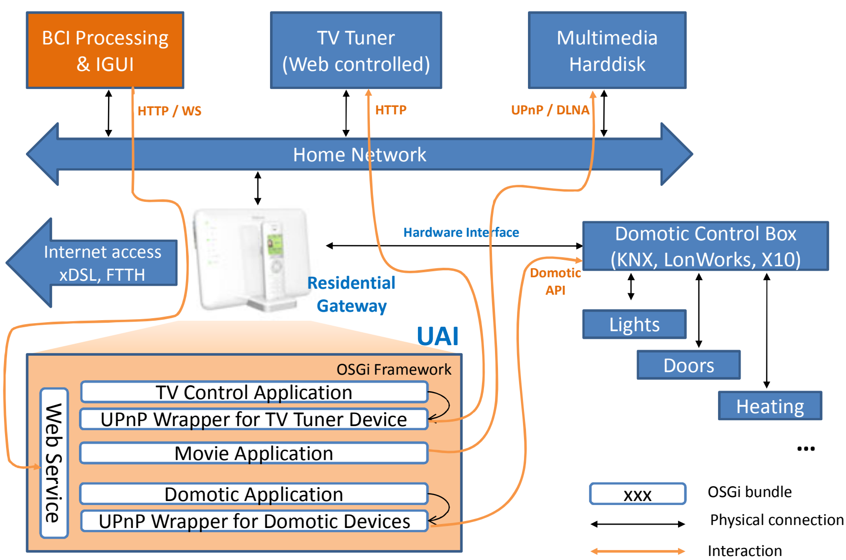

Fig 2. Architecture illustrating interaction of the IGUI with the Universal Application Interface

Three applications have been installed:

1. The domotic control application implements commands needed to operate elements such as lights, doors, windows, and heating. Since the domotic system is not based on UPnP, a wrapper is included in the UAI. The wrapper interacts with the domotic control box through its proprietary API and with the application through UPnP.
2. The TV control application allows the user to change TV channels and control the volume. Even though the TV tuner is IP-enabled, its control interface is not UPnP compliant. This means that a UPnP wrapper is again needed. In this case, no proprie-

tary API and hardware interface are needed, as the TV tuner can be accessed through the home network and controlled by HTTP.
3. The movie application allows the user to select a movie from his/her collection and play it on the TV. Since the multimedia hard disk is UPnP AV/DLNA (Digital Living Network Alliance standard [11] compliant, no wrapper is needed and the application can interact directly with the device.

The implementation of the OSGi framework that has been selected for the UAI is Equinox 3.4.3 [12]. The Eclipse Integrated Development Environment (IDE) is based on OSGi itself, which makes it the ideal tool for developing and testing OSGi applications.

4 IGUI – UAI – Device Communication

UAI applications can be invoked from the IGUI in a uniform way through the provided Web Service named `UAIDispatcherService` and exports only one operation named `raiseCommand`, which accepts three input parameters (device identifier, command identifier, label associated to the IGUI menu) of type string and returns an integer (0: Success, -1: UAI server not found, -2: Unknown application, -3: Unknown command, -4: Unknown device, -5: Unavailable device, -6: Application error). When the web service receives the command invocation from the IGUI it needs to find the application which is able to execute it. For this purpose the UAI's Device Manager maintains a mapping between devices and controlling applications. The web service then dispatches the command to the corresponding application for execution.

The method `executeCommand` is used by the web service to dispatch the command to the application. UAI applications show the following sequence: *Validate the command received from the IGUI, Access the relevant UPnP service on the device, Execute the command by invoking the corresponding UPnP action, Return the result code.* Some applications need to maintain status information between command executions. In this case the pattern is more complex than the one shown above.
Other applications need to subscribe to UPnP events from the controlled devices. OSGi provides the means to register the subscription. The application then needs to implement a listener interface by including a callback method that it is executed when an UPnP event from the device is received.

The OSGi specification includes support for UPnP in the form of a number of interfaces that represent the different elements of the UPnP specification: devices, services, actions, state variables and events. The OSGi framework automatically discovers all UPnP devices connected to the network. They are registered as regular OSGi services that applications can access in the usual way. When a new device implementation is registered, the OSGi automatically publishes its presence in the network. This makes it possible for the UAI applications to control both native UPnP devices and wrappers in a uniform way. If the device becomes unavailable, the wrapper is unregistered.

To facilitate development UAI applications also include a device emulator, which from the application's perspective, is not distinguishable from the hardware device or the wrapper. This aids development and testing within the consortium.

Figure 3(a) shows an application for controlling a domestic light. Figure 4 shows the BCI system in Figure 1 used to control a simple ‘etch-a-sketch’ drawing application. It is based on the original game, where two thumbwheels are turned to guide the direction of the stylus on the screen, one wheel guiding the stylus left and right, while the other wheel guides the stylus up and down. The control is through SSVEP with 4 commands (left, right, up and down). Pausing the drawing is achieved when the user accurately classifies 3 commands of the form [Left, Right, Left], [Right, Left, Right], [Up, Down, Up] or [Down, Up, Down]. The application has been tuned to work with BCI2000 slowing down interaction to a practical drawing speed without which the interaction would be unusable. This illustrates usability factors that must be considered with BCI, and the need to embed some autonomy in the application.

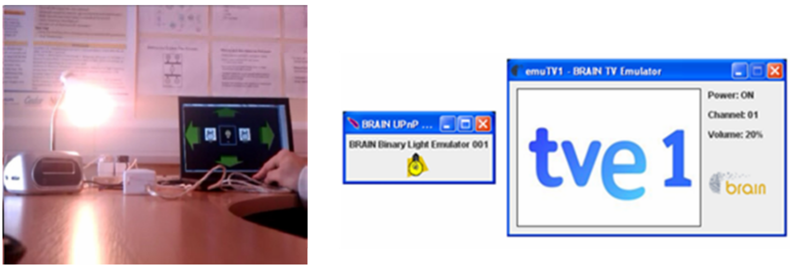

Fig. 3. (a) control of a domestic light, (b) light and TV emulator

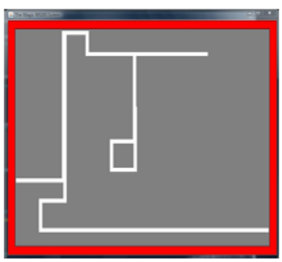

Fig. 4. etch-a-sketch drawing application

An important component of the UAI is the Device Manager (DM). It keeps the details of all devices under control of the BRAIN system and tracks their status. The Device Manager reads the static device information from an XML configuration file. Each UPnP device, wrapper and emulator to be controlled by the UAI must be included in the configuration file.

In the sample device configuration file we can see that two devices have been registered into the UAI: an X10 controlled light and a Dreambox TV tuner [13]. This is the information contained:

- `deviceId`: identifies the device within the BRAIN system. These identifiers are shared between the IGUI and the UAI.
- `upnpstring`: UPnP identifier used by the Device Manager to recognize the device from all discovered UPnP devices. It can be either the unique device identi-

fier or the service identifier. In the case of the Dreambox, a wrapper instance is created for every tuner installed at home; therefore the unique device identifier is used to recognize it. However, in the case of the X10 light, the selected X10 controller uses a random unique device identifier so it is not known in advance. The service identifier is used instead.

- `appId`: qualified name of the class implementing the controlling application. The Device Manager builds the device – application map from this information.
- `locationId`: identifies where the device is physically located. Not used at the moment.
- `ownerId`: identifies the user who is the owner of the device. Not used at the moment but can be used in the future for granting device control privileges to guest users.
- `properties`: contains device specific configuration parameters. These parameters can be used either by the applications or the wrappers.

When the DM is started, it reads the device configuration file and waits for UPnP events. When a device is discovered, the DM tries to recognize it by matching the configured UPnP string with the identifiers retrieved from the device. If a match is found, the device is marked as active and its status begins to be tracked by the DM. If no match is found, the device is ignored. When a tracked device becomes unavailable, the DM marks it as inactive. The DM provides a number of methods to allow other UAI components to access both the static and dynamic device information:

- `getDeviceByDeviceId`: returns all device information for a particular deviceId.
- `getDevicesByApp`: returns the list of devices under control of a particular application.

5 Discussion and Conclusions

So how far can BCIs develop and what will be the time frame? In the BRAIN project, with reflection to Table 1, we have made advances in the following areas:

Recording has been improved with the introduction of a small portable amplifier (TMSi Porti), which can use fibre optic cable or Bluetooth to transmit EEG signals to the computer for digitization. This should increase the acceptability of the BCI equipment. Further miniaturization is possible and in progress. Significant progress has also been made with regard to the testing of water based electrodes, which removes the need for conductive gel [14].

The SSVEP paradigm has been extended to higher frequencies, above 30Hz stimulation rates [5]. These rates are more comfortable to the user, but are associated with a lower signal to noise ratio. Hence new signal processing routines have been used to extract the features associated with High Frequency-SSVEP (HF-SSVEP). Acceptable Receiver Operating Characteristic (ROC) rates of 80% have been achieved. The imagined movement paradigm (ERD/ERS) [15] is currently under investigation. There is a requirement for training and concentration and attention has to be maintained over a longer period of time. Progress has been made with personalizing the

BCI, by the use of automated calibration using a 'wizard'. This attempts to determine the best stimulation frequencies and best EEG locations for determining the four distinctive commands. Similar techniques are required to produce ERD/ERS command classification – in this case only 3 (left hand, right hand, feet) with a suitably modified menu. However the stability and repeatability of the calibration is still under investigation. This may mean that a calibration session is required before each use to account for factors such as arousal, fatigue, time of day, and environmental conditions. Unless operational parameters can be stabilized the length of recording sessions are increased considerably and this mitigates against acceptance.

However there is still a clear gap between demonstrating a software package working in one laboratory for trial subjects and transferring that knowledge to other laboratories, given the plethora of user and software parameters, differences in equipment, operating environment. Significant planning is required to allow testing, debugging and roll-out. For example, achieving a reliable and robust 4-way decision in the SSVEP is proving elusive, particularly at higher frequencies (HF-SSVEP), where the visual response has a lower signal to noise ratio. This is the case in the laboratory setting with enthusiastic motivated subjects. This information allows us to consider the option to use of the GUI with a 2 or 3 way decision process.

In terms of the user and application interface a modular architecture has been developed which will support a range of BCI paradigms and characteristics which allows for user customization. For any assistive interface much effort is required by health care professionals and the HCI developers to produce a system that is targeted to the individual needs and cognitive ability of the user. The IGUI has been developed to support this customization, enabling the visual representation on the screen to be altered or images/ photos of locations and devices to be updated to the most suitable for that person. The separation of the BCI system from the devices through control of the IGUI and UAI enables the development of a BCI system that is independent physically to the applications. This creates portability and the IGUI operation has been shown to support the openBCI platform [16]. The importance of such portability has been demonstrated by OpenViBE [17]. The UAI and supporting infrastructure through Web Services sets the foundation for multi-application support.

Millán *et al* [18] provides a state of the art review of BCI technology and applications. Few applications are publically available outside the laboratory. An exception to this is g.tec's Intendix [19], which has been released as bringing "BCI technology into patients' everyday life'. It is a P300 based personal EEG system, allowing a user to spell out text. This widespread deployment of a BCI technology is certainly a worthy aim, however, as this paper presents, this comes with many challenges ranging from disciplines in science, engineering, computing and healthcare. However, the framework within BRAIN is such that it aims to support each new development as it is achieved.

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Head Movements, Facial Expressions and Feedback in Danish First Encounters Interactions: A Culture-Specific Analysis

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Abstract. This study deals with non-verbal behaviour in a video-recorded and manually annotated corpus of first encounters in Danish. It presents an analysis of head movements and facial expressions in the data, in particular their use to express feedback, and it discusses the results in the light of aspects of Danish culture that seem to privilege rather unconventional and non-emotional behaviour. The data provided can form the basis of multi-cultural studies where parallels are drawn to similar interactions in other languages.

Keywords: head movements, facial expressions, gestural feedback, cultural differences in multimodal interaction.

1 Introduction

This study presents an analysis of how head movements and facial expressions are used in a video-recorded and manually annotated corpus of first encounter interactions in Danish with specific regard to the expression of feedback. It also discusses how aspects of the non-verbal behaviour observed in the corpus can be explained in terms of cultural specificity, and it proposes questions to be investigated from a multicultural perspective.

Many studies converge in showing that head movements correlate with different communicative functions. Nods are typically examples of backchannels, i.e. feedback signals given by the listener without trying to take the floor (Yngve, 1970; Duncan, 1972 and McClave, 2000), but they are also used in turn shifts (Hadar et al., 1984; 1985). In a subset of the Swedish GSLC corpus, it has been observed that 70% of all head movements are related to feedback, and that most of these are nods and up-down movements (Cerrato, 2007).

In our previous work (Jokinen et al. 2008), we studied facial expressions, head movements and hand gesturing in Danish and Estonian dialogues, and noticed significant interdependences between non-verbal expressions and communicative functions. Nods often indicate feedback, while head movements sideways or up-down together with gaze are related to turn-taking. Moreover, in Estonian dialogues there is a significant tendency to elicit feedback by looking at the partner, while acceptance is often accompanied by looking down. When clustering Danish facial data on the basis of the annotation features, we noticed that three clusters appeared in the data: one for eliciting

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feedback, one for acceptance, and one for contact/perception, thus indirectly providing evidence that the three functions are important in multimodal feedback analysis.

In this study, we look at a corpus of first encounter interactions in Danish created in the Nordic NOMCO project (Paggio et al. 2010). Our goal is assessing how head movements and facial expressions are used in the interactions, especially concerning the expression of feedback, and we discuss how these findings can be related to certain aspects of Danish culture.

The paper is structured as follows: in section (2) we review a number of previous studies of multimodal behaviour in different languages, and provide a characterisation of Danish with respect to a number of other cultures; in section (3) we present our expectations concerning the multimodal behaviour and we describe the data collection; in section (4) we describe the results; finally, in section (5) we conclude.

2 Multimodal Feedback in Different Cultures

Cultural differences exist in the way multimodal behaviour is used to express feedback, and a number of studies have already pinpointed specific characteristics of different languages. Maynard (1987), for example, studies head nods in dialogues between Japanese speakers. The most frequent function is found to be feedback by listeners, but speakers also nod a lot in different contexts. It is found, in fact, that the Japanese nod with an average frequency of 5.57 seconds, against 22.5 seconds for Americans. Rehm et al. (2008) have studied differences between German and Japanese speakers' behaviour in first encounters, and found differences in gesture frequency, amplitude and speed, with Germans scoring higher than the Japanese on all three dimensions. Thus, although nods are quite common with Japanese speakers, in general they seem to display less frequent non-verbal behaviour. Allwood and Liu (2010) have analysed cultural differences in first encounter meetings comparing Swedish and Chinese speakers, and found that the Chinese use more laughter, gaze around, gaze sideways and covering their mouth with their hands. On the other hand, only the Swedes use up-down head movements and tilts. Both Swedes and Chinese use more feedback gestures when they speak English in intercultural interactions.

In Hoftede's much quoted theory of cultural dimensions (i.a. Hoftede, 2001), national cultures are placed in a six-dimensional space. The six dimensions are power distance (PDI), individualism vs. collectivism (IDV), acceptance of gender difference (MAS), uncertainty avoidance (UAI), long-term orientation (LTOWVS) and indulgence vs. restraint (IVR). According to this theory (see also Rehm et al. 2008; 2009), at least some of these dimensions can be related to communicative behaviour. For example, high power distance acceptance typically implies more formal behaviour and more physical distance between strangers. Low uncertainty avoidance, on the other hand, goes together with a tendency towards phlegmatic, non-emotional behaviour. In Hofstede's model, the languages targeted in the studies mentioned so far are placed quite differently with respect to the six dimensions. We show five of them in Figure (1).

Clearly, Swedish and Danish cultures are quite similar, and so are Japanese and Chinese, while German culture is more similar to the Scandinavian world in some respects (PDI and IDV) and to the Asian world in others.

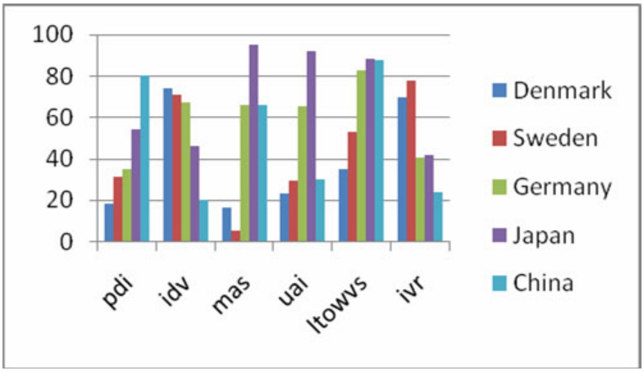

Fig. 1. Scoring of different cultures on Hofstede's cultural dimensions (data taken from www.geerthofstede.nl)

3 Multimodal Behaviour and Data Collection

Although the differences mentioned in the preceding section cannot univocally be mapped onto expected communicative behaviour patterns in Danish speakers, based on the data we have we can investigate a number of possible systematic relations. The most relevant dimensions in our case are power distance and uncertainty avoidance, which would predict for Danish speakers informal, non-homogeneous and non-emotional behaviour, as opposed to the kind of polite and stereotypical behaviour often ascribed, for instance, to Japanese speakers. To see if these differences emerge in the data, we posed ourselves the following questions:

1. How often do the various types of non-verbal behaviour occur? How uniform or varied is this behaviour? In particular, do Danish speakers nod more or less than speakers of other cultures?
2. Are there significant correlations between the different types and the expression of feedback, and how frequent is multimodal feedback in Danish? How do the results compare with findings for other languages?
3. Do the participants influence each other in their non-verbal behaviour as a sign of politeness?

The Danish corpus consists of 6 videos where pairs (mixed gender or same gender), meet for the first time and talk freely for about 5 minutes. This gives about 30 minutes of conversational interaction. The subjects are standing in a studio, facing each other. The videos were orthographically transcribed, and head movements and facial expressions were annotated by hand in ANVIL (Kipp, 2001) based on the MUMIN annotation scheme (Allwood et al, 1997).

4 Analysis of the Data

The total number of gestures identified in the Danish data is 1919. Table (1) shows how they are distributed according to four different gesture shape attributes. Note that these are not mutually exclusive: *Eyebrows* attributes may occur on their own, but also in conjunction with a *Face* or a *Head movement* attribute. *Repeat* always occurs together with *Head movement*.

Table 1. Facial expressions and head movements in the Danish corpus

Face (type/#)		Eyebrows (type/#)		Head mov. (type/#)		Repeat (type/#)	
Smile	330	Frown	44	Nod	249	Single	928
Laughter	143	Raise	222	Jerk	70	Repeated	280
Scowl	0	BrowsOther	1	HeadBackward	101		
FaceOther	29			HeadForward	139		
				Tilt	214		
				SideTurn	182		
				Shake	136		
				Waggle	31		
				HeadOther	86		
Face total	502	Brows total	267	Head total	1208	Repeat total	1208

Head movements constitute the majority of the gestures, and most of them are single movements. They occur with a frequency of 1.49 seconds, compared with 3.5 for face expressions and 8.7 for eyebrow movements. In relation to the number of words (6000 including filled pauses), there are 0.2 head movements, 0.08 face expressions and 0.03 eyebrow movements per word.

