Constantine Stephanidis (Ed.)

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HCI International 2018 – Posters' Extended Abstracts

20th International Conference, HCI International 2018
Las Vegas, NV, USA, July 15–20, 2018
Proceedings, Part II

Part 2

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Foreword

The 20th International Conference on Human-Computer Interaction, HCI International 2018, was held in Las Vegas, NV, USA, during July 15–20, 2018. The event incorporated the 14 conferences/thematic areas listed on the following page.

A total of 4,373 individuals from academia, research institutes, industry, and governmental agencies from 76 countries submitted contributions, and 1,170 papers and 195 posters have been included in the proceedings. These contributions address the latest research and development efforts and highlight the human aspects of design and use of computing systems. The contributions 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. The volumes constituting the full set of the conference proceedings are listed in the following pages.

I would like to thank the program board chairs and the members of the program boards of all thematic areas and affiliated conferences for their contribution to the highest scientific quality and the overall success of the HCI International 2018 conference.

This conference would not have been possible without the continuous and unwavering support and advice of the founder, Conference General Chair Emeritus and Conference Scientific Advisor Prof. Gavriel Salvendy. For his outstanding efforts, I would like to express my appreciation to the communications chair and editor of *HCI International News*, Dr. Abbas Moallem.

July 2018 Constantine Stephanidis

HCI International 2018 Thematic Areas and Affiliated Conferences

Thematic areas:

- Human-Computer Interaction (HCI 2018)
- Human Interface and the Management of Information (HIMI 2018)

Affiliated conferences:

- 15th International Conference on Engineering Psychology and Cognitive Ergonomics (EPCE 2018)
- 12th International Conference on Universal Access in Human-Computer Interaction (UAHCI 2018)
- 10th International Conference on Virtual, Augmented, and Mixed Reality (VAMR 2018)
- 10th International Conference on Cross-Cultural Design (CCD 2018)
- 10th International Conference on Social Computing and Social Media (SCSM 2018)
- 12th International Conference on Augmented Cognition (AC 2018)
- 9th International Conference on Digital Human Modeling and Applications in Health, Safety, Ergonomics, and Risk Management (DHM 2018)
- 7th International Conference on Design, User Experience, and Usability (DUXU 2018)
- 6th International Conference on Distributed, Ambient, and Pervasive Interactions (DAPI 2018)
- 5th International Conference on HCI in Business, Government, and Organizations (HCIBGO)
- 5th International Conference on Learning and Collaboration Technologies (LCT 2018)
- 4th International Conference on Human Aspects of IT for the Aged Population (ITAP 2018)

Conference Proceedings Volumes Full List

1. LNCS 10901, Human-Computer Interaction: Theories, Methods, and Human Issues (Part I), edited by Masaaki Kurosu
2. LNCS 10902, Human-Computer Interaction: Interaction in Context (Part II), edited by Masaaki Kurosu
3. LNCS 10903, Human-Computer Interaction: Interaction Technologies (Part III), edited by Masaaki Kurosu
4. LNCS 10904, Human Interface and the Management of Information: Interaction, Visualization, and Analytics (Part I), edited by Sakae Yamamoto and Hirohiko Mori
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6. LNAI 10906, Engineering Psychology and Cognitive Ergonomics, edited by Don Harris
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HCI International 2018 Conference

The full list with the Program Board Chairs and the members of the Program Boards of all thematic areas and affiliated conferences is available online at:

http://www.hci.international/board-members-2018.php

HCI International 2019

The 21st International Conference on Human-Computer Interaction, HCI International 2019, will be held jointly with the affiliated conferences in Orlando, FL, USA, at Walt Disney World Swan and Dolphin Resort, July 26–31, 2019. It will cover a broad spectrum of themes related to Human-Computer Interaction, 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 will be available on the conference website: http://2019.hci.international/.

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http://2019.hci.international/

Contents – Part II

Design for All, Assistive and Rehabilitation Technologies

Comparative Evaluation of Accessibility and Learnability of Learning Management Systems: Case of Fronter and Canvas

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Abstract. Learning Management systems (LMSs) are becoming integral parts of the teaching and learning process in higher learning institutions. As they are supposed to be used by students who are diverse in terms of ability/disability, gender, learning style, experience, and other factors, they must be designed to be accessible and learnable to all to the extent possible. Several studies have looked into accessibility and usability of LMSs employing different techniques. This study aims to contribute to the existing body of knowledge by providing the user's perspective. The Oslo Metropolitan University is in the process of replacing the LMS Fronter with Canvas. In this study, eighteen students at who have access to the two LMSs have been contacted to evaluate the learnability and accessibility of both LMSs though task-based interviews and justify whether Canvas was the better choice. The findings show that there are aspects where one LMS is better than the other. The paper thus concludes by providing pointers that could be important to ensure accessibility and learnability of LMSs during their implementation.

Keywords: Learning management systems · Accessibility · Learnability
eLearning · Universal design

1 Introduction

Learning management systems (LMSs) are employed to facilitate the teaching-learning process in higher learning institutions. They enable teachers and students to access learning materials at anytime and anywhere, serve as a common source of learning for everyone; and extend students' channel of communication and thus help them to learn in a quicker and efficient manner [1]. To make LMSs more effective, it is important to make them accessible and learnable to all users, which are diverse terms of experience, ability/disability, language, and many other factors.

It is estimated that 15–20% of the Norwegian people live with different forms of disabilities and two out of three students receive special education outside their class [2]. There are some who argue that special education could instill a sense of otherness [3]. Nevertheless, LMSs create opportunities for students to learn at their own paces and, at the same time, share the same classroom with other fellow students.

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Countries which ratified the U.N. convention on the rights of people with disabilities should ensure accessibility of information and communication technology (ICT) systems. Advances in accessibility and universal design provide the tools and the means to design accessible LMSs. LMSs should also be designed to be easily understandable by incoming students which can have different levels of ICT skills.

The Oslo Metropolitan University has been using the Fronter[1] (see Fig. 1) for years and is now in the process of replacing it with Canvas[2] (see Fig. 2). The process is expected to be completed in May 2018. According to personnel overseeing the project, the university is switching to Canvas because it is more flexible, and it has more features when compared with other LMSs. For instance, she said that peer-to-peer review is possible on Canvas but not on Fronter. She also added that Canvas provides more 'space' to the teachers to use different techniques. These were among the main qualities that made Canvas more appealing.

This research aims to evaluate the learnability and accessibility of both LMSs from the students' perspective. It also provides some recommendations on what should be considered in future implementation of LMSs.

Fig. 1. User interface of Fronter

1 https://itslearning.com/global/Fronter/Fronter-home/.
2 https://www.Canvaslms.com/?lead_source_description=instructure.com_.

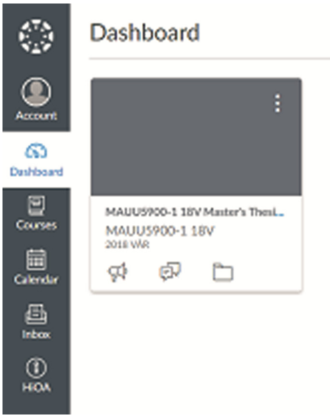

Fig. 2. User interface of Canvas

2 Related Work

Usability refers to the concept of "user friendliness", explaining for how easy is a system to use [4]. Learnability is component of usability which specifically refers to a quality of a system to be easily understandable by first time users without any special training in a shortest possible period [4, 5]. Accessibility, on the other hand, means that people with disability can perceive, understand, navigate, and interact with web-based systems without barriers.

LMSs present different learning environments and features unique to each of them. Therefore, Rangin et al. [6] believe that the purpose of LMSs evaluation should not be to rank them but to remind content and product developers on features that would affect user's experience. The comparative evaluation they conducted on four different LMSs identified accessibility and learnability issues such as lack of sufficient headings, lack of labels at some areas of the LMSs, lack of shortcuts and 'skip' buttons which would affect screen reader users, lack of icon links in some areas, and other related issues.

Pretorius and van Biljon [7] investigated the effect of ICT skills in learnability and usability of LMSs. Their study found that the clarity of language for displaying error messages or in describing basic tasks affects the learnability of LMSs. The study by Al-Khalifa [8] showed that even students well-acquainted with computers and web systems would struggle to easily understand an LMS.