Average and standard deviation for the two most frequent behaviour modalities are given in Table (2).

Table 2. Average and SD in the Danish corpus

	10 subjects		8 subjects	
Behaviour	Average	SD	Average	SD
Head	120.8	39.46	109.37	35.58
Face	43.6	18.86	36.5	13.65

The figures in the two leftmost columns refer to the whole population, whilst those to the right have been calculated after the two most deviant subjects were taken out. The amount of standard deviation is not negligible, in that it consists of about 1/3 of each average. The data taken into consideration in this study are a subset of a larger corpus still under development, thus it remains to be seen whether standard deviation will diminish in the larger corpus.

Looking now at more specific behaviours, *Nod* is the most common of the head movements, with a frequency of 7.23. Compared to the figures in Maynard's study, the Danes nod less than the Japanese but still much more than the Americans. *Tilt*, however, is almost as frequent, closely followed by *SideTurn*. In general, finding a

Table 3. Feedback and modalities in the Danish corpus

	Feedback (%)	Other function (%)
Head	61	64
Face	28	26
Eyebrows	11	11
Total	100	100

number of different head movements seems to confirm the expectation of a varied, non-stereotypical non-verbal behaviour in Danish speakers.

The annotation shows that 803 non-verbal behaviours (about 40% of the total 1919) are used to provide feedback, especially to give feedback, but also to a lesser extent to elicit feedback. Looking now at different modalities and feedback, we see (Table 3) that head movements are the most represented type, followed by face expressions and eyebrows attributes. This reflects in part the fact that head movements are in general the most frequent type. In fact, about 60% of the head movements (as opposed to 40% of all movements) is used to express feedback. This is similar to the results obtained by Cerrato (2007) for Swedish. It remains to be seen if a similar analysis on data for other languages would provide interesting differences.

Looking at specific head movement types shows that feedback is especially associated with head nods and smiles, as shown in Table (4).

Table 4. Feedback and non-verbal behaviour types in the Danish corpus

Behaviour	#	%
FaceOther	22	0.03
Laughter	61	0.08
Smile	140	0.17
HeadBackwards	48	0.06
HeadForward	51	0.06
HeadOther	24	0.03
Jerk	53	0.07
Nod Repeated	108	0.13
Nod Single	58	0.07
Shake	46	0.06
SideTurn	43	0.05
Tilt	55	0.07
Waggle	6	0.01
Frown	20	0.02
Raise	68	0.08
Total	803	1

An interesting question is whether a similar analysis carried out on Japanese or Chinese data would show more emotional behaviour, for example a higher number of smiles and laughs as the study in Allwood and Liu (2010) would suggest.

To elucidate the question of whether the participants influence each other in their non-verbal behaviour, we have analysed the multimodal behaviour of two of the subjects (here, A and B) interacting each with two different people. Four videos were thus used in this analysis. The results show that the subjects either kept their non-verbal behaviour more or less unchanged, or for some behaviours produced more or fewer movements in opposition to what done by the interlocutor. Thus in these first encounters, rather than a mirroring effect, there is a slight indication that participants make a larger effort to seem interested and give feedback in cases when the interlocutors are more reserved.

Table 5. Head Movements and facial expressions of same participant with two different interlocutors

Meeting	Speaker	Smile	Laughter	Nod	Shake
SpeakerA+B	**Speaker A**	13	13	11	4
	Speaker B	28	3	28	21
SpeakerA+C	**Speaker A**	33	19	8	11
	Speaker C	14	6	8	5
SpeakerD+E	**Speaker D**	41	34	12	14
	Speaker E	34	16	44	27
SpeakerD+F	**Speaker D**	50	39	25	7
	Speaker F	61	5	35	14

In Table 5 we show the figures for the most frequently occurring behaviours in the meetings, which comprise Smile, Laughter, Nod and Shake. The dataset analysed here is far too small to provide any conclusive evidence. However, the provisional answer to the question we started out with is that the participants, if they influence each other at all, do not do it in the sense of copying each other's behaviours.

If it is true that we should expect relatively free, individualistic behaviour from Danish participants, lack of mirroring is probably what we should expect. Again, it would be very interesting to investigate this aspect on larger data material, and to carry out a similar analysis on data from more collectivistic cultures like Japanese or Chinese.

5 Conclusion

In this paper we have given an account of a Danish multimodal corpus in which head movements and facial expressions were annotated manually with labels referring to their shape, and analysed with respect to their feedback function. It was shown that the non-verbal behaviour in the corpus confirms expectations based on an understanding of Danish culture according to which Danish speakers are prone to keeping an informal, non-stereotypical and non-emotional style. It was found in fact that compared to other cultures, which have been described as seeking more stereotypical and polite behaviour, Danes nod less and use more varied non-verbal behaviour in connection with feedback. Still in accordance to what we would expect of a relatively individualistic culture, they do not seem to be subject to mirroring effects in the sense that they do not copy each other's behaviour. This aspect, however, should be analysed in more depth on a larger data collection.

Many other questions can of course be asked on culture-specific multimodal behaviour. For example, specific comparisons on the use of emotional cues such as smiles and laughs could be made. Or the effect of familiarisation could be investigated, for instance by testing whether the non-verbal behaviour changes in the course of the conversations. Finally, differences in the use of feedback words could be studied. In all these cases, cultural dimensions can be used to formulate hypotheses on expected behaviour.

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EEG-Based Personalized Digital Experience

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Abstract. To make human computer interfaces more immersive and intuitive, a new dimension could be added. Real-time brain state recognition from EEG including emotion recognition and level of concentration recognition would make an access to information more adaptive and personalized. Modern EEG techniques give us an easy and portable way to monitor brain activities by using suitable signal processing and classification methods and algorithms. We proposed a new subject-dependent fractal-based approach to brain state recognition and innovative applications based on EEG-enable user's interaction. The algorithms of the "inner" brain state quantification including emotion recognition would advance research on human computer interaction bringing the proposed novel objective quantification methods and algorithms as new tools in medical, entertainment, and even digital art methodology applications, and allowing us an integration of the brain state quantification algorithms in the human computer interfaces. In this paper, we describe our fractal-based approach to the brain state recognition and its EEG-enable applications such as serious games, emotional avatar, music therapy, music player, and storytelling.

Keywords: HCI; BCI; fractal dimension; emotion recognition; serious game; music therapy; storytelling.

1 Introduction

Modern Human Computer Interfaces (HCI) could use both verbal and non-verbal types of human communication. Information could be entered to the computer by the user through the input devices such as keyboard, mouse, haptic device, microphone, touch response display, etc. The modern input devices help to create more intuitive and seamlessness user interfaces. To make human computer interaction even more seamlessness, the information could be entered by cameras, sensors-based tracking systems, and by biofeedback sensors. Then, the corresponding algorithms could process the gathered information depending on the application. For example, human emotions could be recognized from face, gesture, or from the combination of biological signals and could be used in different applications such as music therapy, emotional avatar, etc. In this paper, we describe our approach to add one more dimension to human computer interaction. It is so called communication by "brain power". EEG-based communication was used for many years in Brain Computer Interfaces (BCI) and neurofeedback games for medical applications. Electroencephalogram (EEG) is a non-invasive technique recording the electrical potential over the scalp which is

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produced by the activities of brain cortex, and reflects the state of the brain [1]. Recently, new portable wireless EEG reading devices have entered to the market, and it made possible to develop applications personalized and adapted to the user. It could be adaptive games, music therapies, emotion-enable interaction in 3D collaborative environment, etc. In this paper, we propose a new fractal based approach to brain state recognition including emotion recognition and concentration level recognition, and innovative applications based on the EEG-enable user's immersion and interaction. The proposed fractal based method is a general method, and it could be used as a basis for the development of other brain states recognition algorithms as well. The proposed and implemented applications consist from two parts: fractal based brain state recognition algorithms and interactive application systems. In the proposed algorithms, complexity of the signal is estimated by calculating fractal dimensions values changing over time. The algorithms of concentration level recognition and emotion recognition use just one fractal feature per channel that allows us to implement real-time EEG-enable applications. We implemented real-time applications such as concentration games, emotion-enable web-based music player, music therapy, and storytelling.

In Section 2.1, we review Brain Computer Interfaces (BCI) and neurofeedback techniques. In Section 2.2, emotion recognition algorithms are described. Then, the fractal-based approach to the brain state recognition is given in Section 3. Real-time EEG-enable applications including serious games and emotion-based personalized interaction are described in Section 4.

2 Related Work

2.1 BCI and Neurofeedback

Brain Computer Interfaces (BCIs) are the systems allowing the user to control computers/devices directly with the user's brain signals. As an acquisition of EEG signals becomes more and more convenient due to new wireless portable devices appeared recently in the market, the applications of BCI spread even to entertainment industry. Thus, now applications of BCIs could be used not only by disabled people but by any person and even at home. Neurofeedback is a special technique that is used for medical treatments of different psychological disorders. A therapy is often embedded in the neurofeedback system, and the user makes an effort to improve his/her brain state following the system feedback. The feedback could be audio, visual, or even haptic. Thus, the user by doing some exercises recommended by the doctor or just by playing the serious games with neurofeedback learns how to improve his/her brain plasticity. Some researches demonstrated that the EEG distortion can reflect psychological disorders such as Attention Deficit Hyperactivity Disorder (ADHD) [2-3], Autistic Spectrum Disorders (ASD) [4-5], Substance Use Disorders (SUD) including alcoholics and drug abuse [6-7], etc. Neurofeedback could be used for treating these disorders as an alternative approach to medical treatments. These disorders could be treated with QEEG protocol based on power spectrum analysis, as different frequency bands reflect different brain functions [8]. They also could be treated by event related potential (ERP) analysis. Particularly, Slow Cortical Potential (SCP) analysis had shown its usability in ADHD treatment [9], and P300 component training could be used for drug abuse rehabilitation [7].

Recently, the use of nonlinear features of EEG signals became popular due to the nonlinearity of the EEG signals and the possibility of nonlinear EEG feature extraction in real time. In [10-11], based on the two well-known algorithms, i.e. Box-counting [12] and Higuchi [13], concentration level recognition algorithms were proposed and applied in neurofeedback games, and the efficiency of the algrithms was shown. There is a growing demand for real-time brain-state recognition that could be used in medical applications.

2.2 Emotion Recognition Algorithms

EEG-based emotion recognition is a relatively new research topic, and it attracted more attention from the research community since recognition of the “inner” feelings could be very important in medical applications, entertainment, marketing, etc. There are two types of the EEG-based emotion recognition algorithms: subject-dependent and subject-independent ones. The algorithms of both groups consist of feature extraction and classification parts. To our best knowledge, the developed algorithms are off-line processing ones. They differ by the feature extraction methods used such as Fast Fourier Transform [14], Higher Order Crossings [15], etc, by the classifiers employed such as Support Vector Machine (SVM) [16], Neural Networks [17], etc, by the number of electrodes needed to identify the emotional states, and by types of emotions recognized.

Currently, there is a demand for real-time emotion recognition algorithms that could be used in medical applications, serious games, and entertainment. In [18], we proposed and implemented a real-time fractal-based algorithm recognizing 7 emotions and using only 3 channels. Fractal dimension algorithms were applied to compute fractal-based features. The proposed algorithm is subject-dependent. The predefined thresholds are calculated during the training session. The satisfied, pleasant, happy, frustrated, sad, fear and neutral emotions could be differentiated. Since the discrete emotions can be mapped to the 2D emotion model, and fractal dimension values can be mapped to 2D emotion model as well, more emotions that are defined in 2D model could be distinguished.

3 Real-Time Brain State Recognition

The overall structure of the real-time brain state recognition application systems is shown in Fig. 1. The mental state of the user is recognized from his/her EEG in real time. An overall recognition algorithm used in the real-time applications consists from the following steps: data acquisition and pre-processing such as data filtering, then, feature extraction, and subject-dependent classification. Then, the command is sent to the feedback system based on the recognition results.

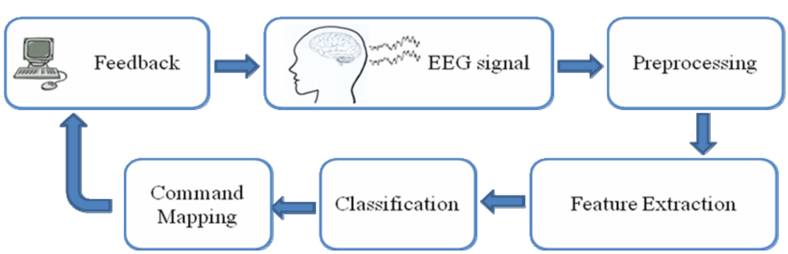


Fig. 1. Diagram for non-invasive BCI system

3.1 Data Acquisition and Pre-processing

EEG data are collected by Emotiv device with 14 electrodes located at AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4 standardized by the American Electroencephalographic Society [19]. The device sampling rate is 128Hz. The collected data are filtered by a 2-42 Hz bandpass filter to get the major waves of EEG [20].

3.2 Fractal Dimension Features Extraction and Classification

The next step after the data pre-processing is feature extraction. Fractal dimension (FD) is used to measure the complexity and irregularity of the object based on an entropy analysis. Entropy is a measure of the disorder in physical systems, or an amount of information that may be gained by observations of the disordered systems. A common practice to distinguish among possible classes of time series is to determine their so-called correlation dimension. The correlation dimension, however, belongs to an infinite family of fractal dimensions [21]. Hence, there is a hope that the use of the whole family of fractal dimensions may be advantageous in comparison to using only some of these dimensions. The concept of generalized entropy of a probability distribution was introduced by Alfred Renyi [22]. There are various methods to calculate fractal dimension (FD). In [23-24], the generalized Renyi approach based on Renyi entropy and calculation of the whole spectra of fractal dimensions to quantify brain states were studied. In our real-time applications, we use only Hausdorff dimension. We implemented two well-known Box-counting [12] and Higuchi [13] algorithms calculating fractal dimension. Both of them were evaluated using mono-fractal Brownian and Weierstrass functions where theoretical FD values are known [10]. Higuchi algorithm gave better accuracy as FD values were closer to the theoretical FD ones, and it was finally chosen to compute the FD features.

We apply a sliding window and calculate one FD value per sample per channel. Number of channels used in the recognition algorithm defines a size of the feature vector as follows:

$$F = \{FD_1, FD_2, \ldots, FD_n\} \ . \tag{1}$$

where n is number of channels. In the concentration level recognition algorithm, we have one feature as only one channel is used [10]. In the emotion recognition algorithm, there are 3 features in the vector as 3 channels are used [18]. Thus, in our approach we use one FD value per channel.

Currently, we implemented a simple real-time subject-dependent classification algorithm based on threshold FD values that are calculated during a short training session. Note that off-line processing with SVM classifier of the EEG labeled with emotions and concentration levels gave us similar accuracy as the real time implementation algorithm used thresholds.

4 Real-Time Applications

4.1 Emotion-Based Digital Experience

We proposed and implemented a real-time fractal-based emotion recognition algorithm where the calculated fractal dimension values were mapped to 2D Valence-Arousal emotion model [18]. It could be possible to recognize in real time any discrete emotions that could be defined with the 2-dimensional emotion model. Satisfied, pleasant, happy, frustrated, sad, fear, and neutral emotions were recognized in [18]. In our algorithm, only 3 channels are used that makes set up of our device faster and more convenient for the user. We implemented the emotion-enable real-time applications such as Emotional Avatar, Music Therapy, Music Player, and proposed Emotion-enable Storytelling.

Emotional Avatar. We implemented an application with the EEG-enable avatar [18]. The music stimuli were used for emotion induction as it was proposed in [25]. We used an avatar available with version of Haptek development package for our application [26]. Haptek Activex control provides functions and commands to change facial expressions of 3D avatars. We defined six emotions by changing the parameters controlling the facial muscles of the Haptek emotion avatar. Those emotions are: fear, frustrated, sad, happy, pleasant and satisfied. In the application, emotions of the user are recognized from EEG and visualized in real-time on the user's avatar with Haptek system. In Fig. 2 (a), the user was listening to music pieces for emotion induction, and the algorithm recognized "sad" emotion that was visualized in real time on the user's avatar. The avatar emotions are changing according to the emotions that the user is feeling during the music listening. In the EEG-enable emotional avatar application in collaborative 3D virtual environment, the current user emotion could be visualized on his/her avatar or could be used in interaction with other avatars or even objects in virtual environments.

Music Therapy. Second, we implemented an EEG-enable music therapy web-site. Music therapy can help the patients deal with the stress, anxiety and depression problems, for example, the patients' anxiety could be released by listening to music during the surgery [27]. Our real-time EEG-based human emotion recognition algorithm is used in the music therapy system implemented on the Web. We proposed and developed the system that works as a therapist. The music choice and duration of the music is adjusted based on the patient's current emotion recognized automatically from EEG. For music therapy helping in pain management, happy (positive/high aroused) songs are played to the user to distract his/her attention from the pain they feel. The user's emotion state is recognized in real time from his/her EEG data. If the happy emotion is not induced by the current song, the player would automatically switch to another one. For music therapy dealing with depression, pleasant (positive/low aroused) songs are played to the user to make him/her feel relaxed. The song would be changed according to the EEG-based feedback. Fig. 2 (b) shows the implemented EEG-enable music therapy website. The user has EEG device Emotiv and an earphone for listening music during the therapy session.

EEG-enable Music Player. Another personalized EEG-based system proposed and implemented is a web-enable music player. In this application, the user's current emotion state is recognized, and then, the corresponding music is played according to the identified emotion. Songs are categorized into six emotion types: fear, sad, frustrated, happy, satisfied, and pleasant.

Information about the current emotional state of the user and the music being played is given on the display of the player. For example, if the emotion state is recognized as pleasant, then the music which is categorized into the genre of pleasant music is played to the user.

(a) (b)

Fig. 2. (a) "Sad" emotion is recognized and visualized on the user 3D avatar implemented with Haptex [26]. (b) The user accesses the music therapy website.

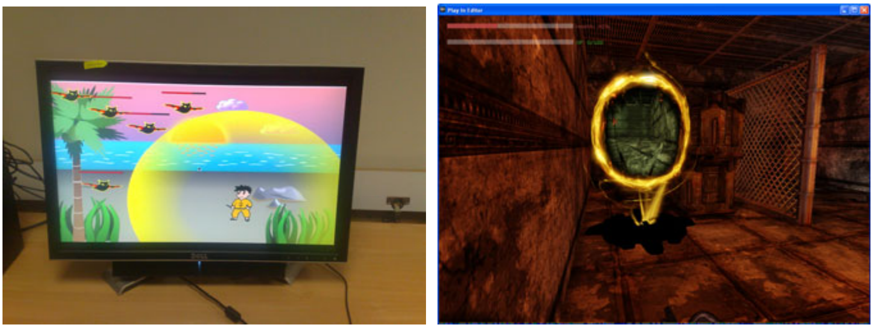
Interactive Storytelling. When people are exposed to the traditional story telling mediums such as reading a novel or watching a movie, they are just passive participants. Even in the games, the players need to follow the predetermined development of plot of the roles they played. However, since development of human computer interfaces including BCI, the EEG-enable interaction could be used in storytelling. The interactive storytelling gives the users a chance to enjoy more active experiences. For example, a story could be changed in real-time according to the user's current emotion recognized from EEG.

In interactive story telling entertainment, it is the user playing the leading role who decides the following storyline [28]. The interactive story telling can be implemented by different ways, for example, processing the text typed by user and based on the understanding of the text, the corresponding development of plot will be given [29]. Cavazza et al [30] took emotion into consideration to drive the interactive story telling system, and speech-based emotion recognition was used to decide the behaviors of each character and the interactions between different characters.

Our real-time EEG-based emotion recognition provides another way to realize the interactive story telling system in entertainment. With the emotion recognized from the users' brain activity, the story development of a movie or a game could be automatically directed by the user. In our preliminary study, we change a story line based on the user emotion detection. If the user is feeling unhappy, the story line could be changed. It would be possible to keep the emotion state of the user according to the predefined graph, for example, to keep the user excited for some time or to scare the user to get optimized emotional personalized experience through the story.

4.2 EEG-Enable Serious Games

The EEG-based serious game design includes two parts: signal processing algorithms and 2D or 3D game part. Raw EEG signals collected by the device from the user brain are filtered and analyzed by signal processing algorithms, and the resulting values are interpreted in the game as an additional game control using just the "brain power". A therapeutic effect of such games could consist from combination of a distraction effect of the game and an effect from the learning by the user/patient how to control the game by voluntarily changing his/her brain state, for example, by learning how to improve the user's concentration level. We developed concentration games such as



(a) (b)

Fig. 3. (a) Screenshot of "Brain Chi" game. (b) Screenshot of the "Escape" game

"Brain Chi" and "Dancing Robot", a game for stress management named "Pipe", and behavior learning game "Escape". They are simple single-player games implemented with the game engines SDL, Panda3D, and Adobe Flash CS4 correspondingly. The recognized relaxation/ concentration/ stress level values from EEG could be interpreted in the games as any visual/audio effects or even as a behavior change of the game characters. We also did a preliminary study on how to use the EEG-enable serious games for pain management and have got some promising results.

Brain Chi. In the "Brain Chi" game, the relaxation/concentration level of the user is associated with radius of a "growing/shrinking" ball. It allows the "little boy" character to fight enemies by "growing" the ball as shown in Fig. 3 (a). In our implementation, the concentration and relaxation levels could be easily associated either with concentration training or relaxation training depending on the therapeutic purpose of the game.

Dancing Robot. In the "Dancing Robot" game, the relaxation/concentration level is associated with the "robot" character behavior. When the concentration level of the user increases, the 3D robot character starts to move faster. If the user is fully relaxed, the robot stops dancing. The change of the quantified level of the user concentration level is interpreted as a "faster/slower" movement of the "robot".

Pipe. The "Pipe" game is adapted after the popular 'Pipe' game and is implemented as a traditional neurofeedback game. The two bars are used to indicate the level of the user stress and the game time left. In the "Pipe" game, water flows faster when the player's stress level increases, and hence it makes the game playing more difficult.

Escape. "Escape" game has an educational purpose. The story in the game requires the player to solve the educational puzzles to get the passwords for unlocking the doors. In this game, EEG could be used as an alternative way to get the passwords when the players can not figure out how to solve those puzzles. The user has to stay concentrated for the specified time, and the password will be given to him. If the player uses "brain power" help, the overall game time allocated for the player to escape is reduced. The screenshot of the game is shown in Fig. 3 (b). The user could go through the portal shown if he/she solves the puzzle.

5 Conclusion

In this paper, we study one more possible dimension in human computer interfaces that is based on brain state recognition from EEG. It could allow the user to have more personalized experience during the computer interaction. We proposed fractal based approach to recognition of brain states including emotion recognition and concentration level recognition. Using just one fractal dimension feature per channel and the simple machine learning algorithm allows us to implement real-time brain state recognition algorithms with acceptable accuracy. Based on the algorithms, we proposed and implemented novel applications making the user experience more intuitive and personalized. We also work on the improvement of the real-time filtering of artifacts of different origin. The work described in the paper is a part of the project EmoDEx presented in [31].

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Perspectives on User Experience Evaluation of Brain-Computer Interfaces

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Abstract. The research on brain-computer interfaces (BCIs) is pushing hard to bring technologies out of the lab and into society and onto the market. The nascent merge between the field of BCI and human-computer interaction (HCI) is paving the way for new applications such as BCI-controlled gaming. The evaluation or success of BCI technologies is often based on how accurate the control of a user is with the technology. However, while this is still key to its usability, other factors that influence the user experience (UX) can make or break a technology. In this paper we first review studies which investigated user experience with BCIs. Second, we will discuss how HCI approaches can contribute to the evaluation of BCIs. Finally, we propose to develop a standardized questionnaire for evaluating BCIs for entertainment purposes.

1 Introduction

Brain-computer interfaces (BCIs) traditionally aimed to provide a reliable control signal for assistive technology for disabled persons. With the merge of the fields of human-computer interaction (HCI) and BCI new applications are being developed for entertainment and education which may be interesting for disabled *and* abled users. The aim of such applications is to create positive experiences that enrich our lives rather than only provide reliable control. To evaluate such systems, the user experience (UX) needs to be the central focus of study, rather than the reliability of the control signal, so that we can better understand how such a system can satisfy the needs of the user. Even though user experience evaluation is not common in current BCI studies, the user's experience can influence objective performance measures, such as BCI classifier accuracies, and has a big impact on whether users are actually willing to use a specific system.

In this paper, we review studies that investigate user experience in BCI research and the benefits of including such evaluations. Then, we will argue how the use of various techniques from the field of HCI can be advantageous for evaluating BCIs. In the last part of this paper we will elaborate on our efforts to develop a standardized questionnaire for evaluating user experience with BCIs.

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2 Current State of User Experience Evaluation of BCI

2.1 User Experience Affects BCI

The BCI studies that do include UX indicate three main reasons to evaluate the UX: to increase user acceptance, to improve performance of the system, and to increase enjoyment.

User-centered approaches can increase usability and user acceptance, which is why some BCI groups involve users in the design process. They assess user needs and develop user requirements [1,2]. Pasqualotto et al. compared the usability and workload of two systems using the System Usability Scale (SUS) and NASA Task Load Index (TLX) [3,4,5] Developing user requirements is only the first step. The next is to assess the UX and user acceptance in a structured way *during* or *directly after* a user has interacted with the system. Subjective and experiential factors can shed light on the UX, combined with objective usability measures.

Several BCI studies suggest a relation between motivation and BCI task performance [6,7], and small but significant effects have been found [8] using an adapted version of the Current Motivation Questionnaire, a questionnaire for current motivation in learning and performance situations [7,9]. Similarly, the users' belief of how accurately they can control a BCI has an influence on their actual performance. Barbero and Grosse-Wentrup observed that participants who normally perform around chance level, perform better when they think they are doing better than they actually are (positive bias). Capable participants, however, performed worse when given inaccurate feedback, whether the bias was positive or negative [10]. Motivation may be only one of the performance-related factors that are influenced by the UX. By evaluating and improving the UX, other relations between the user and BCI recognition performance could be exploited to improve performance measures. There could also be mechanisms with indirect influences. For example, a system that is perceived as more beautiful is also perceived as more usable [11]. This perception could influence motivation which in turn could influence performance.

Most BCI applications currently being developed still serve only as a proof of concept [12], which may be why the entertainment value is often not evaluated. An exception is the BCI game BrainBasher, which was evaluated for the influence of different graphical interfaces and different user tasks, using the Game Experience Questionnaire which addresses immersion, tension, competence, flow, negative affect, positive affect, and challenge [13,14,15]. In the first study, the UX and performance have been determined for a clinical setup with minimal information on the screen. This was compared to a game-like setup of exactly the same task. The game version resulted in higher immersion. The second study compared the UX for imaginary and actual movement. Imagined movement was perceived as more challenging, but when using actual movement the participants stayed more alert.

Although there is not much research yet in this area, important questions arise, and the studies that have been done make clear that the UX can affect a BCI system in important ways.

2.2 BCI Affects User Experience

UX can influence the performance of BCIs, but BCIs can affect the UX as well, in two ways: (1) by using information about the user's mental state to adapt the interface or the interaction itself, with as goal to improve usability and UX; and (2) through the effects of using this particular input modality.

In the first approach, the user is supported in the tasks they are trying to accomplish with the help of BCI, which in turn could increase user satisfaction. For example, error-related brain activity can be detected and used to fix user or system errors for improved error handling [16]. The amount of information presented on screen can be adjusted according to the user's workload [17]. BCI could also be used to create or maintain specific experiences. As an example, brain activity indicators of stress or boredom can be used to keep the user in the optimal state of flow [18].

On the other hand, using BCI for input can already influence the UX by itself. Friedman et al. investigated whether the use of imaginary movement to walk in a virtual world would increase presence, using the Slater-Usoh- Steed presence questionnaire combined with a non-structured interview [19,20]. In a follow-up experiment, Groenegress et al. compared the presence experienced with a P300 interface to eye gaze and wand navigation [21]. Both experiments concluded that the BCI did not have a positive influence. However, the influence of BCI on UX is not limited to presence alone. Besides, BCI inputs are not limited to these two mental tasks. If the influence of certain mental tasks in specific contexts would be known, it would be possible to find the optimal mental tasks for a given application.

Whether BCI is used to affect the UX purposefully or whether this happens just by using this input modality, in both cases it is important to evaluate and be aware of the effects.

3 Applying HCI User Experience Evaluation to BCIs

Although evaluating the usability and UX of BCI systems is not common practice, in HCI research and development, especially for entertainment technologies which simply aim to improve the well-being of users, UX is a major concern. Therefore, the HCI community designs for UX and develops methods to evaluate it. Current methods for evaluating UX in entertainment technologies can be classified into quadrants of a plane which has an objective versus subjective axis and a qualitative versus quantitative axis [22] (see Fig. 1). The objective methods are based on overt and covert user responses during interaction while the subjective methods rely on user expressions after the interaction. The quantitative methods employ statistical analysis on collected data whereas the qualitative methods are interpretations of user responses by researchers. Below, we describe the methods corresponding to the quadrants formed by these two axes and discuss their contribution in evaluating BCI systems.

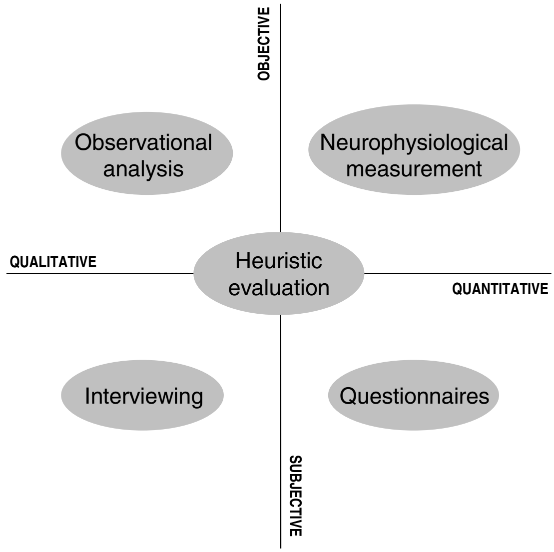

Fig. 1. A classification of current user experience evaluation methods used in human-computer interaction for entertainment technologies (adapted from [22])

3.1 Observational Analysis

Observational analysis is a qualitative-objective method as it relies on interpretation of overt user response by researchers. The classical way of observing overt user behaviour is through audiovisual recorders which provide qualitative data for gestures, facial expressions and verbalisations. There are some difficulties associated with annotating and analysing such rich data though. Firstly, while analysing the data, the researchers should acknowledge their biases, address inter-rater reliability and not read inferences where none are present. Secondly, there is an enormous time commitment associated with observational analysis. The ratio of analysis time to data sequence time ranges from 5:1 to 100:1 [23]. Thirdly, the operation of audiovisual recorders impose restrictions such as noise-free environment during audio recording or consistent illumination during video capturing. Similar restrictions are also imposed by brain activity recording devices. For example, the electrocencephalogram (EEG, measuring electrical brain activity) is affected by user's movement [24], so users are usually asked to keep their body and face motionless. Thus, overt behaviour of users of BCIs will be minimal and observational analysis may not obtain sufficient data to analyze UX. Moreover, severely disabled people, such as patients with locked-in syndrome (LiS) who lose all their muscle control except for vertical eye movements [25] and who constitute a major user group for BCIs, are not able to show any overt behaviour at all. Consequently, in clinical experiments observational analysis is not a strong method for evaluating UX, although for studies in natural environments they might prove useful.

3.2 Neurophysiological Measurement

Task performance metrics have been suggested as quantitative-objective measures of UX but these are not necessarily the indicators of UX. Especially in entertainment applications, there might not be a clear task or users might prefer navigating in the virtual environment without any urge to complete tasks. More recently, use of neurophysiological signals was proposed to model emotional state of users in play technologies [23]. Examples of psychophysiological signals are EEG, galvanic skin response (GSR, measuring skin conductivity) and electrocardiogram (ECG, measuring electrical heart activity). Measured emotions capture usability and playability through metrics relevant to play experience so they provide objective data. They account for user emotion and they are represented continuously over a session. While interacting with a BCI, at least one neurophysiological signal, the EEG, can already be recorded as it is used as an input signal. It is a golden opportunity to extract UX-related features from the brain signals using the same signals. Several problematic issues can be identified when recording psychophysiological signals. Firstly, the sensors attached to the user might induce discomfort to the user, restrict movements or influence the experience. So, the researchers should limit the amount of sensors applied on the user. Secondly, while measuring the UX through the same neurophysiological sensor that is used for controlling the application, UX-related responses should be differentiated from task-related activity.

3.3 Interviewing and Questionnaires

Interviews and questionnaires provide subjective data for assessing UX. They take place after interacting with a system thus are unobtrusive but then not able to extract instantaneous experiences during interaction. For disabled users, especially those with LiS, using subjective methods might not seem to be the easiest way to assess UX as these people might not be able to talk or write. However, if the interviews and questionnaires are prepared in such a way that they can be answered using a few number of choices, such as yes, no and maybe, then they can be completed by these users as well.

Interviewing is a qualitative-subjective technique. During interviews, researchers should be careful to pose the right questions during the interview, if necessary, by monitoring the interaction and detecting unexpected events. The interviewers should remain neutral and refrain from asking leading questions. Questionnaires, on the other hand, are designed to provide quantitative-subjective data. Development of UX questionnaires for entertainment applications has received attention from researchers, especially those who are interested in games. The recently developed Game Engagement Questionnaire [26] includes items related to absorption, flow, presence and immersion. There are also questionnaires focusing exclusively on the components that contribute to UX such as presence [27] and immersion [28]. Another concept that is often related to UX is the usability of the interface. Many heuristics have been proposed for evaluating the usability of video games [29]. However heuristic evaluation does not involve actual users and usability of an interface alone does not represent the UX. Before questionnaires are used to evaluate BCIs, they may require adaptation taking into account that state-of-the-art BCI applications are relatively simple thus modest in providing rich UX. BCI recognition performance should also be taken into account, as a relatively low performance might influence the UX.

The important factors in selecting the right UX assessment method for BCIs can be listed as the ease of deployment and analysis for the researcher, the comfort of deployment on the user, the strength and reliability in representing the actual UX, and the width of the user spectrum. As seen within this section, all the methods partially fulfill these criteria. Nevertheless, questionnaires stand as strong candidates as they are easy and comfortable to apply, suitable for extracting statistical analyses quickly, strong and reliable when validated and applicable to the majority of the BCI users.

4 Towards a Standardized Questionnaire

As we have described in section 3, classical UX evaluation of a system is often done by administering standardized questionnaires, taking qualitative in-depth interviews with users or by observing overt behavior of users. In this part we will elaborate on our proposal for a standardized questionnaire that can be used to evaluate the UX of BCIs for entertainment purposes. To these means we will first describe some case studies from our group.

4.1 Case Studies

In the past, we have made some prototypes of BCIs incorporated into games that we evaluated on UX.

The first prototype is a BCI game called BrainBasher utilizing the ERD/ERS of imagined and actual movement as described in [14]. Users are provided with direct continuous feedback whether left, right or no movement is detected by the BCI. The game was evaluated with a questionnaire, which compared the UX in the imagined and actual movement conditions. Imagined movement was perceived as more challenging to users although also as mentally more demanding and more tiring. While users preferred the imagined movement for short periods, users would prefer actual movement for prolonged periods of playing this game. Users considered the feedback to be valuable, because they could play around and adapt their strategy of imagining movements to what the system would recognize correctly.

The second study which studied UX and user-centered design involved the game IntuiWoW[30] IntuiWoW is a BCI extension of the popular game World of Warcraft. Users were involved in the design process. They could choose which mental tasks should be used for certain actions in the game. In the subsequent evaluation of the prototype which incorporated those actions users found the recognition accuracy of the mental task to be most important for the user's preferences of mental tasks. In addition, UX was improved with ease of use, fun, intuitiveness and suitability.

Thus, these two studies showed that to evaluate usability of a system it is not sufficient to focus on BCI performance but, that also UX needs to be considered. The first study provides us with a base for developing the questionnaire, the second study provides us with more insight as to what factors are the most important to ask the users.

4.2 Questionnaire

Structured standardized questionnaires can provide valuable quantitative information about an application. One possible cause for the lack of structured questionnaires for BCI applications is that the way of interacting with an application is inherently different from classical human computer interaction. Also it is difficult to compare between different BCIs because of different mental tasks and the way the user uses them. To compare between BCIs and to pinpoint on which dimensions UX can be improved, standardized BCI specific questionnaires are required. Current questionnaires on UX such as the Game Experience Questionnaire [15] and Engagement Questionnaire [26] are not sufficient, because these questionnaires assume that only a traditional method of input (e.g. keyboard and mouse) is used.

As the case studies described in the previous paragraph demonstrated, recognition accuracy, ease of use and applicability of the used mental task play an important role in the UX. Because different mental tasks provide the user with different experiences, it might prove difficult to make every item in the questionnaire relevant. For example, while evaluating how a flickering stimulus for a SSVEP-based BCI is perceived by the user can be very valuable, in the case of an ERD/ERS BCI this is not applicable. However, Zander et al [16] categorize mental tasks used for BCIs into three different groups: passive, active and reactive. Within these groups, mental tasks should, at least for the sake of UX evaluation, be largely comparable. For example, reactive BCIs incorporate stimuli for the user to react to (hence the name 'reactive'). Items in the questionnaire can be on the obtrusiveness of the stimulus, to what extent it disctracts attention from the main task of the BCI and to what amount users get tired or sore eyes of it.

Therefore, we propose to develop a questionnaire with modules for each category. Within these categories there can be specific questions about the way the user is interacting with the system. For example, for passive BCIs items in the questionnaire can ask the user if the BCI hardware is comfortable and does not distract from the main task at hand. For active BCIs, items on applicability of the mental tasks and perceived speed of the BCI on the users actions can give valuable information. Also the time that is needed to train the system and the ability to retain that training model over time are important for the UX. To perform an active mental task a user needs a certain amount of concentration. Over time this will fatigue the user and light headaches are not unlikely to develop. When developing and evaluating reactive BCIs, we are more interested in the obtrusiveness of the stimuli that are used. In the case of the aforementioned SSVEP BCI, the flickering of the stimulus is needed to make the BCI work, but variations in size, colour and texture can make a big difference in how the user perceives the obtrusiveness of the stimulus.