Chen et al. [9] conducted heuristic evaluation of two LMSs such as Fronter and Sakai to see how the systems help teachers to create accessible content. The Authoring Tool Accessibility Guidelines (ATAG) 2.0. were adopted to design the heuristic evaluations. The study found low-level conformance to ATAG guidelines. That includes missing possibility to add text descriptions for audio and video files, limited capabilities for keyboard navigation, inaccessibility of status indicators for screen readers and other related issues.

The papers presented above show that the accessibility of LMSs is affected not only the design of the interfaces but also the capability of the content management systems in helping content creators provide accessible content. Moreover, vocabularies and expressions used could affect learnability of LMSs even to those who are well acquainted with ICT.

3 Methodology

3.1 Selection of Participants

Eighteen students who have access to both LMSs were purposefully selected to take part in this study. Six of them were first degree students while twelve of them were master's students including two visually impaired students. Their age ranged from Twenty to forty-five. Seven of them were female and eleven of them were male participants. Moreover, the project manager overseeing the transition from Fronter to Canvas was interviewed to understand the motive behind choosing a new LMS.

3.2 Method of Data Collection and Analyses

Task-based evaluation (interview) method was main method of data collection. The students were asked to perform eight different tasks relating to their normal use of the LMSs. The tasks included logging in, searching files, uploading files, downloading files, checking 'news', checking notifications, checking user guides, and connecting to others. The two visually impaired participants were given the extra task of changing the color contrast, and check the LMSs with the Narrator, an accessibility tool included with Windows operating system. During the execution of the tasks, they were asked to provide their opinions on the features they checked and functions they performed. That was accompanied by a heuristic evaluation informed by Web Content Accessibility Guidelines (WCAG 2.0)[3] and usability guidelines. The data was analyzed thematically.

4 Results

4.1 Features

Toolbar. Both LMSs have toolbars that provide tools for accessing different functionalities of the systems. Fronter's toolbar contains icons for 'Rooms', tools, search, My portfolio, email, and a shortcut to the users Microsoft OneDrive account. Canvas toolbar contains icons such as account, dashboard, courses, calendar, inbox, and a link to university information pages and the user manual. Twelve participants judged icons used in Fronter as more self-explanatory and easy to understand. Only six participants chose icons used in Canvas. Fronter supports the mouseover functionality to provide hints on the item being hovered over. Currently, Canvas lack that capability.

Dashboard. Fronter's first page labeled as 'Today' contains toolbar, notification bell and a news section and shortcuts to recently uploaded documents. Canvas's first page

[3] https://www.w3.org/TR/WCAG20/.

labeled as 'Dashboard' contains a toolbar, calendar, and "Recent Activity". The project manager said that, unlike Fronter, Canvas's 'notifications' section doesn't provide notifications which are not relevant to a user. fourteen participants said that Canvas's dashboard is more understandable than Fronter's. For instance, Canvas displays deadlines at the top whereas, on Fronter, one has to scroll down to find them. Four participants including the visually impaired said they are comfortable with Fronter. the visually-impaired participants said that Fronter is easier to use with screen magnifiers. However, Canvas's user guide states that the LMS is compliant to web accessibility guidelines.

Rooms/Courses. Fronter's 'Rooms' and Canvas's 'Courses' lead to list of courses and course materials available on the LMSs. Fourteen participants said that Canvas's 'courses' is a more understandable label than 'rooms'. Moreover, it is easier to browse through subsections of the courses such as grades, files, syllabus, discussion and others. The participants also indicated that the vocabulary used in Fronter's rooms such as 'hand-in' and 'forum' could be difficult to understand for first time users.

Profile/Account. Fronter's 'my profile' does not allow editing user information by the user. On the other hand, Canvas's 'account' allows the user to change or add preferences such as language settings, notification preferences, and adding a secondary email. Moreover, users can see and access documents uploaded by them and their instructors. All the participants said Canvas is better.

User Guide. All the participants mentioned that Canvas user guide is better than Fronter's because it provides all the information in three different ways (Text, Pictures, and videos). The video tutorials are not accompanied by transcripts or captions, which could potentially impact users with hearing impairment.

Accessibility. Twelve students were comfortable with the color scheme used on Canvas while the rest of them said that it doesn't matter. The students with low vision impairment said that Canvas provides better color contrast. This could be important to those users with color blindness. The icons and labels on Fronter become less visible in high contrast. Canvas does better but, in high contrast, the toolbar becomes brighter which could make it uncomfortable to some users with visual difficulties (see Figs. 3 and 4).

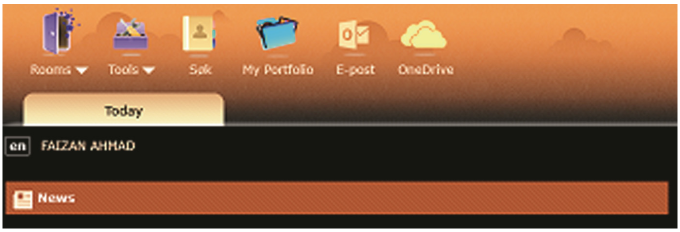

Fig. 3. Fronter user interface in high contrast.

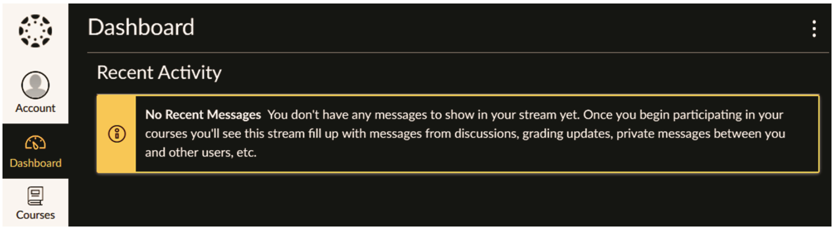

Fig. 4. Canvas user interface in high contrast

4.2 Functions

Search. Fifteen participants said that it is difficult to find files using the search tool on Fronter. Canvas offers a search functionality to search files within a specific course and, according to the students, Canvas is better for searching course materials.

Upload/Download. Canvas provides the chance of previewing files before downloading them. That functionality is missing with Fronter.

4.3 Summary: Learnability and Accessibility of the LMSs

The overall evaluation showed that Canvas could be more understandable to first-time users when compared with Fronter. However, there were some features in which Fronter does better. Tables 1 and 2 summarize the accessibility and learnability issues of the two LMSs as explored mainly through the perspective of users included in this study.

Table 1. Summary of learnability features in both LMSs

Learnability features	Fronter	Canvas
Mouseover hints	Yes	No
Tutorials	No	Yes
Understandability of vocabulary (of tasks, features) for first time users	Partial	Yes
Icons (understandability)	Yes	Partial

Table 2. Summary of accessibility features in Both LMSs

Accessibility features	Fronter	Canvas
Screen magnifier	Yes	Yes
High contrast	Partial (less visual acuity)	Partial (but better)
Keyboard navigation	Partial	Yes
Alterative text to images	No	Yes (allows entry of alternative texts)
Accessibility to screen readers	Yes	Yes
Video captions	No	No

5 Discussion and Conclusion

In this study, we tried to evaluate the learnability and accessibility of two LMSs mainly from users' perspective. Learnability is a very important trait for an LMS as it is important for new students to start using the system with minimal or no training. Moreover, the diversity of uses in terms of dis/ability, experience, and other features makes accessibility an important attribute to an LMS.

Higher learning institutions would have different motivations for switching from one LMS to the other. However, as shown in this study, one LMS could have features which are better learnable and accessible than the other. For instance, this study implies that Canvas is more accessible and learnable than Fronter. However, it also showed that Fronter is better in some aspects according to the participants. That could be the result of many factors including experience. Nevertheless, it is important to incorporate concerns of accessibility and learnability like those discussed here: ensure that icons and buttons are self-explanatory, provide mouseover hints on icons, provide captions for images and videos, enable searching through a course or the whole LMS, and follow other recommendations in the available accessibility and usability guidelines.

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Behavioral Archetypes for Stroke Rehabilitation Technologies

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Abstract. Being a leading cause of death and serious long-term disability across the world, stroke and cerebrovascular diseases became a major burden on health and social care. However, research has shown that early therapy intervention with stroke patients has the potential for significant improvements in terms of cognitive and motor abilities. Integration of technology into rehabilitation such as the robot-assisted therapy, virtual reality applications, and telecare systems have changed the way rehabilitation programs are being delivered and it overcame some of the limitations and challenges that come with conventional therapy programs. Understanding the target audience and their behavior is of crucial importance to be considered in an early design phase especially with this kind of systems that have tedious nature and involve multiple groups of users (patients, therapists, and caregivers). In this study, we aim to adopt a participatory design approach that engages users and stakeholders in developing stroke rehabilitation technologies aligned with behavioral archetypes that are modeled around their behavioral perspectives. We believe that using archetypes in user research gives us a better view of behavior in interaction design of rehabilitation systems and provide developers with a model to validate interactive elements in stroke rehabilitation systems and user flows at a macro level. In this paper, a user study was designed to be conducted to validate behavioral archetypes of these groups through interviews and focus group sessions with different physicians, therapists and caregivers in rehabilitation centers.

Keywords: Stroke · Rehabilitation · Behavioral archetypes
User-Centered design

1 Introduction

According to the World Health Organization, data has shown that stroke remains a leading cause of death and disability since 1990 [1]. As population demographics shift over time and with the increasing number of people affected by stroke comes the crucial importance of rehabilitation and recovery process. Many surviving stroke patients often suffer from severe and long lasting impairments, from motor to cognitive issues, that affect their daily activities [2]. These limitations caused by stroke may include lack of

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muscle control, muscle weakness, total paralysis, vision problems, speech/language problems, or memory loss, depending on the part of the brain that was injured and the severity of the injury [3, 4]. However, recent studies have shown that with proper post-stroke rehabilitation and early, intensive and repetitive exercises patients can gradually restore some degree of their motor and cognitive performance [2].

Due to the slow progress and tedious nature of therapy programs especially with this kind of morbidity, rehabilitation and recovery process usually takes a long time and effort. Sometimes, it may even lead to patient's lack of motivation and early termination of the exercises, which is consistently linked to therapeutic outcomes and recovery [5]. Therefore, researchers nowadays are studying new ways to enhance the process through an efficient, easy to use and personalized design of rehabilitation systems that help the patient to smoothly regain strength and independence [2]. Understanding target audience of a system; their demographics and needs has a profound effect on the design of the system and influences most of the decisions that designers make for a good user experience. However, such information about the user may lose its value and be misinterpreted if presented as static figures and numbers [6]. Behavioral archetype is a fictitious representation or a scenario of a specific group of system users, created during design stage and is modeled around behavioral and motivational perspective. Through behavioral archetypes, designers can understand and respond to their users' needs and preferences in a more engaging and empathetic way especially in healthcare and rehabilitation systems.

This paper discusses the feasibility of using behavioral archetypes as a tool for designing rehabilitation systems for stroke. It is organized as follows: the first section discusses some of the previous work in using technology in stroke rehabilitation and the adoption of personas and behavioral archetypes in user experience design. The second section describes an exploratory design approach for using behavioral archetypes in designing stroke rehabilitation systems and the study design for evaluating these archetypes.

2 Related Work

2.1 Technology in Stroke Rehabilitation

Repeated studies have shown that Intensive post-stroke rehabilitation program can significantly help patients to gradually regain their performance and results in positive outcomes. As technology continues to advance, it changed the way healthcare is being delivered and it helped to overcome some of the limitations and challenges that come with conventional therapies [7]. The integration of technology into rehabilitation was motivated by the need to improve clinical outcomes by enabling novel modes of exercises and to alleviate the burden associated with traditional rehabilitation programs which are based on one-to-one practice sessions with the therapist especially when there is a lack of trained healthcare personnel. Moreover, with the increasing emphasis on cost reduction in healthcare, technology has resulted in a shorter length of stay for inpatient rehabilitation as the patient can continue the therapy even after discharge, in a home based setting [8, 9]. Following are examples of technologies used in stroke rehabilitation.

Robot-Assisted Therapy

Mirror Image Movement Enabler (MIME) (see Fig. 1), developed in 1998, is an example of a Robot-Assisted therapy system that simulates conventional rehabilitation techniques for the upper limb after stroke in which a robot manipulator help patients, at any impairment level, to repeatedly practice and complete stereotyped movement patterns and it supports several modes of Robot-Subject interactions. When compared with an equally intensive conventional treatment, Robot-Assisted therapy had an advantage and had shown significantly greater strength improvements overtime. [9]

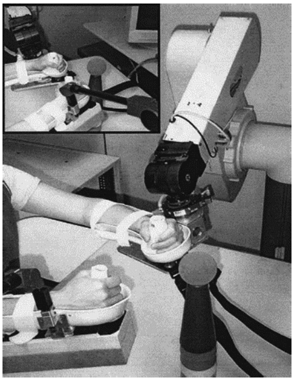


Fig. 1. Robot-Assisted training through MIME. [9]

Brain Computer Interfaces (BCI)

Another novel technology that is being increasingly employed in rehabilitation programs is the brain computer interfaces. BCI is "a computer based system that translates brain signals into commands for an output device to perform a desired action". Research has demonstrated the efficacy of BCI technology in post-stroke rehabilitation as it helps to restore motor control after stroke or other traumatic brain disorders. Because stroke affects parts of the brain that are responsible of motor functions, BCI could be used to induce and guide activity dependent brain plasticity by focusing on motor tasks that require the activation or deactivation of specific brain signals. Several motor action and motor imagery platforms have been developed for EEG acquisition, processing and classification of brain signals such as Emotive headset. [10]

2.2 Personas and Behavioral Archetypes in UX Design

The application of User–Centered Design (UCD) approach has shifted the focus in system development to be driven by user's needs instead of technical requirements. Therefore, knowing the user and his/her interaction with the system became the most relevant factor to achieve usability goals and product success. Representing user's information could be done through segmentation and user modeling techniques such as personas and archetypes that encapsulate users' characteristics, needs and behavior. Persona was originally introduced in the HCI community by Cooper [6] where he described persona as "a precise description of a user's characteristics and what he/she wants to accomplish". It is a fictitious representation of a hypothesized group of users based on their demographics, needs, goals and biographical characteristics that would guide the design decisions and help the project team to visualize user segments and build solutions for them. However, characteristics and behavior of users interacting with the system do not always align, and differences are at times volatile. Personas often do not include details on behavioral patterns and how they interact with the system. Therefore, a novel way that encompasses such patterns is through behavioral archetypes. Behavioral archetypes are fictitious representations of system users that are modeled around their behavioral perspective, motivation and pain points. Using archetypes in user research gives us a better view of behavior in interaction design and provide developers with a model to validate interactive elements and user flows. User modeling has been used in designing healthcare systems to improve the experience of patients and healthcare professionals. [11]

3 Exploratory Design Approach Using Behavioral Archetypes

Research has shown that early therapy intervention with stroke patients has the potential for significant improvements in long-term outcome in terms of cognitive, sensory and motor function. To design and develop interactive rehabilitation technologies for stroke patients, it is important to understand the context of use, pain points for patients and therapists, aspirations of all stakeholders, and motivations. By involving families and health professionals in the early design phase of rehabilitation technologies for stroke, we aim to produce a therapy intervention, which users and stakeholders would embrace and engage with. The objective of adopting a participatory design approach in developing stroke rehabilitation systems is to understand their true needs and, in turn, unmet design opportunities for stroke rehabilitation technologies.

3.1 Method

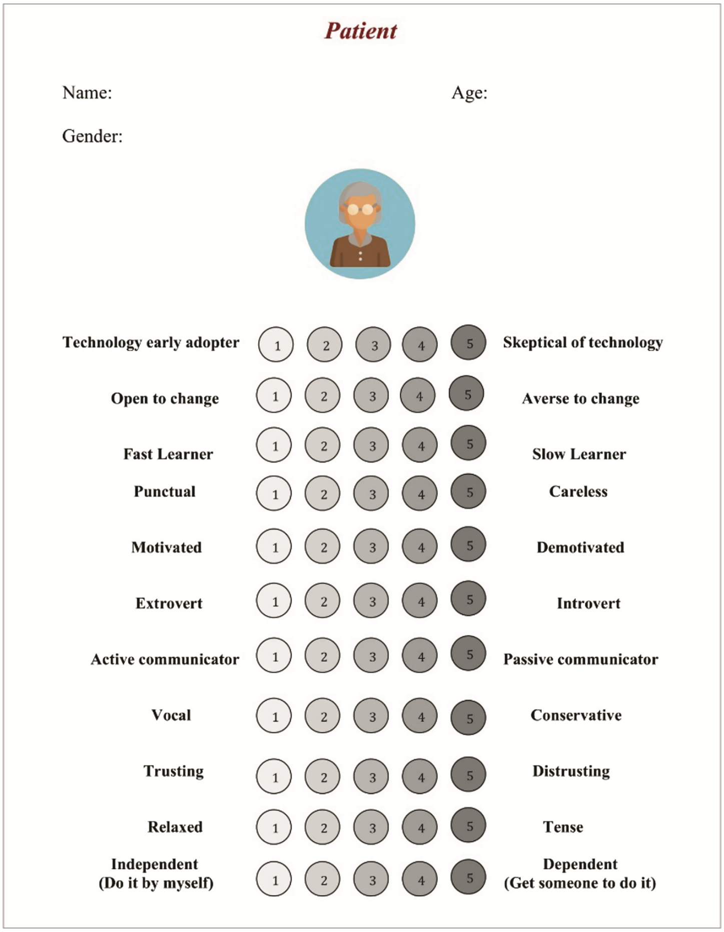
In this study, we are engaging patients and domain experts including caregivers, therapists and physicians as co-creators and co-designers in the development process of stroke rehabilitation systems by using behavioral archetypes. Co-creation and co-design is a participatory design method where stakeholders and domain experts are being involved in collective acts of creativity in designing the system where they play several roles depending on their level of expertise and creativity [12]. We defined a set of archetypes for each stakeholder (patient, caregiver, therapist, and physician) that could be used in designing stroke rehabilitation systems and we aim to validate them with domain experts and patients through interviews and focus groups to see the feasibility of using them as a tool in the design of such systems.