However, there are some difficulties with the categorization of BCIs into 'active', 'passive' and 'reactive'. One can think of BCIs in which the interaction paradigm is ambiguous to two categories.

Consider for example a P300 based lie detector, in which the 'user' gets presented with stimuli and the interogator can find out if the user is interested in what is presented to him, or has seen something before. This is a reactive BCI paradigm used in a passive interaction paradigm, because there is no direct immediate feedback to the user.

Another example is the previously mentioned IntuiWoW [30] in which the user's parietal/occipital alpha power is used to control the form and function of the avatar in the game. Users can actively influence there alpha power by relaxing or aggitating themselves, or they can just play the game and let the BCI passively adapt the avatar to their state of mind.

So, to construct our questionnaire, we need to look at the way users interact with the BCI. And while the categorization into passive, reactive and active BCI paradigms provides a good starting point, we need to not just look at how the user performs the mental task, but as well at how the recognition of that mental task is incorporated in the application.

To get BCI research one step further and to bridge the gap between the technology and the user, we need to develop and incorporate standardized measures inspired by HCI. While (neuro) physiological measures are still in (early) development, standardized questionnaires can provide valuable information.

5 Conclusions

In this paper we stressed the need for UX evaluation of BCI applications. While some research has been done on this, it remains largeley an uncultivated area of research. However, we can learn from methods developed in the field of human-computer interaction. Especially standardized questionnaires can be a valuable tool to evaluate BCIs. We proposed a questionnaire in which a core with general questions and modules for the different kinds of mental tasks and ways of interacting with the BCI is developed. This way, we can compare user experience between applications or within one game with different possible input modalities. This can provide developers of BCI applications with valuable information on where the weak and strong spots in the design are, as to create a better UX and acceptance of BCIs.

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BCIs in Multimodal Interaction and Multitask Environments: Theoretical Issues and Initial Guidelines

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Abstract. The development of Brain Computer Interfaces (BCIs) enters a phase in which these devices are no longer restricted to applications in controlled, single-task environments. For instance, BCIs for gaming or high-end operator stations will function as part of a multimodal user interface in a multitask environment. This phase introduces new issues that were not relevant for the development of the initial special-use applications and we should address these issues systematically. In this paper, we will present the potential conflicts and how models of information processing can help to cope with these. We will conclude with providing guidelines.

Keywords: BCI, BMI, HCI, guidelines, hybrid BCI, information processing, multimodal, user interface, theoretical models.

1 Introduction

The initial development of Brain Computer Interfaces (BCIs) focused on providing users with special needs a way to communicate when other interaction means failed. However, there are also several good reasons to consider BCIs for healthy users, for instance to make control or communication more intuitive or reduce the risk of overloading sensory modalities or the motor system [1]. As a result, the scope of BCI applications under investigation expands rapidly and starts to include applications for gaming and adaptive automation.

For users with special needs, a BCI is often developed as the only interaction device and used for a specific communication task performed in isolation. In more complex situations, a BCI is part of a multimodal user interface and may be used in a multitask situation in which the user performs different tasks sequentially or even in parallel. This introduces relatively new user-system interaction issues and here we aim to have a closer look at for instance the (human information processing) models relevant for these situations. Appropriate integration of BCIs in multimodal interaction and multitask environments is a prerequisite for successful BCI applications for healthy users [2].

The expanding scope of BCI applications also requires reconsidering common BCI definitions. The assistive technology community often uses the strict definition provided by [3]: A BCI is a communication and control system that does not depend in

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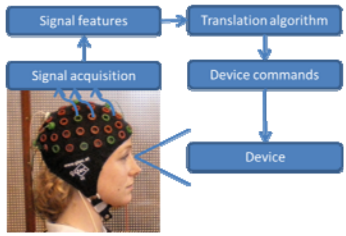

Fig. 1. Classic view of a BCI systems from the assistive technology approach

any way on the brain's normal neuromuscular output channels, that provides real-time interaction and includes feedback of the outcome to the user. We propose a broader definition more adjusted to the HCI community: "*a BCI uses signals from the brain to control a device or the interaction between the user and a device (near) real time, and/or provides signals directly to the brain to either communicate information or alter brain activity*". This definition includes systems that use brain signals to assess the user state for instance to adjust the task allocation or interaction modality between user and system. As such, brain signals can be considered an expansion of the set of physiological measures already used in user-system interaction such as heart rate variability. Also, BCIs can either refer to communication from the brain to a system, or vice versa (sometimes referred to as Computer Brain Interface, CBI), or both. However, the vast majority of current BCIs for healthy users uses communication from the brain to a device only.

Zander and colleagues [4] made a useful distinction between active, reactive and passive BCIs, based on the user's effort and task to control the BCI. In active BCIs, users actively generate specific brain signals to give a specific command, for instance by doing mental calculation or imaginary limb movement. Reactive BCIs do not require active generation of brain signals but interpret the brain's automatic reaction to so-called probe stimuli. The user can modulate this reaction pattern by modulating attention, which can be used to select a specific probe stimulus. Finally, a passive BCI analyses brain signals without the user needing to perform specific mental tasks, but uses neural correlates of constructs such as engagement, mental workload and drowsiness [5].

Figure 1 depicts the classic view of a BCI. The user actively generates a specific brain pattern (e.g. motor imagery). A sensor system (e.g. EEG) acquires and processes the brain signals followed by extraction and classification of the signal features by computer algorithms (see [6] for a review). The results are translated into device commands and executed by the device (e.g. a wheelchair) and the user can perceive the result. In this classic setup, there is only one task and no other interaction channels between user and device. We will discuss the extensions: to a dual-task situation, to combining two BCIs and to the integration with other user-system interaction modalities.

2 Challenges for the Use of BCIs in a Dual Task Environment

Figure 2 uses a model of a (closed-loop) user-system interaction in which the user is simply modeled with a perception, cognition, and action step. The user perceives system information (this phase -arbitrarily- includes bottom-up processing in the brain, i.e. by the sensory cortices), further processes this information in the brain (i.e., higher order cognitive processes) and performs an action affecting the system. With this latter phase we exclusively refer to the peripheral motor system. We include planning the action -again arbitrarily- in the cognition phase. The panels of Figure 2 illustrate the extension from a single task situation (left column) to a dual task situation (right column) for an active, reactive and passive BCI. Please note that the division in perception, cognition and action is useful in the current context because dual task situations can affect these phases separately, while the effects from one phase to the next are rather independent, for instance error rates or the distribution of errors are unaffected by earlier phases [7-9].

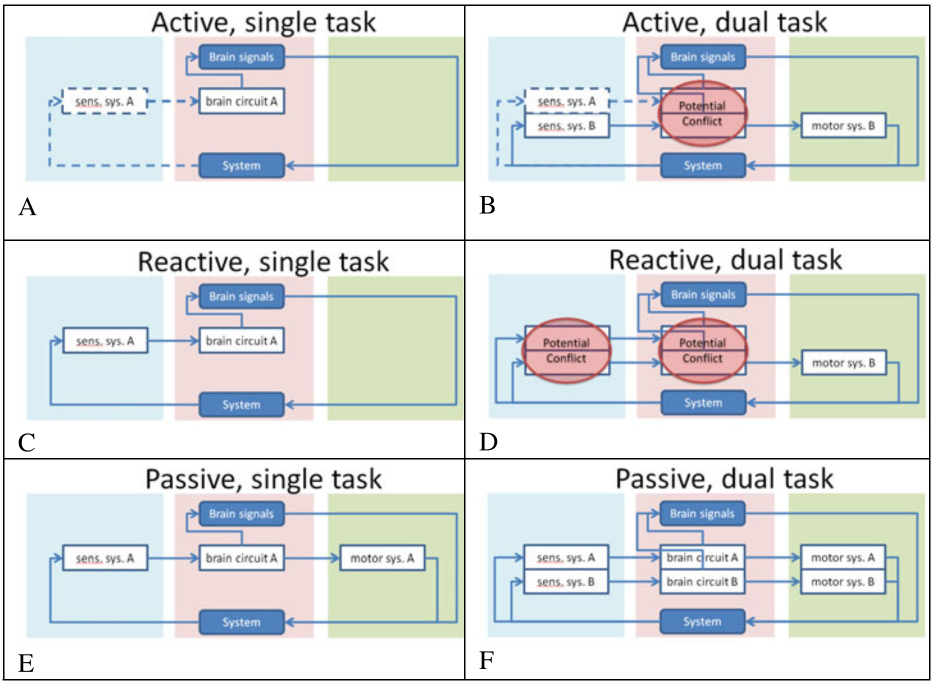

Fig.2. Extending the three BCI classes from a single task situation (left column) to a dual task situation (right column). The ovals indicate a potential conflict that may arise in BCI use in dual-task situations.

The classic BCI as described earlier can be considered as an active, single task BCI. The user performs task A (here task A is controlling the BCI) through employing brain circuit A (e.g. motor imagery). The acquired brain signals result in system changes that are (possibly) perceived by the user through sensory system A and there is no motor action step in this BCI (please note that for an (open-loop) active BCI, there is no strict requirement for a specific sensory system A – hence the dotted lines in panel A). For a second task B (BCI or non-BCI, cognitive or motor), the user may employ a brain circuit B, use motor system B to give the commands to the system and possibly perceive the results of this input through sensory system B. Panel B depicts the situation when we combine the active BCI with this task B. In this "active, dual task" situation, a conflict may rise at the level of the brain and the acquisition of brain signals which we will describe in more detail below. Panels 2C and 2D depict the situation for a reactive BCI. A reactive BCI uses the brain's reaction to specific probe stimuli. These probe stimuli rely on a specific sensory system A and the reaction to this probe stimulus in brain circuit A. As in panel A, there is no motor action involved in a single task, reactive BCI. Panel D depicts the situation for a task B added to the reactive BCI and shows that potential conflicts may arise at both the sensory system and the brain (e.g. because both may use the same sensory channel (e.g. visual) or brain process (e.g. attention). Finally, panels 2E and 2F depict the situation for a single and dual task passive BCI. Here, the BCI uses naturally occurring brain patterns when the user performs task A, and the same when the user performs tasks A and B. Of course, a conflict may occur when the user performs both tasks, but this will not affect the workings of the passive BCI. On the contrary, the goal of the BCI may even be the detection of such a conflict.

2.1 Psychological Models for Dual Task Situations and Coping with Conflicts

Here we briefly introduce Wickens' Multiple Resource Theory (MRT, e.g. see [10] for an overview) because this model provides relevant guidance on how to reduce dual task interference. The basic version of the MRT knows three independent dimensions, here given with their associated brain circuitry: a) stage of processing: perceptual and cognitive (posterior to the central sulcus) vs. selection and execution of action (anterior to the central sulcus); b) code of processing: spatial (right hemisphere) vs. verbal/linguistic (left hemisphere); and c) modality: auditory (auditory cortex), visual (visual cortex), and possibly tactile (somatosensory cortex). A large body of evidence confirms the assertion that the degree to which two tasks use different levels along each of the three dimensions reduces interference between the tasks. Several variants (e.g. [11]) and extensions to this basic MRT have been suggested in recent years. For instance Boles et al. extended the number of perceptual resources by distinguishing spatial positional, spatial quantitative and other resources (for recent work here, see [12]).

Applying a reactive BCI in a dual task environment can potentially lead to a conflict at the stage of the sensory system (perceptual processes) and the brain (higher order cognitive processes). At the sensory system, the probe stimuli required by a reactive BCI may interfere with sensory processing required for task B. This risk of sensory overload is relatively common in user-system interactions and several information processing models further detail the risks and possible solutions. A way to reduce the effects of a potential conflict is to employ different sensory systems for the probe stimuli of task A and the system feedback for task B (but see [13] for interference of concurrent stimulus processing). Although both may often be visual, the use of auditory and haptic displays increases [14]. Recent examples of using tactile stimuli as probes in a reactive BCI show that this is feasible and performance is comparable to that with visual stimuli [15, 16]. Interestingly, the use of multisensory stimuli in the context of BCIs is not widely used while this is a proven solutions in other domains.

A more complicated and challenging issue is the potential conflict that can arise at the level of the brain for active and reactive BCIs. There are actually two issues here. The first is similar to the sensory conflict described above: the tasks may use the same resources (brain circuits) and thus result in an overload situation (this is not different from two non-BCI tasks that use the same cognitive resources). The second is that even when tasks A and B use different and not-interfering brain circuits, the brain signals acquired by the BCI may still be affected by those of task B. This is inherent to most signal acquisition systems. For instance, the electrical signals acquired by EEG sensors have a low spatial specificity and not only represent activity of brain areas directly underlying the sensor but also areas centimetres away. Solving this issue is outside the scope of this paper and progress made in both sensor technology and computational algorithms may reduce this issue.

Coping with dual tasks that use the same cognitive resources (brain circuits) is an important challenge. Within the BCI domain, this challenge has also been tackled from a single task perspective, e.g. [17] provides a good overview. Dual task situations will further complicate the challenge. First, we must state that people are not very good at executing two tasks at the same time or in close succession [18], even though the brain seems to adjust to dual tasks situations (e.g., by dividing tasks among the left and right anterior prefrontal cortex compared to using both in a single task situation [19, 20]). However, some tasks interfere less with each other than others. A rule of thumb is that the more the two tasks share the same resources or brain circuits, the more they interfere. Although there is a large set of possible task combinations that has not been investigated yet, data indicating such competition are available for the more common combinations. For instance, working memory and visual search compete for the inferior and middle frontal cortex [21], manual tracking and visual detection seem to compete for the primary motor and somatosensory cortices involved with controlling the tracking-hand [22], manual tracking (driving) and listening affects the parietal lobe [23], and two motor tasks compete for the primary motor cortex [24]. Unfortunately, the literature is more keen on reporting tasks that do interfere than those that don't. Identifying two tasks that do not or only to a certain degree interfere and of which the brain circuits are spatially separated is an important challenge and must be based on neuroscientific as well as behavioural studies. A good point of departure are the dimensions of the MRT.

Another relevant aspect is that simply trying harder cannot overcome the limitations of a central cognitive bottleneck [25], but training may reduce the amount of interference. This training effect is not only visible in increased performance but also in the reduced overlap in employed brain circuits. For instance, Rémy et al. [26] investigated the combination of a bimanual task with a visual search task. After training of the manual task, the overlap between regions involved in both tasks was reduced, possibly due to automaticity of the manual task.

3 Combining BCIs

In this section, we will have a closer look at the consequences of combining different BCI classes. Please note that in the assistive technology domain, the term hybrid BCI was introduced to refer to combinations of BCIs or of a BCI with other control devices (e.g. [27]). In the user-system interaction domain, the common term is multimodal interface. Earlier work on this topic was restricted to either the serial use of two BCIs (e.g. one BCI serving as an on-off switch of a second BCI) or as redundant input channels in the same task [27, figure 1]. Here we focus on multi-task situations in which two BCIs are used (simultaneously) for two different tasks. Again, conflicts may be expected at the sensory system (when combining two reactive BCIs) and/or the involved brain circuits (when combining two active BCIs or an active and a reactive BCI). For combinations with a passive BCI, no conflicts are involved. Recent examples are the multimodal BCI described by [27] using event-related desynchronization and steady-state evoked potentials in a redundant set-up (i.e. both provide input to the same task and are integrated to provide the input to this single task) and [28] using (actively generated) alpha rhythm and SSVEPs.

Combining two active BCIs or an active and a reactive BCI may result in a conflict between the involved brain circuits. Combining two active BCIs is essentially a dual task and as such may suffer from the same effects described in the previous section, and choosing two appropriate tasks is essential. For instance, Sangals and Sommer [29] showed that a simple choice task with foot responses interferes with response preparation for a manual choice task. This indicates that two active BCIs based on motor (imagery) tasks may not be a good choice. The situation is even more complicated than a single active BCI in a dual task situation in the sense that the two brain circuits involved should not only be 'independent' of each other, but also spatially distributed or the sensor system may have difficulties in classifying the two tasks. The brain circuit conflict for combining an active and a reactive BCI is potentially less severe. In principle, performing a mental task and paying attention to probe stimuli can be combined. Since the 'attention wave' required by the reactive BCI will be located centrally, it is recommended to use a mental task for the active BCI that involves brain circuits located more lateral or frontal, or which signal is clearly distinct from the attention wave (e.g. based on spectral features).

When combining two reactive BCIs (i.e. each connected to a different task), it is strongly recommended to use two different sensory modalities to present the probe stimuli. But even then, it is doubtful whether the user is able to pay sufficient attention to targets in the two modalities to obtain a unique and measurable brain pattern. This is related to the fact that both BCIs will also compete for the same central brain circuits or resources as for instance shown for auditory and visual stimuli [30, 31]. Or in other words: the location of the relevant brain signal indicating whether attention was paid to a stimulus is more or less independent from the stimulus modality. For instance, Brouwer and colleagues [15, 16] investigated visual, tactile and bimodal visual/tactile probe stimuli and found only small differences in location of the P3 (i.e., the 'attention wave') as function of sensory modality. This means that exact time-locking of probe stimuli and EEG is critical and probe stimuli in both modalities should be out-of-phase. Another problem that may arise is the cost involved in switching attention between sensory modalities (e.g., in terms of required time [32, 33]). This means that for instance, using the two BCIs consecutively and not parallel may introduce a new bottleneck.

4 Integrating BCIs in a Multimodal User Interface: Relevant Issues

Especially in applications for healthy users, a BCI will not be a stand-alone interface between user and system but part of a multimodal user interface. Like other input and output modalities, integrating a BCI in a multimodal interface requires careful consideration of several aspects. Up till now, little or no attention in the design of BCI applications is given to usability related aspects such as comfort and ease of use). Here we will list several issues that are of particular relevance for BCIs, but we do like to stress that general guidelines with respect to interaction design should also be taken into account such as adjusting the interaction to the user, task and context of use characteristics (see ISO 9241 series on international usability standards).

- BCI as control device should be combined with a compatible display modality. Known compatible combinations in multimodal interfaces are for instance manual control – visual display, and vocal control – auditory display [34]. This is an important research topic for BCIs.
- The choice for a specific BCI category should be based on the task requirements and the strength and weaknesses of specific BCIs. As we coined the term modality appropriateness for the choice of display modality, we propose to use BCI appropriateness for this choice.
- A topic of specific interest is how to combine a (active or reactive) BCI with other control devices and prohibit interference [35].
- For passive BCIs, policies related to the fusion of BCI results with other physiological data must be developed.
- A specific BCI issue is the question of how to switch a BCI on and off. Since users cannot simply switch their brain activity on and off, specific solutions are required. One should also ensure that the current system interaction state is communicated to the user and that the system appropriately provides feedback when it initiates a modality change.
- In case the classification accuracy is limited, the system should confirm its interpretations of the user input (when appropriate after fusion and not for each modality in isolation). In this situation, users should have an option to choose alternative interaction modalities and be allowed to switch to a different modality.