3.2 Participants

A stratified purposeful sampling approach will be conducted for this study that divides the population into groups by a specific characteristic, not geographically. The study sample is separated into physicians, therapists, caregivers and patients. A sample from each of these strata will be taken using convenience sampling methods.

3.3 Apparatus

The behavioral archetypes are listed in a single-page form (see Fig. 2) for each category of stakeholders (patient, caregiver, therapist, and physician). These forms will be used in interviews and focus group sessions to evaluate the presented archetypes and how they could contribute to the design process.



Patient

Name: Age:

Gender:

Technology early adopter	1	2	3	4	5	Skeptical of technology
Open to change	1	2	3	4	5	Averse to change
Fast Learner	1	2	3	4	5	Slow Learner
Punctual	1	2	3	4	5	Careless
Motivated	1	2	3	4	5	Demotivated
Extrovert	1	2	3	4	5	Introvert
Active communicator	1	2	3	4	5	Passive communicator
Vocal	1	2	3	4	5	Conservative
Trusting	1	2	3	4	5	Distrusting
Relaxed	1	2	3	4	5	Tense
Independent (Do it by myself)	1	2	3	4	5	Dependent (Get someone to do it)

Fig. 2. Patient's behavioral archetypes form.

In defining the archetypes and to make sure they reflect the important qualities that shape our social and psychological aspects, we considered the Big Five personality traits, also known as the Five Factor Model (FFM), which is a well known theory in psychology and social science that summarizes the different factors of personalities into five broad scalable dimensions of personality traits which are Openness to experience, Extraversion, Conscientiousness, Agreeableness, and Neuroticism. Each of these dimensions represents a range between two extremes (e.g. extraversion vs. introversion). In our study, we chose archetypes that could relate to these personality dimensions with a scale from 1 to 5 for each archetype. For example, openness was covered by archetypes regarding technology adoption and openness to change, extraversion was covered by archetypes such as motivation and activeness in communication, and neuroticism was represented as relaxation and independence. [13]

4 Conclusion

Adopting participatory design approaches such as personas and other user modeling techniques is of crucial importance for optimizing the usability by understanding user's needs and pain points especially in healthcare and rehabilitation systems that have a great impact on health and quality of life. However, demographic data and other personal characteristics are not always reflecting behavioral patterns and how people interact with systems. Therefore, using behavioral archetypes would eliminate this gap by considering behavioral models of different groups of users and how you expect them to interact with the system. This research studies the feasibility of using behavioral archetypes for designing stroke rehabilitation technologies. The paper discussed the design of an exploratory study that will be conducted to validate a set of defined archetypes for stroke rehabilitation systems by domain experts. Evaluation sessions will be carried on with physicians, therapists, caregivers and patients through interviews and focus groups to evaluate the proposed set of archetypes for each category. Future work would involve using these archetypes in developing rehabilitation systems for stroke and in testing the usability of such applications. It will help developers to understand and respond to users needs and problems in a more empathetic way.

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Design Guidelines for the Implementation of an Interactive Virtual Reality Application that Supports the Rehabilitation of Amputees of Lower Limbs Patients with Post-Traumatic Stress Disorder (PTSD)

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Abstract. This article describes the way in which emotions become a crucial component that complements the work of HCI in design and validation of applications created in virtual reality (VR) environments, applicable to the recovery processes of psychological disorders of being's humans, such as PTSD.

Keywords: Affective computing · Virtual reality · PTSD · Emotion

1 Introduction

In this article, we review a series of strategies for the design and development of immersive virtual reality computer applications, which are aimed at the rehabilitation of post-traumatic stress disorder - PTSD. Today applications are implemented that contribute to the improvement of the quality of life of people and that in most cases suffer from different types of diseases: physical, movement limitations and disorders that require treatments.

Virtual reality design specifies the need to establish a hierarchy of needs that lead to an appropriate development of interaction. In the present article that aspect is oriented to recovery processes of psychological disorders. A description is made of the most representative aspects to design in RV and then the necessary criteria are established to consider the emotions in that design, in such a way that the relevance of the affective computation is denoted as a method to guarantee the satisfaction of the users. of interactive applications and feedback to the designer of this type of environment. The Human

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Computer Interaction (HCI) in conjunction with affective computing are a fundamental tool for the construction of virtual reality environments.

2 Guidelines to Address Psychological Treatments Related to Human Behavior

Cognitive-behavioral treatments have proven effective in the treatment of emotional disorders since they use the metaphor of man as an information system, that is, similar to a computer system [1]. Humans process information from the environment before issuing a response; classifies, evaluates and assigns meaning to the stimulus it receives based on the set of experiences it has stored in its memory, which are derived from its previous experiences, from the interaction with the environment, from its beliefs, assumptions, attitudes, visions of the world and self-assessments [2]. In this way to give an answer to the environment, previously with all that experience and knowledge acquired a hierarchy is created. Normally patients suffering from PTSD do not want to face situations that remind them of the trauma. Currently, the use of virtual reality in cognitive behavioral therapies is increasingly applied, is based on a principle: Teach the patient to unlearn their reaction to fear, undo that traumatic process suffered during the incident in an environment sure, so that you can gain control over your physiological reaction. Based on this premise, it highlights the importance of virtual reality software development, because they are controlled environments that give users greater confidence [3].

The DSM-V [4] is the diagnostic compendium of the American Psychiatric Association, which provides news regarding the coding, classification and diagnosis of mental disorders that have broad effects on many specialties. In the DSM-V posttraumatic stress disorder is coded with 309.8. On the other hand, in the international statistical classification of diseases and health-related problems ICD10 [5], a statistical classification of diseases must cover the entire range of states within a number of categories; according to the endorsement given by the World Health Organization (WHO) to this classification. In the ICD-10 the PTSD is coded with F43.1 and as in the case of the DSM-V, in this classification all the characteristic features of a person suffering from PTSD can be identified. At an international level there are disagreements regarding the codification made in the DSM-V, which is of North American origin and with a strong psychiatric focus, for this reason WHO is preparing the ICD-11 that will unify the classifications of diseases of origin mental [6].

3 Behavior Cognitive Treatment

Cognitive therapy states that emotional disorders arise from irrational thoughts. If the thoughts that are behind a behavior are analyzed and made logical and rational, the psychological problem will be solved. There is a systematic distortion in the processing of information, in this way the emotional disturbance depends on the potential of the individuals to perceive negatively the environment and the events that surround them.

Cognitive behavioral therapy (CBT) has several objectives:

(1) Learn to evaluate relevant situations logically and realistically.
(2) Cognitive behavioral therapy proposes a change in attention to take into account all the relevant data in these negative situations.
(3) Learn to formulate alternative, logical and rational explanations in order to obtain an adaptive result in social interactions.
(4) Change the thoughts, so that when an irrational automatic thought is detected, it is changed by the rational and logical thought that has been elaborated.
(5) The CBT proposes to test rational thoughts, conducting behavioral experiments that provide opportunities to verify that they lead to a more adaptive behavior in the interaction with other people and in the resolution of problems.