5 Discussion and Preliminary Guidelines

We started by making an inventory of relevant issues when extending the use of different types of BCI from a single task environment to a multitask environment. Although we can build on the lessons learned from the user-system interaction domains and relevant information processing models such as the MRT, there is a need to get better insight in how to choose BCI modalities and tasks that only minimally interfere, i.e. they should be functionally and spatially separated. We expect that the identification of non-conflicting tasks will benefit from studies in high resolution brain imaging. A relevant addition of the MRT is linked to the sharing of task goals. For instance, tasks that would normally interfere like driving and listening will do so to a lesser degree when they share the same task goal, i.e. listening to navigation instructions. The same may hold for BCI tasks in a multitask environment. We also looked into the situation where BCI feedback or probe stimuli may lead to sensory overload or interference. The use of alternative sensory modalities or multisensory stimuli may reduce this risk, but the sensory modality should also be compatible with the BCI task. An important next step here is to have a quantitative evaluation of the identified conflicts.

Now that BCI technology is maturing and the range of possible applications expands, it is necessary to look more closely at general usability aspects. So far, usability does not seem to play the role it must when preparing BCIs for operational use outside the lab and for a growing range of users. This also means that the range of BCI paradigms should be stretched beyond the commonly used motor imagery for active BCIs and P3 matrix speller for reactive BCIs. Systematically looking into the task requirements and context of use can result in a better match of BCI as control device and other user-system interaction components. Having said that, we would also like to stress that BCI applications can still be considered embryonic and that many technological issues should be solved in hardware development, signal processing and system integration. Based on the issues we discussed and general user-system guidelines we formulate the following preliminary guidelines for BCI design and multimodal interaction:

- A BCI should be used if it improves satisfaction, efficiency, or other aspects of performance for a given user, task and context of use.
- The BCI category should match the task requirement.
- The BCI coding should match the task requirements (e.g. letters for a spelling device and directions for a navigation task).
- The feedback to the user or the BCI probe stimuli should match the BCI coding and presented in the appropriate sensory modality (e.g. letters visually, directions through spatial audio).
- The feedback to the user should match with the strengths, weaknesses and possibilities of the BCI and not go beyond its capabilities.
- Ensure that the display modalities are well synchronized temporally as well as spatially.
- Minimise possible interference between the BCI task and other tasks, both functionally and in relation to the spatial specificity of the BCI acquisition system.
- Aim to combine tasks that share the same task goals.
- Minimise possible interference between the sensory system involved in the BCI and other user-system interaction components.
- Performing tasks sequentially instead of simultaneously may reduce sensory or cognitive conflicts but may also involve costs of task and/or modality switching.

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Fitts' Law in Bivariate Pointing on Large Touch Screens: Age-Differentiated Analysis of Motion Angle Effects on Movement Times and Error Rates

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Abstract. Fitts' Law is a famous and highly satisfactory model to predict movement times in ergonomic studies. The original Fitts' Law only considers one-dimensional movements. In the field of human-computer interaction however one has to deal with at least two dimensions. Due to inconsistency in previous research concerning the integration of the motion angle into the Fitts' formulation, we investigated the influence of this factor on movement times and errors systematically. 30 subjects, separated in two age groups (younger: 21-36 years, elderly: 58-77 years) were tested in executing a pointing task on a large touch screen. The results reveal that the motion angle has a sinusoidal effect on the movement time for both age groups. Subsequently Fitts' Law was refined by an additional summand which is an explicit sine function of the motion angle. Based on our findings we give practical recommendations where to arrange information elements on large touch screens.

Keywords: Fitts' Law, Motion Angle, Bivariate Pointing, Movement Times.

1 Introduction

Although Fitts' Law is a strong model to predict movement times the role of the motion angle in two-dimensional pointing tasks is still unclear. In this study we investigated the angle-effect regarding movement time and error rate in detail. Based on the results a refined model of Fitts' Law was built and evaluated. Besides theoretical implications the results provide practical recommendations for the spatial arrangement of information elements on large touch screens.

Large touch screens provide a promising alternative to classical computer workstations in application areas where one has to display and manipulate complex information at once (plant design, project management, architecture, etc.). With touch screens the way people interact with computers has changed as the separation between information input and output is repealed. Research has shown that this interaction-technique can be beneficial for many user-groups, particularly for the elderly [10, 11, 13, 14, 15]. To display complex information and to enable natural input the touch screen technology has developed to large scaled multitouch screens. The effectiveness and efficiency of information input however depends highly on the ergonomic design of the user-interface. When transferring software originally designed for classical desktop

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computers to large touch screens one has to consider that the regular button size used in many software systems is optimized for mouse input and that movements of the hand-arm-system are error prone when buttons are located in the upper parts of the touch screen. Crucial questions are where to display menus, buttons or icons on large touch screens, and which size these elements should have in order to enhance pointing performance. To determine ergonomically “optimal” target sizes and target positions Fitts' Law provides a highly satisfactory model. Fitts' Law states that the movement time (*MT*) is linearly dependent on the index of difficulty (*ID*) of a pointing task. The *ID* of a movement is defined as the dyadic logarithm of the quotient of amplitude of the movement (*A*) and target width (*W*):

$$MT = a + b \cdot \log_2 (2^*A/W) . \quad (1)$$

Fitts' original study only considered one-dimensional movements; however on large touch screens one has to deal with two-dimensional movements. To adopt Fitts' Law to bivariate pointing one has to consider two potential influencing factors: the definition of the target width and the motion angle between the starting position and the target object. In the present study we focus on the motion angle.

A literature analysis showed that in 1954 Fitts already found an angle effect concerning the error rate. He mentioned that pointings to the left side (180°) are more accurate than pointings to the right (0°) [8]. Two decades later, when adopting Fitts' Law to human computer interaction, Card et al. (1978) analyzed performance in text selection regarding different angles (0°-360°, in 45° increments) using a mouse, a joystick, step keys and text keys. They found that the motion angle has a significant effect for every investigated input device except for the mouse. For the joystick for example the movement time is slightly higher (3 % of the mean movement time) when the target is approached diagonally [2]. In 1991 Boritz et al. investigated the approach angle for different pieces of pie menus (0°-360°, in 45° increments) and the time to move the mouse cursor to the target. They found that the movement time is higher for 270° than for 0° [1]. MacKenzie et al. (1992) compared motion angles of 0°, 45° and 90° in bivariate pointing tasks using standard mouse input. In accordance to Card et al. they found that movement time is higher when the motion angle was 45° than when it was 0° or 90° [12]. Whisenand & Emurian (1999) examined the effect of the motion angle (0°-360°, in 45° increments) on the movement time and accuracy in a discrete drag-drop and point-select task with squared and circular target objects using a computer mouse. They found the highest movement times for 90° and 270°. The lowest movement times were found for 180° and 0° [16]. Iwase & Murata (2002, 2005) examined the effect of motion angles (0°-360°, in 45° increments) in more detail. In their study with elderly subjects using either a touch panel or a mouse for input, they found differences in movement times for motion angles of 0°, 45°, 90°, 135°, 180°, 225°, 270° and 315° degrees. For touch panels they found a periodical sinusoidal relationship between movement time and angle defined by the following function [9, 13]:

$$MT = \alpha \cdot d - \beta \cdot \log_2 s + \gamma \cdot \sin 2\theta + \delta \cdot \sin \theta + c \, . \tag{2}$$

In which α, β, γ, δ and c are the multiple regression coefficients, d is the distance, s is the target size and θ is the angle between start- and target object. Du et al. (2007) also report a sin-curve pattern in their investigation of pointing tasks on a board [5].

As there is inconsistency in previous research in how to include the factor motion angle to Fitts' Law the aim of this study is to investigate the influence of this factor on movement time and errors systematically.

2 Method

The study included a pointing task with target objects varying their position on the screen to answer the question how the motion angle influences movement times and error rates. The data was analyzed with respect to the age of the participants in order to gather information about age related changes in pointing performance.

2.1 Subjects

Altogether, a sample of 30 right-handed subjects was tested in the experiment. They were paid volunteers aged from 21 to 77 years. The subjects were divided by age into two groups with 15 persons each. The age of the younger group (9 male, 6 female) ranged from 21 to 36 years (M = 29.39, SD = 4.52); the age of the older group (8 male, 7 female) from 58 to 77 years (M = 67.82, SD = 5.47).

2.2 Apparatus

The hardware used to register the pointing movements was the so termed “DiamondTouch” screen developed by Circletwelve Inc. [3]. The DiamondTouch screen is basically a tabletop device (projection area 865 mm x 649 mm, 4:3 ratio) with a touch-sensitive surface of 1070 mm in diagonal. The images are projected from top. Through capacitive coupling between a transmitter array located in the touch surface and separate receivers the subjects sit on, the attached computer can distinguish multiple touch inputs. The physical setup of the system consists of the DiamondTouch screen connected to a PC via USB cable, and a video projector (1600 x 1200 pixel) mounted above the tabletop and aimed down onto the touch surface.

2.3 Procedure

The pointing task was carried out with the DiamondTouch screen lying on a table with a height of 755 mm. The subjects were seated on a chair in front of the DiamondTouch screen. The investigator demonstrated and supervised a sample target block to familiarize the subject with the task and the test environment. The subjects were instructed to point as quickly and as accurately as possible. In the experimental task the participants had to point with the right index finger from the start position (Ø = 20 mm) located in the centre of the table to a target object (Ø = 40 mm). The

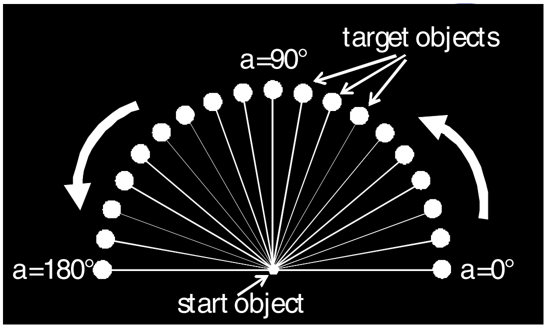

Fig. 1. Sketch of the experimental setup. Exemplarily shown for a starting position at 0°.

size of the start position was chosen according to the 95th percentile of index finger width for men [4]. Each subject completed eight blocks. A block consisted of 38 pointings in that the position of the target object varied from 0° (pointings to the right side) to 180° (pointings to the left side) in 10° increments and back from 180° to 0° in 10° increments. The subjects started alternately with pointings where the target was located at 0° or 180°. This setting was first executed with an amplitude of 400 mm, followed by an amplitude of 200 mm (Figure 1).

2.4 Data Analysis

Movement time data and errors were aggregated into a mean movement time in milliseconds and a mean error rate in percent (in decimals) for each participant. The significance level for each analysis was p=0.05. The statistical software package SPSS Version 17.0 was used to compute the descriptive and inferential statistics.

3 Results

3.1 Descriptive Analysis

Movement Times. In Figure 2 the mean movement time data of the 200 mm condition is depicted depending on the angle (0°-180°). In fact, the movement time of both age groups clearly varies over the angle in a periodical pattern similar to the sin-curve. In both age groups the lowest movement time was found for an angle of 30° (young: 284 ms; old: 312 ms), the highest movement time was found for an angle of 140° (young: 357 ms; old: 361 ms). As obvious, the movement time of the older age group lays approximately 21 ms above the movement time of their younger counterparts.

The time data for the 400 mm condition (see Figure 3) follow the same sin-shaped pattern for both age-groups. In the younger age group, the lowest movement time was found for an angle of 40° (411 ms), in the older age group the fastest pointing occurred at a 20° angle (437 ms). The highest movement time occurred at a 160° and 180° angle respectively for the younger (484 ms) and the older age group (520 ms). Again, the movement time of the older age group is approximately 30 ms higher.

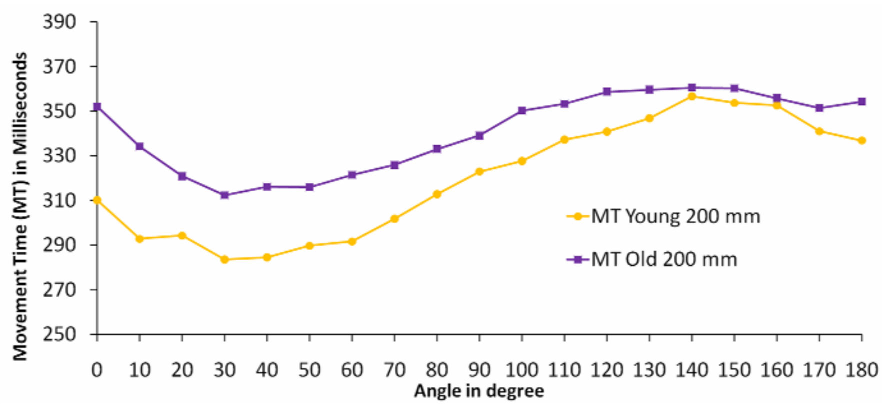

Fig. 2. Movement time data of the 200 mm condition for both age groups

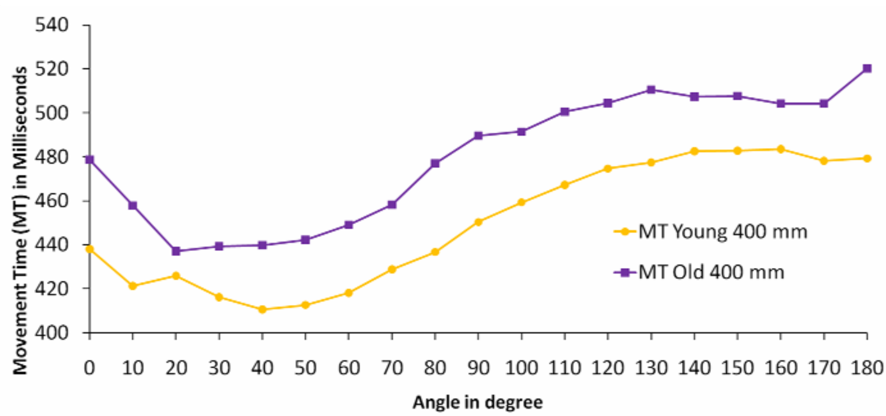

Fig. 3. Movement time data of the 400 mm condition for both age groups

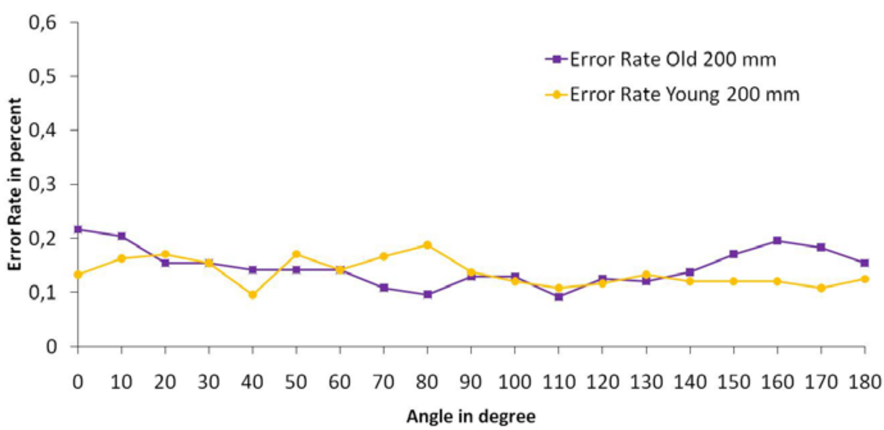

Fig. 4. Error rate data of the 200 mm condition for both age groups

Error Rates. For the 200 mm condition Figure 4 depicts the mean error rate in percent (in decimals) for each angle and both age groups (please note that the number of pointings per angle is 16). For both age groups the angle has low impact on the error rate. The mean error rate varies rather unsystematically around 0.14.

The investigation of the 400 mm condition results in a similar error pattern for both age groups. The highest error rate is found in both age groups between 0° and 20° degree with a mean error rate around 0.38 for the younger and a mean rate around 0.55 for the elderly. By trend, the error rate decreases in the range of 20° (young=0.43 /old=0.53) up to 110° degree (young and old=0.09), reaching minimum values at 130° (young=0.05) and at 120° (old=0.08).

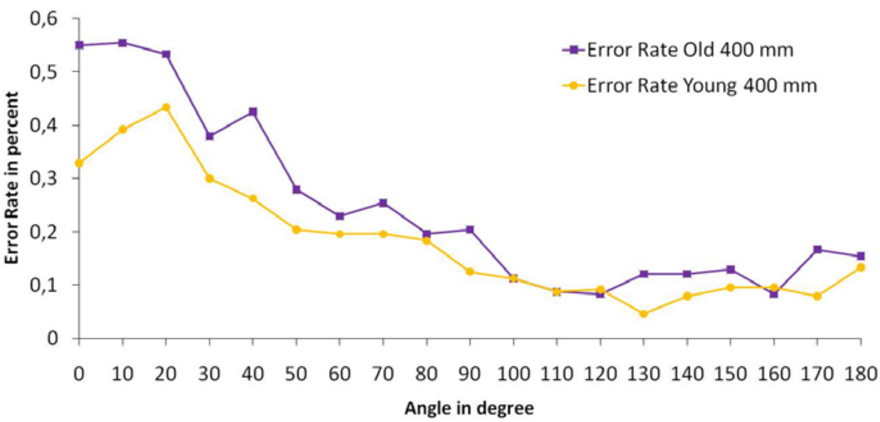

Fig. 5. Error rate data of the 400 mm condition for both age groups

3.2 Analysis of Variance (ANOVA)

Regarding the assumptions of inferential statistics, it must be noted that the KS-Test indicated significant deviations from normal distribution for at least some of the movement time (19 of 76) and error rate data (40 of 76). However, the overall pattern of the data is bell-shaped and ANOVA provides a robust measure when the sample size is equal across the groups [7]. Mauchly test indicated that the assumption of sphericity had been violated; degrees of freedom were thus corrected using Greenhouse-Geisser estimates of sphericity. Additionally, the variable ω^2 for repeated measures was calculated to quantify the strength of significant effects [5, 7].

Movement Time. The mean movement time for each angle was analyzed with ANOVA. For the 200 mm condition a significant main effect of movement time was found relating to the angle ($F_{(9.83,652.25)}=17.42$, $p=0.000$) and a medium effect size of $\omega^2=0.33$ within subjects was calculated. An additional significant effect was found for age group ($F_{(1,66)}=45.19$, $p=0.000$) and a large effect size of $\omega^2=0.60$ between subjects occurred. In addition the interaction between angle and age group is significant ($F_{(9.83,652.25)}=9.25$, $p=0.000$, $\omega^2=0.19$). Thus, angle had different effects on movement time depending on the participant's age group.

For the 400 mm condition significant effects of angle ($F_{(8.92,267.68)}$=26.59, p=0.000), age group ($F_{(1,30)}$=14.90, p=0.001) and a significant interaction effect of angle and age group ($F_{(9.83,652.25)}$=4.82, p=0.000) were found. Here the effect size of the angle is larger with ω^2=0.45. Age has a medium effect size of ω^2=0.32 within subjects. The interaction effect of angle and age group is low with ω^2=0.11.

Error Rate. Regarding the error rate for the 200 mm condition, the results of the ANOVA do not show any significant effects or interactions of within or between-subject factors. In the 400 mm condition a significant effect of angle was found ($F_{(6.99,194.84)}$=33.47, p=0.000) and a large effect size of ω^2=0.52 within subjects was calculated.

3.3 Building of a Refined Model

In accordance to our findings a nonlinear sinusoidal model on the basis of movement time, motion angle, amplitude and target width was build in order to refine Fitts' Law. Therefore the ID formulation is expanded by an additive sinusoidal term:

$$MT = a + b \cdot ID + c \cdot \sin(2\alpha)\ . \quad (3)$$

The results of performance modeling are listed in table 1 for both age groups.

Table 1. Parameters and coefficients of determination of the refined model

Age group	*a*	*b*	*c*	R^2
Young	-111.58	129.83	-35.70	.984
Old	-121.83	139.25	-30.25	.981

In Figure 6 the empirical and modeled movement time data are depicted for the two distances and both age groups.

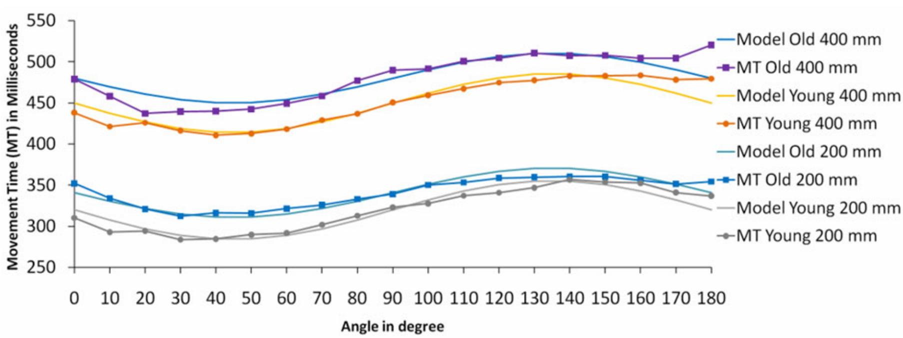

Fig. 6. Empirical and modeled movement time data

This manifest model yields a high fitting with the experimental data, resulting in a R^2 of 0.984 for the younger age group and a R^2 of 0.981 for the older age group.

4 Discussion

The results unambiguously show that there is a significant influence of the factor motion angle in bivariate pointing tasks. The movement time data varies in a clear sinusoidal pattern across the angles investigated. This sin pattern is evident at both amplitudes – 200 mm and 400 mm – and for both age groups. Regarding the age of the participants, the mean movement times of the older age group are significantly higher than the movement times of the younger age group. Depending on the age group and the amplitude we found the lowest movement times for motion angles between 20° and 40° and the highest movement times for motion angles between 140° and 180°. Regarding the error rate, the results differ for the two amplitudes. For the 400 mm amplitude a significant angle effect was found for both age groups. The error rate decreases in the range of 0° up to 90° and then keeps a minimum for both age groups. For the 200 mm amplitude we found no significant angle effect; the mean error rate is nearly constant over the angle.

The sinusoidal pattern of movement times depending on the angle is in accordance with findings of Iwase & Murata [9, 13] and Du [5]. Moreover we found this effect to be evident for 10° angular steps, at two different amplitudes and for a wide range of age. The appeal of Fitts' Law lies in its simplicity and the remarkably good fitting. By adding a term representing the sinusoidal curve to Fitts' original formulation, the effect of the motion angle can be modeled easily.

With the account of errors it is also possible to give practical recommendations for the field of interface and software design concerning the spatial arrangement of buttons or menus on large touch screens. Certainly, the question where to display information elements in order to enhance effectiveness and efficiency of information input depends on the task characteristics and the importance of either speed or accuracy. If the objective is to point a button in preferably short time, it should be located in the right part of the screen (20°-40°) though a higher error rate has to be accepted. In contrary if the accuracy is most important it depends on the amplitude. For an amplitude of 400 mm we recommend a motion angle of 90° as the lowest error rates occur between 90° and 180° and coevally (in this interval) the movement time is lowest for 90°. Whereas for a smaller amplitude (200 mm) an angle between 20°-40° should be preferred as the error rate remains nearly constant.

The focus of the present study was to identify the influence of the factor angle on the movement time and to refine Fitts' Law by this factor. This was done systematically by varying the factor angle in 10° steps between 0° and 180°. The amplitude was varied in two steps; the target width was kept constant. Since just two amplitudes and one target width were investigated, it is only possible to generalize the results to a limited extent. Certainly, there is need to validate the refined model in a more applied setting using a larger ID range by investigating a broader range of amplitude and target width combinations.

In this study we could show that the motion angle clearly affects the user performance in bivariate pointing tasks and that the refined model leads to a significant better movement time prediction than Fitts' original law. In order to design software for large touch screens we therefore recommend using the refined model.

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Adaboost with SVM-Based Classifier for the Classification of Brain Motor Imagery Tasks

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Abstract. The Adaboost with SVM-based component classifier is generally considered to break the Boosting principle for the difficulty in training of SVM and have imbalance between the diversity and accuracy over basic SVM classifiers. The Adaboost classifier in the paper trains SVM as base classifier with changing kernel function parameter σ value, which progressively reduces with the changes of weight value of training sample. To testify the validity of the classifier, the classifier is tested on human subjects to classify the left- and right-hand motor imagery tasks. The average classification accuracy reaches 90.2% on test data, which greatly outperforms SVM classifiers without Adaboost and commonly Fisher Linear Discriminant classifier. The results confirm that the proposed combination of Adaboost with SVM classifier may improve accuracy for classification of motor imagery tasks, and have applications to performance improvement of brain-computer interface (BCI) systems.

Keywords: Adaboost; SVM; Classification; Kolmogorov entropy; ERS/ERD; Motor imagery.

1 Introduction

Brain–computer interface (BCI) is a system with direct transmission of information from brain to computer by analyzing the feature of electroencephalogram (EEG), which provides an alternative communication channel independent of brain's normal output pathways of the peripheral nerves and muscles ([1],[2],[3]). EEG recording is simple and noninvasive and can reflect the different brain states and the feature information so that the current BCI technology is mostly based on EEG signals including slow cortical potentials, P300 potentials, visual evoked potential and especially motor imagery EEG recorded from the scalp. Therefore, EEG analysis on discriminating motor imagery tasks in alpha and beta rhythms (i.e., 8-30Hz) over primary sensorimotor cortex is greatly significant for the construction of motor imagery based BCI [4, 5].

Currently, the mostly used methods for classification of left and right hand motor imagination are linear and non-linear classifier such as Mahalanobis distance, Fisher Discriminant Analysis (FDA), neural network etc. Support Vector Machine (SVM)

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(Vapnik, 1998) is one of the research focuses in classification methods. By using a kernel function to map the training samples from an input space to a high-dimensional feature space, it finds an optimal separating hyperplane in the feature space and controls its model complexity and training error. AdaBoost, one of the most popular technique in machine learning, creates a set of component classifiers by maintaining weights over training samples and adaptively adjusting them after each iteration. In this paper, the Adaboost with RBFSVM as base learner is proposed to apply to discriminate the left and right hand motor imagery tasks. The satisfactory classification results on test data are obtained with the average classification accuracy of 90.2%. Therefore, it has promising potentials to identify the different mental tasks for BCI application.

2 Methodology

2.1 Experiment Data

The hand motor imagination experiment is executed to obtain EEG data with a 1000 Hz sampling rate. Three subjects (male, 24 years old, right-handed) participated in this experiment. EEG data of hand movement imagination was recorded from 32 channels according to the international 10-20. The subjects were seated in front of a screen and asked to imagine either left- or right-hand movement (120 trials, 60 left, 60 right). As shown in Fig.1, Each trial lasted for 14 s. The fixation appeared in the center of the screen as the preparation cue until second 3. Then, a hand, either left or right, appeared on the screen indicating the motor imagery of the corresponding hand for 6 second. The subjects could have a rest from second 9 to second 14. Subjects did not have any feedback during the experiment.

The signal from C3 and C4 over the primary sensorimotor cortex is mainly used in the study because we are interested in the activity of this brain area. More accurately, the signal of C3 and C4 channels after Laplacian filtering are studied in the paper, therefore the neighbors of C3 and C4 are also included.

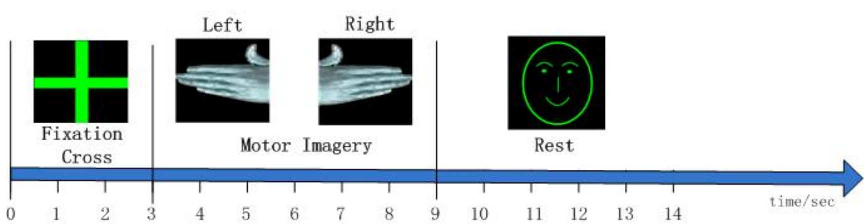

Fig. 1. Timing chart of the experiment

2.2 Feature Extraction by Kolmogorov Entropy

EEG usually oscillates in some particular frequency bands, such as delta (0–4 Hz), theta (4–7 Hz), alpha (8–13 Hz) and beta (14–30 Hz). The motor imagery EEG mainly appears within alpha and beta band. Therefore, the EEG within 8–30 Hz is obtained after band filtering in the paper. Studies by Pfurtscheller showed that the amplitude of alpha and beta rhythms in contralateral hand area would decrease during imagination or preparation for the unilateral hand movement, which was called as ERD (event-related desynchronization); while the amplitude of the corresponding rhythm in ipsilateral hand area would increase, which was called as ERS (event-related synchronization) [6]. The desynchronized EEG process causes the increase of Kolmogorov entropy of EEG over two brain hemispheres, and vice versa. So this paper extracts Kolmogorov entropy as feature vectors characterizing ERD/ERS over left and right hemispheres during motor imagery.

Kolmogorov entropy measures the average rate of information loss and chaotic motion in phase space [7], and quantifies the nonlinear dynamic properties of trajectories in the reconstructed phase space of single channel EEG, which is C3 and C4 in hand motor imagery in the paper. It can be defined as follows: suppose that the d-dimensional phase space is divided into boxed of size ld, the state of the system is now quantified at intervals of time τ [8]. Let Pi0,…,in be the joint probability that $\vec{x}(t=0)$ is in box i0, $\vec{x}(t=\tau)$ is in box i1, …, and etc. According to Shannon, the quantity

$$K_n = -\sum_{i_0 \cdots i_n} P_{i_0 \cdots i_n} \ln P_{i_0 \cdots i_n} \tag{1}$$

is proportional to the information for locating the system on a special trajectory $i_0, \ldots, i_n$, if probabilities $P_{i_0 \cdots i_n}$ is known before. Therefore, Kn+1-Kn is the information for predicting in which cell i_{n+1} the system will be. The value of Kn+1-Kn measures the loss of the information of the system from time n to n+1. Thus, Kolmogorov entropy is defined as the average loss rate of information as follows:

$$\begin{aligned} KE &= \lim_{\tau \to 0} \lim_{\varepsilon \to 0} \lim_{n \to \infty} \frac{1}{n\tau} \sum_{i=0}^{n-1} (K_{i+1} - K_i) \\ &= -\lim_{\tau \to 0} \lim_{\varepsilon \to 0} \lim_{n \to \infty} \frac{1}{n\tau} \sum_{i_0 \cdots i_n} P_{i_0 \cdots i_{n-1}} \ln P_{i_0 \cdots i_{n-1}} \end{aligned} \tag{2}$$

The EEG experimental data within the specific frequency band in 8-30Hz.is divided into 1s segments to extract the Kolmogorov entropy. Finally the relative continuous EEG Kolmogorov entropy time course can be obtained as feature vector.

2.3 Adaboost with RBFSVM-Based Classifiers for Classification

Adaboost is a recent popular developed machine learning method for pattern classification. Freund and Schapire developed the Adaboost model [11], in which the performance of the weak learner can be enhanced effectively by calling the weak or base learning algorithm repeatedly. Each time the training samples with the different distribution are fed into weak learner. The easily classified samples are assigned lower weights and the hard are assigned higher weights, in order to force the base learner to focus on the 'hardest' ones. After many rounds the obtained N weak prediction rules are combined linearly to construct a final classifier, by which the test samples can be classified. The Adaboost algorithm takes a weighted majority vote of all the weak predictions and so the prediction accuracy of the final obtained classifier would be effectively boosted [9, 10].

Developed from the theory of Structural Risk Minimization, SVM is one of the best classifiers since it finds the hyperplane maximizing the separating margin between classes. By using a kernel function to map the training samples from an input space to a high-dimensional feature space, SVM finds an optimal separating hyperplane in the feature space. According to research experiences, SVM classifier with Gaussian Radius Basis Function kernel (RBFSVM) has a satisfactory performance. In order to improve the performance of the classifier, AdaboostSVM, is used to combine RBFSVM classifiers in this paper [11].

The problem is that how to set the parameters, i.e. variance σ for RBFSVM component classifiers during Adaboost iterations. Too large value of σ will result in too weak components classifier, while smaller value of σ will make the strong RBFSVM component overfit the training samples, and result in inefficient boosting because the errors of these component classifiers are highly correlated [11].

In this paper, initially a suitable large value is set to σ, which is the mean standard deviation of all samples. Then RBFSVM with this σ is trained as many cycles as possible as long as more than 50% accuracy can be obtained. The value of σ is decreased slightly by a predefined step. By slightly decreasing the value of σ, we prevent the new RBFSVM component from being too strong for the current weighted training samples, and thus moderately accurate RBFSVM component classifiers are obtained. The reason why moderately accurate RBFSVM component classifiers are favored lies in the fact that these classifiers often have larger diversity than those component classifiers which are very accurate. These larger diversities may lead to a better generalization performance [11]. The detailed procedure is described as follows.

1. Let $Z=(x_1,y_1),(x_2,y_2),\ldots,(x_n,y_n)$ be a set of training samples, where $xi \in X$, $yi \in Y=\{-1,1\}$,represent the feature vectors and classification labels respectively.
2. Initialize the weight of training samples: $w_1(i)=1/n$.
3. Let T be iteration times. For $t=1:T$
   a. Train weak component learner with weighted training samples to obtain hypothesis h_t;
   b. Calculate the training error ε_t

$$\varepsilon_t = \sum_{i=0}^{n} w_t(i) \tag{3}$$

   Where $y(i) \neq h_t(i)$;

   c. Set the weight of weak component learner

$$\alpha_t = \frac{1}{2}\ln\frac{1-\varepsilon_t}{\varepsilon_t} \tag{4}$$

   d. Update the weight of training samples

$$w_{t+1}(i) = \frac{w_t(i)\exp\left[-\alpha_t y_i h_t(x_i)\right]}{D_t} = \frac{w_t(i)}{D_t} * \begin{cases} e^{-\alpha_t}, y_i = h_t(x_i) \\ e^{\alpha_t}, y_i \neq h_t(x_i) \end{cases} \tag{5}$$

   Where D_t is a constant, such that $\sum_{i=1}^{n} w_{t+1}(i) = 1$

e. Output the final hypothesis

$$H(x) = sign[\sum_{t=1}^{T} \alpha_t h_t(x)] \tag{6}$$

3 Results

Based on the feature vectors of Kolmogorov entropy of EEG over two brain hemispheres, the Adaboost classifier with SVM as base learner is applied to discriminate the left and right hand motor imagery tasks for test data. For Adaboost model, the only one parameter i.e the number of iteration T needs to be determined by the predefined small enough training error. Here we choose T=10.

To testify the effectiveness of AdaboostSVM classifier, we select two other classifiers to obtain the classification accuracy for comparison. One is Fisher Linear Discriminant, and the other one is SVM. Fisher linear discriminant is commonly used to classify the different brain state. It is widely recommended to use for the highly accuracy in BCI system. The classification accuracy results of three subjects are showed in Table 1.

For the test data, the results can also be satisfactory with the average classification accuracy of three subjects reaching 90.2%, which highly outperforms Fisher Linear Discriminant (77.6%) and SVM (82.9%).

Table 1. Classification accuracy with different classifier of left- and right-hand movement imagination of three subjects

Subject	Classification Accuracy (%)		
	AdaboostSVM	Fisher	SVM
1	91.7	77.3	83.3
2	85.2	74.1	77.8
3	93.8	81.3	87.5
Average	90.2	77.6	82.9

4 Discussions

In this paper, the Adaboost classifier with RBFSVM as base classifier with changing kernel function parameter σ value, which progressively reduces with the changes of weight value of training sample, is proposed and testified with motor imagery data. Table 1 shows the comparison of classification results on the left and right hand motor imagery tasks by using Fisher Linear Discriminant classifier, and SVM classifier and the Adaboost with SVM as base learner. It can be clearly seen that the results by Adaboost with SVM as base learner is much better than that by SVM only, and SVM is obviously effective than Fisher Linear Discriminant.

Adaboost with RBFSVM-based classifier results in a set of RBFSVM base classifiers with good balance between the distributions of accuracy and diversity over RBFSVM base classifiers and better classification accuracy compared with SVM classifiers. With the ensemble of weighted weak hypotheses, the final classifier is boosted so that the classification performance is effectively boosted. The primary results show that AdaboostSVM classifier can effectively improve the classification performance of motor imagery tasks. Therefore, it could be applied in the mental tasks classification for BCI construction.

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AVIN (Assisted Visual Interactive Notepad): A Novel Interface Design to Expedite the Eye Writing Experience

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Abstract. Eye typing, which utilizes eye gaze input to interact with computers, provides an indispensable means for people with severe disabilities to write, to talk, and to communicate. Despite more than two decades' of research into eye typing (which, for the most part, focused on the hardware/technical aspects associated with implementing a system), there lacks a well designed solution that has incorporated the key research findings and integrated them into a unified system. Hence, we designed and developed a novel user interface AVIN (Assisted Visual Interactive Notepad) for eye writing that expedites the writing workflow to enhance the overall user experience. Our preliminary user testing results showed that a novice user can achieve 7 wpm with an hour's typing practice, and a more experienced user can achieve 15 wpm with ten hours' practice; whereas an expert user can only reach 6-8 wpm using the standard QWERTY design.

Keywords: Eye typing, user interface (UI) design, eye tracking, user experience.

1 Introduction

Eye typing, which utilizes eye gaze input to interact with computers, provides an indispensable means for people with severe disabilities to write, to talk, and to communicate. Despite more than two decades' of research into eye typing (which, for the most part, focused on the hardware/technical aspects associated with implementing a system), there lacks a well designed solution that has incorporated the key research findings and integrated them into a unified system (Majaranta & Raiha, 2002, 2007). In this paper, we designed, prototyped, and tested a novel eye typing system, AVIN (Assisted Visual Interactive Notepad), to support the eye typing workflow and to enhance the overall eye writing user experience.

People direct and move their eyes to receive visual information from the environment. The two most typical eye movements are "fixation" and "saccade". Fixation is defined as the duration of time that the eye lingers at a location. In visual search or reading, the average fixation is about 200-500 milliseconds (ms). Saccade is defined as the rapid movement of eyes, lasting about 20-100 ms, with a velocity as high as 500 degree/sec (Fischer & Ramsperger, 1984).

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It is natural to imagine using eye gaze as a computer input method for a variety of reasons. For example, research has shown that eye fixations are tightly coupled to an individual's focus of attention (Just & Carpenter, 1976; Rayner, 1998). Eye gaze input can potentially eliminate inefficiency associated with the use of an "indirect" input device (such as a computer mouse) that requires hand-eye coordination (e.g., looking at a target on a computer screen and then moving the mouse cursor to the target). Additionally, eye movements are much faster and require less effort than many traditional input methods, such as moving a mouse or joystick with your hand. Eye gaze input could be particularly beneficial for use with larger screen workspaces and/or virtual environments (Jacob, 1995). Last, perhaps the most important reason for considering and improving the utilization of eye gaze input, is that under some circumstances other control methods, such as using a hand or voice, might not be applicable. For example, for physically disabled people, their eyes may be the only available input channel for interacting with a computer.