These steps include cognitive thinking and behavior content change techniques, which change patient behaviors [7]. To achieve success in the care process, it is necessary to create a team and build trust between the therapist and the patient. One of the most used practices in CBT management is Exposure Therapy (Exposure of the Imagine: Building a Hierarchy and choosing the first memory [1]), where the patient faces a real scene of the experiences in the moment of suffering the trauma.

Figure 1 shows a typical hierarchy of treatment processes considered in exposure TCC, the evaluation of the consequences of actions in the environment is noted. This is a first criterion to consider in the design recommendations for the RV App.

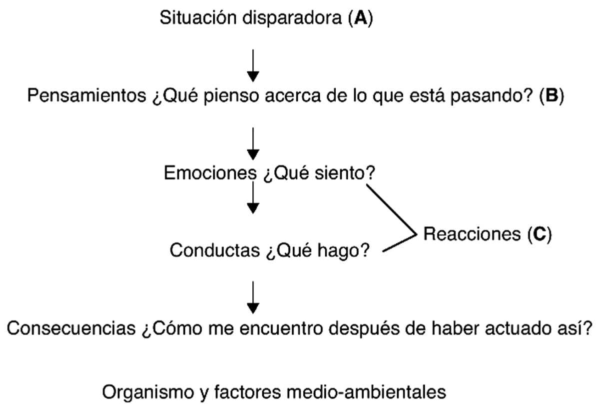

Fig. 1. Hierarchy of the imagination in CBT behavioral therapy (Own).

4 Diagnostic Interview

In light of the DSM-V and the ICD-10, different types of psychological disorders can be found, which must be appropriately diagnosed for decision making in the treatment with CBT. In the case of a diagnosis of PTSD, the result of the diagnostic interview for PTSD should be taken into account. Currently this interview is structured in the CLINICIAN-ADMINISTERED PTSD SCALE FOR DSM-5 (CAPS-5) [8], which is a standard procedure to obtain essential qualifications and produce reliable and valid scores in the diagnostic determination. This process is performed by an expert in a PTSD diagnostic interview.

5 Inventory or Anxiety

This procedure is useful in the description that people make of themselves and allows to determine the degree of anxiety RASGO - ESTADO [9] in which the patient is. In this process, a rating scale is used, such as the following:

(1) Not at all
(2) A little
(3) Pretty
(4) A lot.

Where (1) corresponds to the lowest score associated with the feeling and (4) more present. These four rating scales apply to 40 affirmations. Figure 2 shows an example of the inventory:

1.- Me siento calmado	1 2 3 4
2.- Me siento seguro	1 2 3 4
3.- Estoy tenso	1 2 3 4
4.- Estoy contrariado	1 2 3 4
5.- Estoy a gusto	1 2 3 4

Fig. 2. Scales of qualification of feelings in anxiety inventory (own).

6 Virtual Reality and Psychological Treatments

Virtual reality (VR) allows simulating the "reality" in three-dimensional environments supported by a computer, which, equipped with the necessary interfaces, gives the user the possibility to "be" in the generated environments so that it can interact with virtual objects. The experience of "immersion", of feeling there, of experiencing this experience as something real is what has been called "presence" [10] in RV environments. This is nothing more than a user experience that shows from the psychological point of view that this feeling of being and experiencing something significant and relevant is important, since it gives the possibility of using such virtual environments as powerful therapeutic tools that help the person to change, while protecting them while the change occurs [11]. In short, it is about being able to modify behaviors, thoughts, experiences, emotions… through "special" virtual experiences. Virtual experiences designed and adapted to the needs of the person, with the aim of promoting, facilitating and enhancing the process of change. Therefore, it is not surprising that in recent years its use has been extended in the field of psychological treatments. Among the most relevant applications that have been developed, are those that have to do with exposure techniques commonly used in the treatment of phobias. There has also been considerable progress in the fields of eating disorders.

6.1 Virtual Reality and Anxiety Disorders

This type of disorder in human behavior (disorder) is one of the most prevalent [12]. Exposure is one of the most effective therapeutic techniques to treat this type of disorder, because an important aspect of anxiety is the fact that the affected person avoids making contact with what causes the disorder. For example, in social phobia the person avoids situations in which he may receive a negative evaluation of others; people with panic disorder or agoraphobia, avoid situations in which you feel it is difficult to escape or seek help, in case of a threatening event, such as having a panic attack. The primary characteristic of exposure therapy is the confrontation with the dreaded situation; but this confrontation is carried out in a repeated, systematic and gradual manner. Emotional processing is implicit in the efficiency of exposure [13].

The exhibition can be staged through the imagination of the stimulus that provokes the anxiety (exposure of the imagination); or by putting the person in a context in which he or she is exposed to a real-life situation that causes anxiety (live exposure). Here the therapeutic strategy that is involved is the identification of the keys that activate the anxiety and that are associated with the situation to which one is afraid. The person is then exposed to these keys and, with the therapist's help, the person learns how to cope with the anxiety in the situation, until the anxiety gradually diminishes and disappears. VR allows you to simulate reality and help the patient face the situation he fears in an effective, safe and controlled way [11]. VR has been used for the treatment of panic and agoraphobia (TPA), by designing a series of virtual environments [14] and studies have also been carried out on its efficiency [40, 15, 16], They compared the results obtained through cognitive-behavioral treatment, including exposure through VR in one of them. The results showed that both conditions were equally effective. The work carried out by Botella carried out a study that included three experimental conditions, these are exposure through RV (which also allowed exposure to both external stimuli and interoceptive stimuli), live exposure and a waiting list control group. The results showed that exposure by RV and in vivo exposure were equally effective, with both conditions also obtaining results superior to the waiting list condition. In spite of the scarcity of studies carried out to date and the need to replicate them with broader clinical samples, the results obtained show that VR techniques have an important utility in the treatment of TPA.

The techniques of RV in the treatment of phobias, has been the most widespread field in relation to clinical psychology. An important reference is the work carried out by the Rothbaum group [17], in a case of acrophobia, which gave rise to the performance of many other works showing mostly the positive results and the effectiveness of these tools for the treatment of Phobias [18].

Along with the previous results, the phobia to fly is the specific phobia in which more studies on the effectiveness of VR techniques have been carried out. There are several studies about the effectiveness of VR in this problem.

In summary, several controlled studies have shown that exposure therapy by means of RV is more effective than non-treatment conditions and obtains the same efficacy as exposure in vivo. In addition, it has been observed that the benefits and gains obtained with the treatment through VR are maintained in the follow-ups carried out in the different studies. Finally, there is evidence of a preference on the part of patients for exposure by VR to exposure in vivo before beginning the treatment of phobias, both in subclinical and clinical samples [19].

6.2 Treatment of Phobias Through Virtual Reality

Probably the greatest development of current applications of virtual reality on mental disorders is that of phobias, it is stated that the pioneers in conceiving the idea of using VR for psychological disorders was North's group, North, and Coble in the year of 1992 [20]. They started their work on phobias to fly, which is one of the most frequent and that affects and limits people to move generating social and labor consequences. In a first experiment, they simulated a city seen from above and treated a 32-year-old woman for eight 30-min sessions, at the beginning of each session, the elevated anxiety measures, but progressively diminished after the first minutes of exposure and reached the highest level, value of zero [21].

6.3 Virtual Reality and Eating Disorders

A field of great relevance in the application of VR is the treatment of eating disorders (TCA). This is caused by the presence of distorted body image; hence a premise in the treatment of eating disorders is to pay attention to body image [22].

The treatment consists of taking the patient to a confrontation with his body image, leading him to correct the wrong ideas he has about the figure and the weight. It is important to note that everything that is involved in what is the body image is something abstract and this hinders the methods with which it can be addressed in therapy. At this point, it is where the RV can be useful. VR can "physicalize" the mental image that the patient has about himself, creating a representation of it and also facilitating immediate communication between the therapist and the patient [14].

6.4 Applicability and Clinical Utility of Virtual Reality in PTSD in Criminal Violence

There is a reference of more recent works, where the therapies with RV have been applied with encouraging results. The work carried out by de la Rosa Gómez and Cárdenas López of the National Autonomous University of Mexico demonstrates this premise [3]. The study shows efficacy results of the treatment of Posttraumatic Stress Disorder (PTSD) for criminal violence using virtual reality. The clinical sample consisted of 20 participants from Cd. Juárez, Mexico, who voluntarily agreed to join the research, with ages between 18 and 65 years. All participants met the criteria of the Dignostic and Statistical Manual of Mental Disorders (DSM-IV-TR) for PTSD and were randomized to two treatment conditions:

(a) prolonged exposure treatment using virtual reality (TERV; n = 10)
(b) prolonged exposure treatment by imagination (TEI, n = 10).