Despite these benefits, eye gaze is not typically used as an input method for computer interaction. There remain critical design issues that need to be considered before eye gaze can be used an effective input method for eye typing.

2 Eye Typing Design

Even though eye typing has been studied for more than 20 years, previous research focused predominantly on the hardware design or technical design issues, such as how to achieve satisfying tracking accuracy and robustness, rather than on the user experience design aspects of the eye typing system (Majaranta & Raiha, 2002, 2007).

A typical eye typing system includes an eye tracking device and an on-screen keyboard interface (the graphical user interface, or GUI). The eye tracking device (referred to as an eye tracker) generally comprises an infrared camera, located near the computer, which monitors a user's eye movements. Typically, the device will track a user's point of gaze on the screen, and send this information to a computer application that analyzes the data and then determines the specific "key" of the on-screen keyboard at which the user is staring and wants to select. Thus, to start typing, a user will direct his/her gaze at the "key" of interest of the on-screen keyboard and confirm this selection by fixating on this key for a pre-determined time threshold (referred to as "dwell time").

In order to achieve the optimal eye typing performance and user experience, a number of design issues needed to be taken into consideration (Majaranta & Raiha, 2002).

2.1 Keyboard Layout Design

Most on-screen keyboards for eye typing utilize the standard QWERTY keyboard layout. While this layout is familiar to regular computer users, it may not be optimal for eye typing purpose. As some disabled users may not be adept at using a QWERTY keyboard in the first instance, modifying the keyboard layout to improve their user experience is considered to be a viable option.

Most contemporary eye typing systems are configured such that the on-screen keyboard occupies the majority of the central area of the screen. The typed content is displayed in a small region, typically above the on-screen keyboard along the upper part of the screen. This layout design does not consider a typical user's writing process. As illustrated in Figure 1, a typical writing process includes a first step of "thinking" about what to write, then selecting and typing a letter. After cycling through this process a number of times, a complete word is typed, and the process returns to think about the next word or words that need to be typed. Once the text is completed, the user will review and edit the typed content, the finally "finish" the typing process.

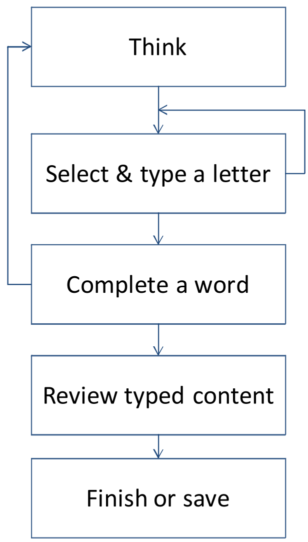

Fig. 1. A flowchart illustration of the conventional writing process

Traditional on-screen keyboard designs are configured to address the step of selecting and typing a letter, without considering the necessary support for other steps in the writing process, and/or the transitions between these steps. For instance, as the on-screen keyboard occupies the central area of the screen, it is difficult for the user to "think" about what to write next without unintentionally staring (gazing) at the keyboard. The user's eye gaze may accidently "select" a key, which must then be deleted before new letters are typed. Obviously, these tasks disrupt the natural flow of the thought process. Furthermore, the separation between the centrally-located on-screen keyboard and the 'text box' (generally in an upper corner of the screen) makes the transition to reviewing the typed content difficult, leading to eye fatigue on the part of the user.

2.2 Other Design Issues

Word prediction techniques have become popular in many text input methods. As a user starts typing a letter or letters, a list of words associated with the typed letter(s) will be suggested and presented in an order typically by their frequency of use. The user can either search the suggested list of words to find the target word they want to type or can continue to type the next letter, or letters, to complete the word. Research has shown the benefits of using the word prediction, such as reducing the number of keystrokes per character of text, and increasing the eye typing speed (e.g., Majaranta & Raiha, 2002).

As the QWERTY on-screen keyboard occupies the majority of the central area of the screen, this leaves limited screen real estate for the suggested word list. Usually only a small number of words are displayed, e.g. 5-8. As a result, users tend to type more keystrokes to reduce the risk of searching the word list, but without finding the target word. Increasing the size of the word list can reduce keystroke per word, but needs more screen real estate with the potential to increase the users' visual scanning time. There has not been a good design solution that balances these tradeoffs.

Other design factors, such as feedback and visualization, can also have effects on typing performance. Research (Majaranta, MacKenzie, Aula, & Raiha, 2006) has shown the positive effects of proper audio and visual feedback, which can improve both the eye typing performance and subjective experience. Effective visualizations can improve visual search performance. For example, studies show that people can perform subset search based on color, luminance etc. (e.g, D'Zmura,1991).

3 AVIN Design

We proposed and designed a novel user interface AVIN (Assisted Visual Interactive Notepad), a three-layer interface that allows for controlling computer input with eye gaze to expedite the writing process and typing experience (See Figure 2 for an example).

3.1 Novel Three-layer Layout to Support the Writing Workflow

It was our explicit design goal with this unique three-layer user interface to address the remaining limitations of conventional eye typing on-screen QWERTY keyboards, with the intended benefits of expediting the natural writing workflow and enhancing the overall user experience.

As described in detail below, the novel arrangement comprises a three-layer disposition of functionality – (1) letters, (2) words, and (3) typed text – that supports improved transitions between the various activities that occur during eye typing, as discussed above and shown in Fig. 1. The letters are selected from the outer ring, allowing for frequently-used words to be scanned in the inner ring, with the selected letter (word) displayed in the center text box.

As letters and words are arranged alphabetically, a natural spatial proximity between the letters and words is created, allowing for a more efficient visual search for a target word. As explained in more detail below, visual and audio feedback may be used to supplement the typing process, enhancing the overall eye typing experience.

Figure 2 is a screenshot of the three-layer interactive on-screen keyboard formed in accordance with the present design concept. A first layer, the *outer ring*, shows the standard 26-letter English alphabet, arranged alphabetically and moving clockwise from the upper left-hand corner. In this example, the letters "A", "V", "I", "N" form

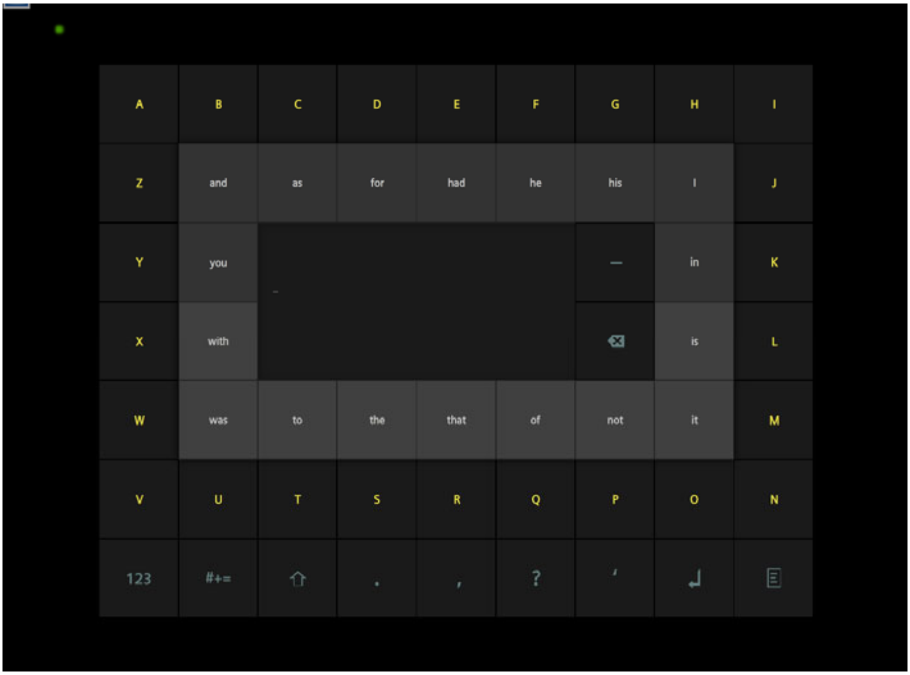

Fig. 2. A screen example of the AVIN embodying our three-layered design

the four corner letter, creating a rectangular "ring" structure. It is to be understood that in regions of the world where other alphabets are utilized, the keys would be modified to fit the alphabet (including the total number of alphabet/character keys included in the display).

The second tier of our on-screen keyboard, the *inner ring*, is a set of constantly-updated "frequently used" words. In this particular example, a group of eighteen words is displayed, again in the alphabetical order starting from the top, left-hand corner. The screenshot shown in Fig. 2 is an "initial" screen, before any typing has begun, thus a general set of frequently-used words is displayed. The use of eighteen terms is considered optimal, striking the balance to offer an abundance of word choices without being overwhelming. As elaborated upon below, the word list comprising inner ring is constantly updated; as letters are typed, the word set will be updated to reflect the actual letters being typed.

The third layer of on-screen keyboard comprises a central/inner region, which is the area where the typed letters will appear (referred to below as "text box"). A limited set of frequently-used function keys is included within inner region. In the specific example illustrated in Fig. 2 & 4, a "space" key and a "backspace" key are shown. By placing the typed content in the central area of the screen, the user may easily review the content and ponder what is to be typed next without fear of "accidently" inadvertently selecting a key by gazing at the screen for an extended period of time (as was the case for prior art on-screen keyboard arrangements).

Our on-screen keyboard comprises also a row of function keys, including a mode-switching functionality key (upper case vs. lower case), a numeric key, punctuation keys, etc. Again, the specific keys included in this row of function keys may be adapted for different situations. In the specific arrangement shown in Fig. 2, the row is positioned below the outer ring.

3.2 Visual and Audio Feedback to Confirm User Action or Command

Similar to previous eye typing arrangements, the current system uses dwell time to confirm a key selection. In AVIN, “dwell time” is visualized by using a running circle over the selected key. Fig. 3 illustrates this aspect of the present design concept, where the user has gazed at the letter “A”. When the user fixates on this key, the circle will start (shown as circle on letter “A”). The user can easily cancel this action before the circle is completed by moving his/her gaze to another key before the circle is completed. Presuming in this case that the user desires to select the letter “A”, the circle will run until completed, based upon a predetermined dwell time threshold. When the circle has completed, additional confirmation of the selection of this letter can be provided by the “A” block changing color (visual confirmation), and/or a “clicking” (i.e., audio confirmation) may be supplied. The selected letter will then “fly” to central region (text box) for display.

3.3 Visualizations and Animation to Facilitate Users’ Visual Search

The addition of visual confirmation (such as color change) for a selected letter, with or without the utilization of an audio confirmation, is considered to enhance the user’s experience, providing feedback and an affirmation to the user.

As shown in Fig. 4, the selection of the letters “uni” has caused the frequently-used words within inner ring to change, in this example, to frequently-used words beginning with the letter “uni”. Again, the words are arranged alphabetically, starting from the upper left-hand corner. Thus, the user can quickly scan these words and see if any are appropriate for his/her use. Since the letters “uni” have already been typed, these are dimmed in the display of the frequently-used words. This feature can be further modified by using two different luminance contrast levels for the words, based on their absolute frequency of use. The leading letters in all the words that are redundant with the already-typed text may be “dimmed” to provide an additional visual aid.

Fig. 3. (a) The border for “E” is highlighted showing the eye-over effect, and (b) the circle shows the selection in progress (See text for details.)

Fig. 4. Dimming the typed letter(s)

Once a particular letter has been selected (in this example, “i”), a subset of letters predicted to be the next most likely to be typed are highlighted around the outer ring (or change in color – generally, made visually distinctive) to aid the user more rapidly and easily identify the next letter. Research has shown the positive effect of letter prediction on typing performance.

4 User Studies

4.1 Method – Part I

Participants. Six full time staff and student interns (5 men and 1 woman) from Siemens Corporate Research naïve to the goals of the study volunteered to participate. All participants had normal or corrected-to-normal vision, and were free of color blindness.

Implementation. For the purpose of prototyping and evaluation of the AVIN design, we utilized a SMI iView X Red eye tracker. The SMI tracker is a video-based contact-free eye tracker with the sampling rate of 50 Hz. The AVIN prototype was implemented using ActionScript 3.0, and can be run in Adobe Flash Player or Adobe Air environment. A 21-inch Dell monitor was used to display the AVIN interface with a resolution of 1280 x 1024 pixels.

Testing materials. The 500 phrases produced by MacKenzie & Soukoreff (2003) were selected as the testing materials.

Experiment design. There were two experiment conditions: the AVIN interface and the standard QWERTY interface, which was used as a control condition. A within-in subject design was used, where each participant was tested in both experiment conditions. The order of the experiment condition was counterbalanced across all the participants.

Testing procedure. Participants were tested individually. After reading an instruction sheet and providing demographic information, each participant was seated in front of the SMI eye tracker at a distance to the display of about 70 cm. A five points-calibration is needed before starting the eye typing application. The participants received a practice session, which required them to type letters A-Z twice. After the participants became familiarized with the keyboard layout, they would start practice writing sentences, and the audio was presented to them through the computer speakers.

When the participant was ready to listen to a sentence, he/she simply pressed the "Enter" key on the regular keyboard. A sentence was then randomly picked from the 500 phrases database (MacKenzie & Soukoreff, 2003) and read out to the user. The user can listen to the sentence as many times as he/she needs: the sentence will be repeated by itself if any key input is detected. Once the user started typing any key, then he/she would not be able listen to the sentence again.

For each experiment condition, there were two sessions, and each took about 30 minutes. Participants received breaks in between.

4.2 Results & Discussions – Part I

Fig. 5 shows that, after one hour of practice, the users can type on average 7.08 words/min using the AVIN design vs. 7.49 words/min using the QWERTY design. ANNOVA test show no difference between QWERTY and AVIN conditions (F (1,10)=0.29, p=0.60). This result is encouraging for two reasons. First, past research (e.g., Majaranta & Räihä, 2002) has shown that an expert user can only reach 6-8 wpm using the familiar QWERTY design, and using the AVIN design a novice user can achieve 7 wpm within only one hour of typing practice. Second, almost all users expressed that because they are familiar QWERTY layout, it is much quicker for them to learn to type. However, once they become more familiar with the AVIN design, their eye-typing performance can be improved significantly.

To test this hypothesis, a second part the study was conducted, where one user was invited back to do the eye-typing using the AVIN design for ten days (one hour per day).

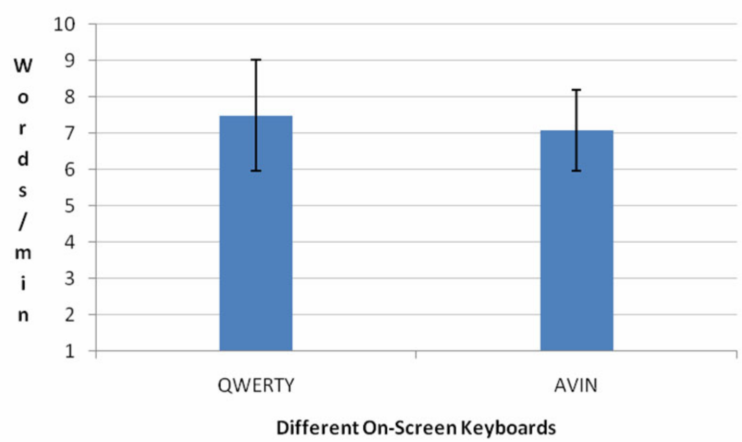

Fig. 5. Eye typing performance for different on-screen keyboard designs after one hour of practice

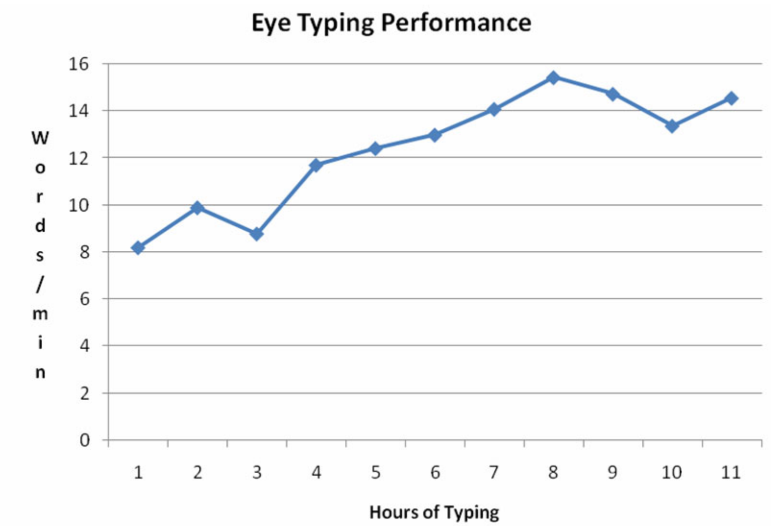

Fig. 6. Eye typing performance increasing with hours of practice

4.3 Method & Results – Part II

One of the previously tested six subjects volunteered to participate. The same materials were used as previous experiment. The participant was tested every weekday for an hour for 10 hours using the AVIN system.

Fig 6 shows that the eye typing performance increases almost linearly as the user spent more hours of practice using the AVIN system. After about 10 hours' practice, a more experienced user can achieve about 15 wpm.

5 Discussions and Conclusion

Reported in this paper was the design, prototype, and testing of a novel eye typing system, AVIN (Assisted Visual Interactive Notepad), to expedite the eye typing workflow and enhance the overall eye writing user experience. Our preliminary user testing results showed that a novice user can achieve 7 wpm after one hour of typing practice, and a more experienced user can achieve 15 wpm after ten hours of practice. In contrast, an expert user can only reach 6-8 wpm using the standard QWERTY design.

More user validation data, in particular the longitudinal data, are needed to prove the effectiveness of the AVIN design.

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Online BCI Implementation of High-Frequency Phase Modulated Visual Stimuli

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Abstract. Brain computer interfaces (BCI) that use the steady-state-visual-evoked-potential (SSVEP) as neural source, offer two main advantages over other types of BCIs: shorter calibration times and higher information transfer rates. SSVEPs elicited by high frequency (larger than 30 Hz) repetitive visual stimulation are less prone to cause visual fatigue, safer, and more comfortable for the user. However in the high frequency range there is a practical limitation because only few frequencies can elicit sufficiently strong SSVEPs for BCI purposes. We bypass this limitation by using only one stimulation frequency and different phases. To detect the phase from the recorded SSVEP, we use spatial filtering combined to phase synchrony analysis. We developed an online BCI implementation which was tested on six subjects and resulted on an average accuracy of 95.5% and an average bit rate of 34 bits-per-minute. Our approach has the advantage of entailing only minimal visual annoyance for the user.

1 Introduction

The steady state visual evoked potential (SSVEP) refers to the response of the cerebral cortex to a repetitive visual stimulus (RVS) oscillating at a constant *stimulation frequency*. The SSVEP manifests as peaks at the stimulation frequency and/or harmonics in the power spectral density (PSD) of EEG signals [1]. Because of its proximity to the primary visual cortex, the occipital EEG sites exhibit a stronger SSVEP response.