The intervention was carried out in 12 sessions [23], two weekly sessions, in face-to-face and individual modality, of 90 min. Two virtual scenarios were used for exposure in the treatment of PTSD. There was an improvement in the measures of PTSD, anxiety and depression for the two groups that received the treatment. However, only statistically significant differences were reached between the treatment groups in the diagnostic measures and the avoidance subscale, obtaining superior therapeutic gains in Virtual Reality Exposure Therapy (TERV). The results support the spread of empirically validated and effective treatments in the area of mental health for the Mexican population. This work is based on the entire study carried out by Cristina Botella and the Rothbaum group, where once again the effectiveness of VR treatments is evident.

7 Hierarchy of Needs of Virtual Reality

In keeping with Maslow's theory of basic needs and human essence, an equivalent hierarchy of needs in virtual reality is established: Comfort, ease of interpretation, utility and delight. To achieve user experience in presence these levels must be incorporated into the design and development of interactive applications.

Figure 3 shows the equivalent hierarchy, assumed by Beau Cronin [24] when making an analogy with Maslow's hierarchy, which proposes the needs and factors that motivate people; this hierarchy is modeled by identifying four categories of needs and is constructed considering an ascending hierarchical order according to its importance for survival and the ability to motivate.

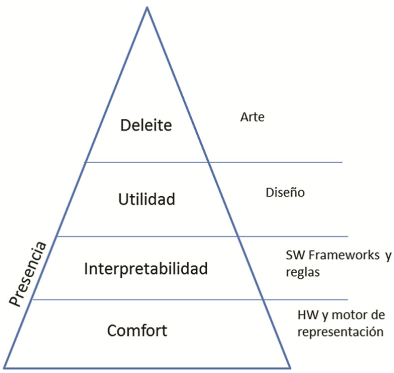

Fig. 3. Equivalent hierarchy [24]

7.1 Comfort

It integrates some very basic requirements, many of which refer to the accurate representation of the simulated environment in immediate response to the head and body movements. This level consists of satisfying our deeply unconscious expectations about the nature of our sensory inputs and how they interact with our actions. It is largely the responsibility of the RV hardware, such as the Head Mounted Display - HDM and the video accelerator card. At this level of the hierarchy, the quality of the render is defined, as well as the frameworks used to create and represent the content or application.

7.2 Interpretability

It is essential to satisfy the need for the simulated environment to be coherent: so that the senses can assimilate it, that it contains enough signals to guide us without being overwhelming, and to follow the logic normally found in everyday experience. The RV has the ability to break some guidelines of the rules of physics: we can fly, exhibit superhuman strength and even deform time and space. But these improved experiences must be quantitative and metaphorical extensions of normal life, which give the user that feeling of presence in the simulated environment.

Another way of thinking about Interpretability is that, of all the stimuli we can create with virtual reality systems, in only a small fraction of them will they have any meaning for our perceptual systems. The better the rules that govern these limitations are understood, the more efficient we will be in creating immersive environments. For this reason, interpretability depends to a large extent on rules and conventions, although it is largely supported by software frameworks that channel creativity in the appropriate directions [24].

7.3 Utility

This is a very specific concept of the application, but it really comes down to assessing the following premises:

Did the virtual reality experience fulfill its basic value proposition? In the case of psychological treatments to recover trauma such as post-traumatic stress, by applying cognitive behavioral therapies of exposure, you must work the design in a way that satisfies giving value to the user, for example losing the fear of facing scenarios that caused the trauma [3].

Does the film tell a story that makes sense? UX-VR virtual reality user experience must be added.

Did the presence session allow a rich and high fidelity communication? In these cases, it is extremely important to have a sufficiently robust team to guarantee the fidelity and availability of communication.

Did the virtual tour give you a precise idea of the context of therapy exposure? In utility, the most robust artifacts of the hierarchy of needs are conceived given that it is closely linked to the basic structure of what will be the satisfaction of the user according to ISO/IEC 25010 within the subcategories of quality in use, the utility contributes to satisfaction and puts a series of indicators that relate to this hierarchy.

7.4 Delight

Define is the realm of design art:

Did the user experience leave you thinking for days afterwards?

Was the presence session almost as good as visiting the site that caused the traumatic event?

Do you experience so much impact that the user wants to return to the next therapy? If the development fully meets the answers to these questions, it is imperative the effort that must be made to ensure the delight, first conquer the needs of lower level through engineering, design and attention to detail.

Although these levels are different, the boundaries between them are still quite permeable. The tools and frameworks must mature considerably, for example before a designer of interactive virtual reality applications can feel free of the basic problems of Comfort and Interpretability.

As in Maslow's original hierarchy, it makes little sense to worry about the higher levels before the lower ones are in place. One interpretation of the recent rebirth in virtual reality is that Oculus finally deciphered the Comfort code, through a combination of low weight, wide field of vision and fast and accurate tracking of the head [4]. For a long time people have ideas on how to offer interpretable, useful and delightful virtual reality experiences, and now we can finally prove them. The first two levels, Comfort and Interpretability, determine to a large extent the sensation of presence. The user should feel comfortable in the simulation, and the environment should be "read" as something natural, not necessarily realistic, but obeys the basic expectations we have about how our body interacts with its environment. If these conditions are met, then you will feel as if you are inhabiting the simulation; Of course, if it is useful and emotionally attractive.

If you want to obtain a viable minimum product - MVP, it is necessary to try to cover a vertical part throughout this hierarchy, ideally extending from Comfort to delight. On the one hand, it would be a mistake to think that addressing Comfort and Interpretability is sufficient:

Why would users want to continue using the experience, or recommend it to others if it is not useful and enjoyable?

These levels are also acceptable in an interesting and not obvious way, for brain stimulation systems supported in immersive virtual reality experiences. It can be concluded from this first part that the hierarchical levels proposed are coherent with the need to be able to generate delight for users who have suffered traumatic events that cause them avoidance, isolation and fear.

8 Frameworks

There are three main frameworks to choose from when designing for RV: Mozilla A-frame, Daydream VR and Unity VR/Unreal SDK.

(1) Mozilla A-frame is used for virtual reality applications and can be used on platforms such as Google Cardboard, Samsung Gear and Oculus Rift.
(2) Daydream VR is for mid-range Virtual Reality and works only with mobile phones.
(3) Unity VR/Unreal SDK are for high-end equipment that include Oculus Rift, HTC Vive and HoloLens (AR).

9 Emotions

The new wave of research also questioned the old Cartesian dualistic division between the mind and the body. The emotional experiences do not reside in our minds or brains only, they are experienced throughout our body: in hormonal changes in our bloodstream, nerve signals that go to the muscles tensing or relaxing, running through the blood to different parts of the body, postures bodily movements, facial expressions [25]. Our bodily reactions in turn feed back into our minds, creating experiences that regulate our thinking, in turn feeding our bodies. In fact, an emotional experience can begin through bodily movements; For example, dancing wildly could make you happy. Neurologists have studied how the brain works and how emotional processes are a key part of cognition. Figure 4 shows one of the emotional processes that are basically in the middle of most of the processing mechanisms, from the frontal lobe in the brain, through the brainstem to the body and back [26].

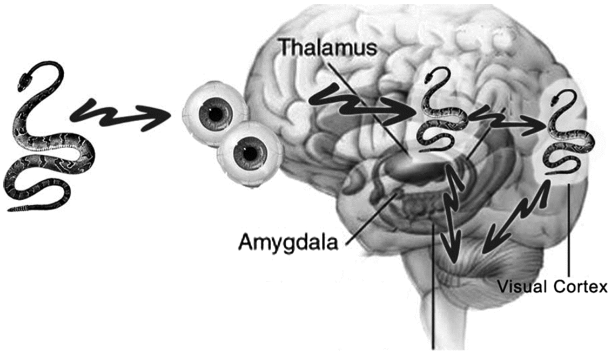

Fig. 4. Model of fear of LeDoux when seeing a snake [26]

Emotion is a mechanism of social and dynamic communication. We learn how and when certain emotions are appropriate, and we learn the appropriate expressions of emotions for different cultures, contexts and situations. The way in which we make sense of emotions is a combination of the experiential processes in our bodies and how emotions arise and are expressed in specific situations in the world, in interaction with others, projected by the cultural practices we have learned. A valid claim is that we are physically affected by the emotional experiences of others. A clear example of this is that smiles are contagious.

In HCI, the importance of considering the emotions of users explicitly in the design and evaluation processes is highlighted. In general terms, HCI research is established in three different directions with three very different theoretical perspectives on emotion and design.

1. The first perspective, widely known and very influential, is that of Rosalind Picard and his group at MIT, later adopted by many other groups, in Europe, in particular by the HUMAINE network. The cognitivistically inspired design approach he named Affective Computing in his groundbreaking 1997 book.
2. The second design approach could be seen as a reaction contrary to Affective Computing. Instead of starting from a more traditional perspective of cognition and

biology, the Affective Interaction approach starts from a constructively and culturally determined perspective on emotion. Its best known defenders are Phoebe Sengers, Paul Dourish, and Bill.

3. Finally, the approach that distinguishes emotions from general interaction leads astray. Instead, see emotion as part of a broader set of experiences for which we can design; it is called the Technology as Experience movement [27]. In a certain sense, this is what traditional designers and artists have always worked on [28], creating interesting experiences where a particular emotion is a cementing and congruent force that unites the different parts of the general system of art pieces and viewer/artist. The defenders of this direction are, for example, John McCarthy, Peter Wright, Don Norman and Bill Gaver [29].

10 Emotional Computing

The field of artificial intelligence (AI) picked up the idea that human rational thinking depends on emotional processing. "Affective Computing" by Rosalind Picard had an important effect in the fields of AI and HCI [30]. His idea, in short, was that it should be possible to create machines that relate to, arise or deliberately influence emotion or other affective phenomena. The roots of affective computing really come from neurology, medicine and psychology. It implements a biological perspective of the emotional processes in the brain, the body and the interaction with others and with machines.

Emotions or affects in users are considered identifiable states or, at least, identifiable processes. Based on the identified emotional state of the user, the objective is to achieve an interaction as real or human as possible, adapting without problems to the emotional state of the user and influencing it through the use of several expressions [31]. Figure 5 shows Ortony's model of emotions.

This model has its limitations, both in its requirement to simplify the human emotion to model it, and in its difficult approach on how to infer the emotional states of the end user through the interpretation of human behavior, through the signs and signals that we issue That said, it still provides a very interesting way to explore intelligence, both in machines and in people [27].

11 Affective Interaction

An interactive perspective on the design does not attempt to detect a singular explanation of the "correct" or "true" emotion of the user or to illustrate about it, as in a prototypical affective computer application, but rather makes available emotional experiences for reflection. This type of systems creates a representation that incorporates the daily experiences of the people on which they can reflect. The own and richer interpretation of the users guarantees that it will be a more "true" story than what they are experiencing.

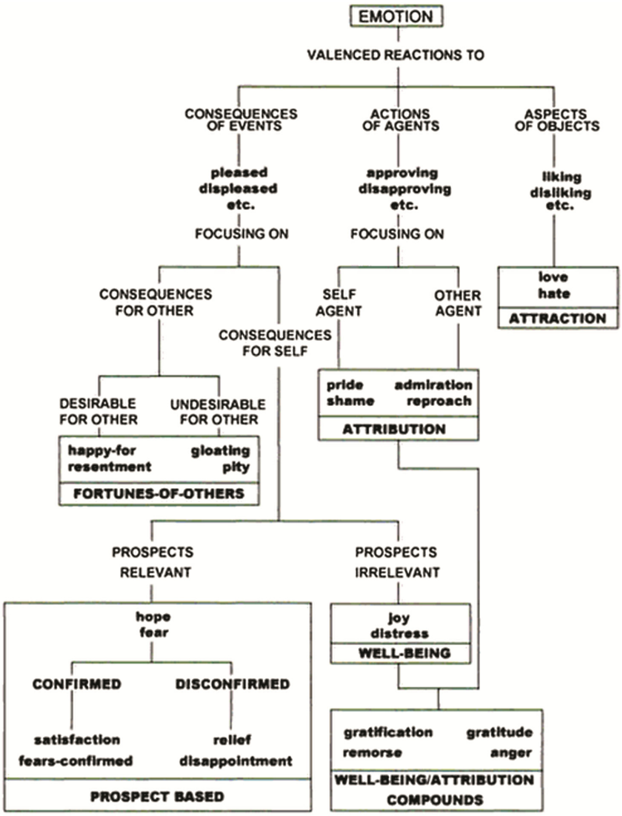

Fig. 5. Emotion model of Ortony, Clore and Collins [31]

According to Boehner [32], the interaction approach for design:

1. Recognizes affection as a social and cultural product.
2. Entrust and support interpretative flexibility.
3. Avoid trying to formalize what is not formalized.
4. Supports a wide range of communication acts.
5. It focuses on people who use systems to experience and understand emotions.
6. It focuses on designing systems that stimulate reflection and knowledge of affect.

Kristina Hook and her research group modify two of these considerations:

1. Modification of # 1: The interaction approach recognizes affect as a social, bodily and cultural product incorporated.
2. Modification of # 3: the interactional approach is non-reductionist.

The first change is related to the bodily aspects of emotional experiences. But explicitly pointing to them, some of the physical and bodily experiences that could involve an interaction with an interactive affective system are added. They also take a slightly different position with respect to design principle number three, "the interactional approach avoids trying to formalize the non-formalizable". To avoid reductionist ways of accounting for subjective or aesthetic experiences, Boehner and his colleagues try to protect these concepts by claiming that the human experience is unique, interpretive and ineffable.

12 Considerations

It is important to highlight the eleven initial considerations commented for the establishment of the design requirements or what we can call the requisite requirements. These guidelines are a fundamental part in the success of the development of interactive virtual reality applications for the treatment of PTSD.

The guidelines for the breakdown of this type of applications are considered taking into account the phases of the traditional development process such as: definition of requirements, design, development and validation. This allows us to propose a taxonomy of our own that allows us to specify the management of the own processes of software development.

Figure 6 shows the own taxonomy, which shows the different stages that must be met for the development of this type of applications, highlighting the validation stage where prototyping is the basis to add value to the application. These prototypes are validated with the principle of design science, which allows evaluating lessons learned, benefits and aspects to be improved. These topics are consistent with the needs of virtual reality to reach the user's delight.

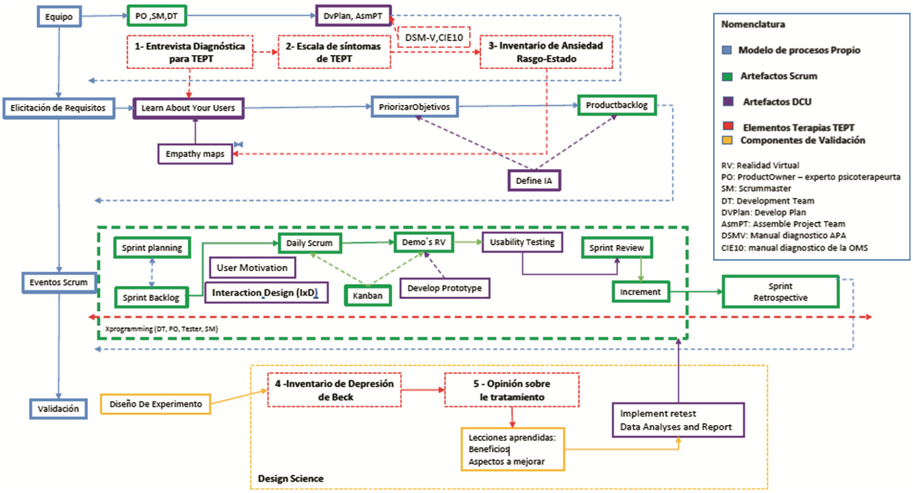

Fig. 6. Taxonomy of the own process model (own)

To address the development of interactive applications that are related to processes of psychological rehabilitation of PTSD, it is essential that there is a multidisciplinary team of expert psychotherapists, to achieve an adequate interpretation of the requirements by the designers of the software.

Attitudes, decision-making, human behaviors in the face of traumas obey a series of hierarchies that determine the process for the achievement of a pleasant experience or delight of the user.

For application design processes that require detecting or identifying reactions that are not necessarily physical or not psychic, it is essential to consider Russell's OCC-model, so that behaviors can be coupled with learning in the virtual reality treatment process.

There is a clear convergence between the hierarchy of needs of virtual reality, cognitive behavioral therapy and affective interaction, since the latter handles a series of approaches associated with emotional experiences, which ultimately must be standardized to achieve improvement in the treatment of PTSD.