Among non-invasive EEG based brain computer interfaces (BCI), SSVEP based BCIs provide higher information transfer rates (ITR) and require shorter calibration times [2]. SSVEP based BCIs operate by presenting the user with a set of repetitive visual stimuli (RVSi). In most of current implementations, the RVSi distinguish from each other by their stimulation frequency [3,4,5]. The SSVEP corresponding to the RVS receiving the user's attention is more prominent and can be detected from the ongoing EEG. Each RVS is associated with an action or command which is executed by the BCI when the corresponding SSVEP is detected.

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The majority of current SSVEP-based BCIs use stimulation frequencies in the 4 t0 30 Hz frequency band [6]. RVS at these frequencies as compared to higher frequencies, have several disadvantages: 1) they are prone to visual fatigue which decreases the SSVEP strength, 2) they entail a higher risk of photic or pattern-induced epileptic seizure [7] and 3) they overlap with the frequency band of spontaneous brain activity. Higher stimulation frequencies are thus preferable for the sake of safety and comfort of the BCI user.

Only a limited number of frequencies above 30 Hz can elicit a sufficiently strong SSVEP for BCI purposes [8]. In the classical SSVEP based BCI design where each RVS has a unique stimulation frequency, this limitation implies a reduction in the number of possible BCI commands and consequently the bitrate. A possible way to tackle this limitation is to combine two or more frequencies to drive a particular RVS [9,10]. Thus, if N frequencies are available, k frequencies selected among these N can be used to drive each RVS. The total number of different RVSi is then $\binom{N}{k}$ which is larger than N if $N > k + 1$ and $k > 1$.

An alternative way which is the one adopted in this paper, consists in using the same stimulation frequency but different phases [11,12,13]. Detecting the phase of the stimulus that receives the user's focus of attention is possible because the SSVEP is phased-locked to the visual stimulus [1].

The SSVEP phase can be estimated using the Discrete Fourier Transform (DFT) [11,14] or the Short Time Fourier Transform (STFT) [15]. These methods require a relatively long signal segment with a duration that is a multiple of the stimulation period. In addition, only the absolute SSVEP phase is estimated. This means that the calibration stimuli (the ones used to train the estimation algorithm) and the operation stimuli should be synchronized. The need for such synchronization can be removed if the phase difference between the SSVEP and the *stimulation signal*, i.e. the one that drives the RVS, is considered instead of the absolute phase. Hereafter, for convenience reasons we refer to this phase difference as to the SSVEP phase.

The SSVEP phase can be estimated using the Hilbert transform on a spatially filtered signal. We propose in this paper, an online BCI implementation based on the phase detection of SSEVPs evoked by high frequencies. This paper is organized as follows. Section 2 describes the signal processing steps leading to the phase estimation. The experimental methods are presented in Section 3. Section 4 analyzes the results. The conclusions are finally presented in Section 5.

2 Signal Processing Methods

Signal processing methods are utilized to obtain a two-dimensional *feature vector* from a multi-channel EEG signal of a given duration (*EEG epoch*). Pattern recognition methods are then used to estimate the subject's intended command from the feature vectors. A diagram illustrating this process is presented in Figure 1.

The multi-channel EEG is first spatially filtered. This consists in linearly combining the signals from all EEG channels into a single signal. The SSVEP

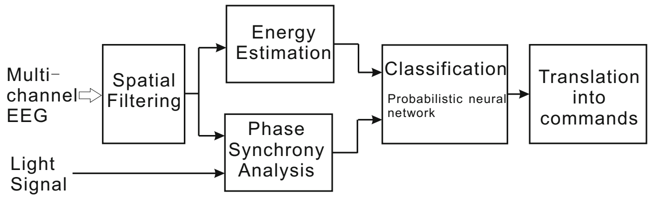


Fig. 1. Signal processing methods

energy, the first component of the feature vector, is estimated from this signal by applying a peak filtered centering at the stimulation frequency. The choice of linear weighting coefficients is based on [16]. This is explained in Section 2.1.

The phase, the second component of the feature vector, is estimated by computing the average phase difference between the stimulation signal and the spatially filtered signal. We refer to this estimation process as to phase synchrony analysis [8].

The feature vectors are submitted to a probabilistic neural network to determine the RVS on which the user focuses her/his attention (see Section 2.3).

2.1 Spatial Filtering

We consider an EEG epoch $\mathbf{X}$ which can be written as a $T \times N$ matrix having as columns N, T-sample long signals $\mathbf{x}_i \quad i = 1, \ldots, N$. The spatially filtered signal $\mathbf{x_w}$ can be written as a linear combination of the $\{\mathbf{x}_i\}$. This implies: $\mathbf{x_w} = \sum_i w_i \mathbf{x}_i = \mathbf{Xw}$, where $\mathbf{w} = [w_1, \ldots, w_N]'$. The spatial filter coefficients are estimated so that the ratio between the SSVEP and background activity is maximized [16]. The *maximum contrast combination* method in [16] proposes to estimate $\mathbf{w}$ in a per EEG epoch basis using:

$$\mathbf{w} = \arg\max_{\tilde{\mathbf{w}}} \frac{\tilde{\mathbf{w}}'\mathbf{X}'\mathbf{X}\tilde{\mathbf{w}}}{\tilde{\mathbf{w}}'(\mathbf{X} - \mathbf{QX})'(\mathbf{X} - \mathbf{QX})\tilde{\mathbf{w}}}, \tag{1}$$

where $Q = \mathbf{S}\left(\mathbf{S}^{\mathrm{T}}\mathbf{S}\right)^{-1}\mathbf{S}'$ and $\mathbf{S}$ is a matrix which has as columns the signals in the set $\mathbf{\Phi} = \{\sin(2\pi hf\mathbf{t}), \cos(2\pi hf\mathbf{t}) | h = 1, ..., H\}$ with $\mathbf{t} = [0, \ldots, T-1]'$. These are sinusoidal signals at the frequency of stimulation f and H harmonics. Since in this paper we consider high stimulation frequencies (> 30 Hz) and the EEG spectral content is restricted to 60 Hz, only the stimulation frequency is considered, i.e. $H = 1$.

In (1), the per-epoch covariance matrices $\mathbf{X}'\mathbf{X}$ and $(\mathbf{X} - \mathbf{Q})'(\mathbf{X} - \mathbf{QX})$ are used to estimate the SSVEP activity and the background activity respectively. A better and more stable estimate of the covariance matrix can be obtained if the covariance matrices of several EEG epochs are averaged. Thus, we propose to estimate the optimum spatial filter as follows.

$$\mathbf{w} = \arg\max_{\tilde{\mathbf{w}}} \frac{\tilde{\mathbf{w}}' \sum_{k=1}^{K} \mathbf{X}_k' \mathbf{X}_k \tilde{\mathbf{w}}}{\tilde{\mathbf{w}}' \sum_{k=1}^{K} (\mathbf{X}_k - \mathbf{Q}\mathbf{X}_k)'(\mathbf{X}_k - \mathbf{Q}\mathbf{X}_k)\tilde{\mathbf{w}}}, \tag{2}$$

where $\mathbf{X}_k$ is the k-th EEG epoch and K is the total number of epochs that are considered.

The SSVEP energy (first component of the feature vector) is estimated by applying to the signal $x_{\mathbf{w}}(t)$, a 1-Hz narrow band FIR filter centered around the stimulation frequency (*peak-filter*). This results in the narrow band signal $z_f(t)$ from which the SSVEP energy E can be estimated in a time window $[\mathrm{t}, t + \Delta t]$ as: $E = \frac{1}{\Delta t} \int_{t}^{t+\Delta t} |z_f(t)|^2 dt$.

2.2 Phase Synchrony Analysis

The phase (second component of the feature vector) is estimated through a process termed phase synchrony analysis. This computes first the instantaneous phase difference $\delta_f(t)$ between $z_f(t)$ and the stimulation signal filtered through the peak-filter centered around f. This signal is denoted as $l_f(t)$.

The analytical signals associated with $z_f(t)$ and $l_f(t)$, $A\{z_f\}(t)$ and $A\{l_f\}(t)$ respectively can be written as:

$$\begin{aligned} A\{z_f\}(t) &= z_f(t) + jH\{z_f\}(t) = R\{z_f\}(t)e^{j\Theta\{z_f\}(t)}, \\ A\{l_f\}(t) &= l_f(t) + jH\{l_f\}(t) = R\{l_f\}(t)e^{j\Theta\{l_f\}(t)}, \end{aligned} \tag{3}$$

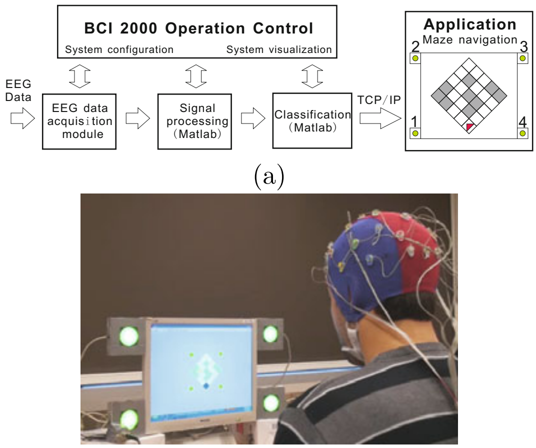
where $H\{z_f\}(t)$ and $H\{l_f\}(t)$ are the Hilbert transforms of $z_f(t)$ and $l_f(t)$. $R\{\cdot\}$ and $\Theta\{\cdot\}$ are the instantaneous amplitude and phase respectively. Thus, the instantaneous phase difference $\delta_f(t)$ is equal to $\Theta\{z_f\}(t) - \Theta\{l_f\}(t)$. The phase is estimated as the median of $\delta_f(t)$ in a given time window, e.g. the epoch duration.

2.3 Feature Vector Classification

A probabilistic neural network (PNN) is used to estimate the user's focus of attention from the feature vector. A PNN is a radial basis network which estimates the probability density function of each class from labeled training data [17] using the Parzen window technique [18]. In our case, the training data correspond to feature vectors obtained from EEG epochs recorded while the BCI user was instructed to pay attention to a particular RVS.

3 Experimental Methods

Our BCI implementation uses the BCI2000 software platform [19]. The signal processing algorithms are coded in MATLAB™ . The BCI application consists in a computer-rendered 2D maze where a cursor can be moved along four possible directions (upper-left, upper-right, lower-left, and lower-right). The movement



(a)

(b)

Fig. 2. (a) Software architecture of our BCI implementation. (b) The BCI application consists of a 2D maze in which the cursor moves according to the RVS which receives the user's attention. The command sequence to successfully complete this maze configuration is "2232323344144111".

direction is decided depending on the RVS which receives the user's focus of attention.

Four RVSi were arranged around a computer screen as illustrated in Figure 2b. RVSi were embodied in 10×10 cm boxes containing a (green) power LED shining through a diffusion screen. The stimulation signal consisted in a square wave (50 % duty cycle) at the stimulation frequency. Four phases $(\phi, \phi + \frac{\pi}{2}, \phi + \pi, \phi + \frac{3\pi}{2})$ were used to command the RVSi (see Figure 3b) where ϕ is the initial phase at the onset of the stimulation signal. The corresponding stimulation signals were generated using four synchronized function generators (from Agilent technologies, model 33220A).

The EEG signals were collected using a BioSemi Active-two acquisition device [20]. The signals from the 32 electrodes shown in Figure 3c were recorded with reference to Cz and were re-referenced to the average of all 32 signals. The impedance between scalp and electrodes was kept below 5 kΩ using conductive gel. The device sampling frequency was set to 2048 Hz. During processing the signals were downsampled to 256 Hz. The participants were asked to sit still and try to complete the navigation task as fast as possible.

The stimulation signal was measured using a photodiode located near the RVS with phase ϕ. The signal from the photodiode was recorded simultaneously to the EEG signals to perform the phase synchrony analysis (see Section 2.2).

3.1 Optimal Stimulation Frequency

The stimulation frequency eliciting the strongest SSVEP response (optimal stimulation frequency) is user dependent [21]. Thus, we implemented a procedure

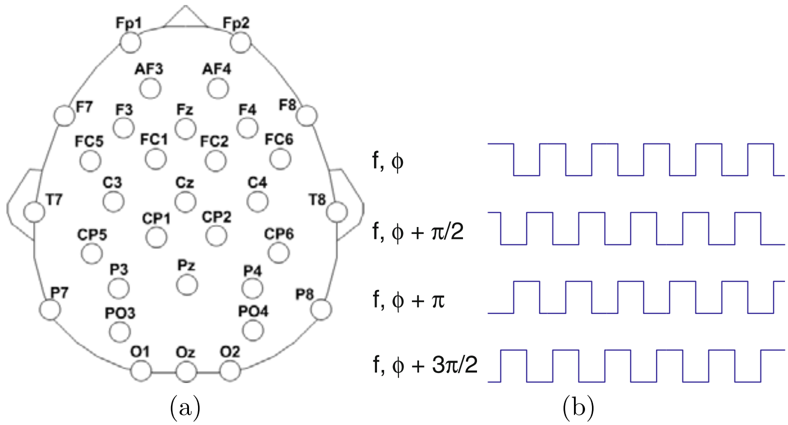


Fig. 3. (a) Measured EEG sites. (b) Stimulation signals at four phases

aiming at determining the optimal stimulation frequency in the range from 32 to 40 Hz. For a given user, this procedure consisted in presenting RVSi at all the integer stimulation frequencies between 32 and 40 Hz. The presentation order was randomized.

For a particular stimulation frequency, the stimulation was presented in a sequence of four intervals each of them composed of a 4-second long period of stimulation followed by a 4-second long break. To determine which stimulation frequency elicited the strongest SSVEP potential, we used the first stimulation period to estimate the optimal spatial filter as explained in Section 2.1. We applied such filter to the whole EEG signal, i.e. the whole sequence, followed by the peak-filter at the stimulation frequency (see Section 2.1). We then estimated the SSVEP energy in one-second long (non-overlapping) windows as explained in Section 2.1. This resulted in 32 values (16 for the stimulation periods and 16 for the non-stimulated periods) on which a threshold based detection of the SSVEP was performed. Since this constitutes a detection problem with a single threshold a receiving-operator curve (ROC) [22] can be determined by progressively varying the threshold from the lowest SSVEP energy in the stimulation periods to the highest SSVEP energy in the break periods. The area under the ROC (AUC) is a good indicator of the detectability of the SSVEP at the stimulation frequency. The optimal stimulation frequency corresponded to the one which resulted in the highest AUC.

3.2 Parameter Calibration

The goal of the calibration is to determine the optimal BCI operation parameters for a particular user, i.e. the coefficients of the spatial filter and the classifier parameters.

During calibration the user was presented with a sequence of 16 intervals each of them composed of a 4-second long stimulation period (at the optimal subject's frequency) followed by a 4-second long break. In each of the intervals, the user was instructed to pay attention to a particular RVS out of the four presented. Each RVS received the user's attention four times. The sequence was randomized.

The spatial filters were determined on the data recorded during the first stimulation period while the PNN parameters were determined using data from the rest of the intervals.

3.3 BCI Operation and Information Transfer Rate

During operation the user was instructed to move the cursor in the 2D maze along a fixed path. There were no bifurcations so that there was a unique way to move in the maze. Backward moves were not allowed.

When a command was detected by the system, the cursor changed its orientation towards the targeted direction and move there. No movement happened when the detection indicated a non-allowed move.

Correct moves were accompanied by a low pitched tone while incorrect ones were signaled by a high pitched tone.

As shown in Figure 3b, the command sequence to successfully complete this configuration without any erroneous move was '2232323344144111', where 1,2,3 and 4 are associated with the left bottom, the left top, the right top, and the right bottom LEDs respectively. This sequence is balanced so that each direction has to be taken four times. This avoids biasing the results due to a preferred direction.

The bitrate was estimated based on the user's proficiency in moving the cursor through the maze and along the specified path. We defined the accuracy as the ratio between the number of correct moves and the total number of moves.

To evaluate the performance of a BCI, consistent criteria are necessary. The most popular criterion is the information transfer rate (ITR) which measures the information transmitted by the system in a unit time and is calculated based on the popular bitrate definition provided in the seminal paper [23]. This definition suggests the following formula to obtain bitrate and ITR for C classes and classification accuracy p.

$$\begin{aligned} R(bits/symbol) = \log_2(C) + p\log(p) \\ +(1-p)\log_2[(1-p)/(C-1)], \end{aligned} \tag{4}$$

$$ITR(bits/minute) = R \times 60/\tau, \tag{5}$$

where τ is the average time (in seconds) necessary to detect a symbol or to execute a command.

4 Results

During operation, a 1.5-second long window was used to take a decision. This window was subdivided into three sub-windows with 75% overlapping. Each

Table 1. Experimental results

Participant	Freq. (Hz)	Detected command sequence	Accuracy (%)	Latency (second)	ITR (bits/minute)
S1	40	'2232323344144111'	100	4.17	28.78
S2	40	'2232323344144111'	100	2.95	40.64
S3	39	'223232233441434111'	88.9	2.29	34.53
S4	40	'2232323344144111'	100	3.05	40.63
S5	39	'2232232233441443111'	84.2	2.41	27.91
S6	40	'2232323344144111'	100	3.70	32.42
Mean	-	-	95.5	3.10	34.15
S.D.	-	-	7.1	0.73	5.57

sub-window would lead to a classification. The command was decided if at least two classifications resulted in the same decision. For example, if the three classifications were '101', the detected command would be '1'.

Six subjects (S1 to S6) participated in our experiments. Their performance is reported in Table 1. For each participant, the optimal stimulation frequency is reported in the second column.

The command sequence is reported in the third column of Table 1. Participants S1, S2, S4, and S6 were able to navigate through the maze with 100% accuracy. The erroneous commands are underlined for participants S3 and S5. The accuracy estimate was used as p in (4) to estimate the bits-per-symbol R when the number of classes C is equal to 4.

The average command latency in the fifth column results from dividing the total time it took the participant to complete the maze by the total number of commands. This term was used as τ in (5) to estimate the information transfer rate in bits-per-minute. The ITR is reported in the sixth column of Table 1. The across-participant averages and corresponding standard deviations (SD) are reported in the last rows of Table 1. Our results show an average ITR of 34 bits-per-minute which constitutes a promising result considering that high-frequency repetitive visual stimulation has been applied and that the phase of the RVS was used to distinguish among four possible commands.

5 Conclusion

In this paper, we have presented an SSVEP-based BCI implementation which uses high frequency repetitive visual stimulation. The different stimulation targets which are attended by the user to generate commands are distinguished by their phase. Thus a single stimulation frequency and different phases are used.

This approach has clear advantages from the viewpoint of usability and visual comfort as high frequency stimulation is less prone to cause visual fatigue. In addition, selecting a single stimulation frequency considerably shortens the calibration procedure which is necessary to determine which stimulation frequencies are best suited for a given user.

The signal processing approach consisting in cascading spatial filters with the phase synchrony analysis proved to be successful to implement a phase variant SSVEP-based BCI. Indeed, our evaluation on six participants show a high SSVEP detection accuracy (95.5%±7%) and an (across subject) average information transfer rate of 34.15 ± 5.57 bits/minute.

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