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Personalized Recommendation System for Efficient Integrated Cognitive Rehabilitation Training Based on Bigdata

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Abstract. In this study, a personalized recommendation system for efficient integrated cognitive rehabilitation training based on bigdata was developed. The system consists of 5 main phases (collection, storage, processing, analyzing, visualization). First, in the pre-processing process before the collection phase, resulting scores from multiple cognitive rehabilitation contents and patients' personal information are saved in database. In the collection/storage phases, the patient information saved in the database is saved in bigdata platform. In the processing phase, the data are processed/refined in a necessary form to be utilized in the analysis and statistical processing program, R. Lastly, in the analysis/visualization phases, personalized contents of integrated cognitive rehabilitation training are recommended to patients using the K-Means method of the unsupervised learning algorithms and spiral model through patients' personal information, MMSE results, cognitive rehabilitation contents results based on the processed/refined data. Patients can utilize the personalized recommendation system for integrated cognitive rehabilitation training based on bigdata to implement cognitive function evaluation and personalized training at home.

Keywords: Cognitive rehabilitation · Bigdata · MMSE · K-MEANS

1 Introduction

Senile cerebropathia emerges a significant social problem amid the rapid population aging of Korean society [1]. Recent study reported that the cognitive function of the elderly has an effect on impaired functioning of daily activities, elevating social interest in cognitive function. Against this backdrop, study has been actively made on the rehabilitation treatment for senile cognitive function, which has been typically implemented in the clinical field, along with computer-based cognitive rehabilitation treatment [2].

Such a computer-based cognitive rehabilitation program has many advantages compared with the traditional cognitive rehabilitation tools [3]. First, the computer-based programs provide different difficulty levels in line with patients' ability for training personalization and, moreover, training contents and function can be easily amended.

Second, patients can follow training at home without accompanying a therapist and receive instant feedback through the program to correct erroneous responses. Third,

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through the program, patients can train their weak points continuously and repeatedly. Forth, the contents provoke patients' interest and active engagement. It is effective to maintain high-level patients' engagement. Fifth, patients' data on content implementation are objectively measured and managed; and, by doing so, patients' status and characteristics during their training are compared and analyzed to possibly apply to treatment plan [4].

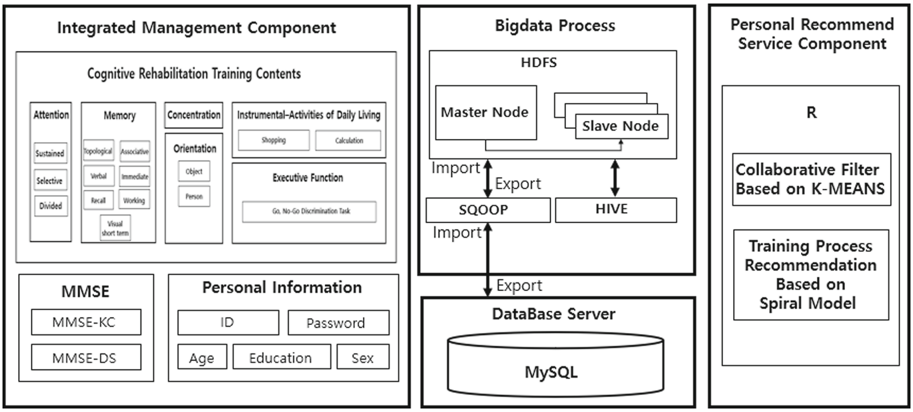
Since the results of cognitive training through a cognitive rehabilitation program could vary according to training application methods, any simple repeated training of computer-based cognitive rehabilitation could hardly help recover a patients' cognitive function [5]. For this reason, accompanying a therapist is indispensable and which increases financial burden, posing a financial limitation. In treatment for patients with mild cognitive impairment, continuity is significant. But the treatment going on presently in hospitals is implemented only for a short time. This is because of the spatial limitation that hospitals cannot accommodate all patients and temporal limitation that a guardian of a patient is affected in their daily schedule as he or she has to spare time to accompany a patient for treatment. To overcome these financial, spatial and temporal limitations, a personalized recommendation system for integrated cognitive rehabilitation training based on bigdata was established.

In this study, based on patients' personal information, MMSE results, and cognitive rehabilitation contents training results, bigdata was analyzed; and patient-specific personalized cognitive rehabilitation training course and content difficulty levels are recommended. Patients, based on the system propose din this study, can implement both personalized training and evaluation at home. Through the evaluation, they can not only detect the initial stage of mild cognitive impairment, but also follow personalized training programs to enjoy effective training.

2 Methods and Results

The personalized recommendation system for efficient integrated cognitive rehabilitation training based on bigdata proposed in this thesis was researched in order to overcome the limitations presented in the Introduction. The system contents have sophisticated structure of difficulty levels and automatically adjust difficulty levels through algorithm depending upon average response time and game training results. In this manner, the system can provide personalized training for each patient in real time, and, as the difficulty level moves up, train patients to maintain higher accuracy in detailed evaluation items such as color differentiation, location differentiation, etc. Training results consist of training time, number of responses, accuracy, response time, etc. and accessible by each desired date, allowing therapists, patients and guardians to easily check and understand for organized rehabilitation management. In this study, we compared and analyzed patients' status and characteristics during the training process, based on the study that treatment effective could be improved if the system understands a subject's cognitive ability; sets up a goal for his or her level in a phased manner; provides feedback when the goal is achieved to set up another goal in the next phase, rather than simple repetition of cognitive programs. In this manner, the system in this study identifies which cognitive ability a patient needs to improve and recommends appropriate training contents based on the spiral model so that patients can train themselves without the help of a therapist.

The overall architecture is structured with Integrated Management Component, Bigdata Process, and Personal Recommend Service Component as shown in Fig. 1. The Integrated Management Component consists of training contents package for cognitive training, evaluation package for evaluation, and personal information. Such information is saved in MySQL DB Server. In the Bigdata Process, the distribution framework for bigdata analysis, Hadoop EcoSystem was employed [6]. The Personal Recommend Service Component contains the analysis functions for personalization recommendation service and performs analysis in connection with Hadoop EcoSystem. Here, the Personal Recommend Service Component consists of Collaborative Filtering based on k-means module for data clustering and inference along with a module providing patients with the Training Process Recommendation Based on Spiral Model proposed in this study.



(a) Integrated Management Component (b) Bigdata Process (c)Personal Recommend Service Component

Fig. 1. Contents recommendation architecture based on bigdata

2.1 Integrated Management Component

As shown in Fig. 2, the cognitive rehabilitation training contents are classified under 6 high-level cognitive functional ability areas. Each area is divided into Memory, Executive Function, Concentration, Activities of Daily Living (ADL), Attention and Orientation. These areas are further divided into detailed training areas that include one or more training contents, respectively. Patients can follow training in a phased or complex manner from the lower-level detailed areas to high-level cognitive functions in this system.

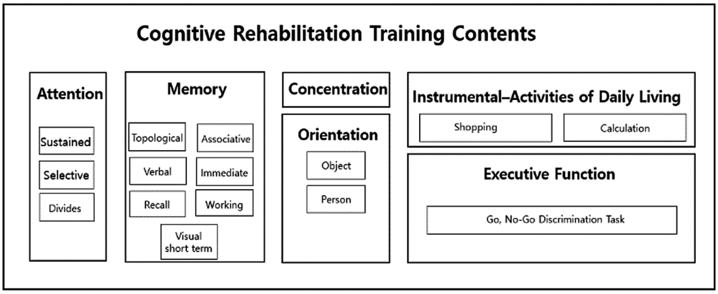


Fig. 2. Cognitive rehabilitation training contents

In this study, test is implemented based on the questionnaire of MMSE-KC (Mini-Mental Statue Examination - Korea Child), a Korean version of mini-mental status examination considering question item appropriateness and validity [7]. Then, each cognitive functional area is scored. This information is saved in Database Server (MySQL) along with patients' personal information (age, number of education years, sex, etc.).

2.2 Bigdata Process

Step 2 is to analyze bigdata using Hadoop EcoSystem. As shown in Fig. 1(b), this bigdata analysis process consists of collection, storage, processing, analysis and visualization. Then, based on the analyzed data, the system provides service. In the collection/storage phases, the data saved in Step 1 are pre-processed and collected through SQOOP. SQOOP is a tool to efficiently Import/Export large-volume data between the database system and the storage, Apache Hadoop HDFS (Hadoop Distributed File System). The tool imports patients' personal information saved in MySQL, contents training results, and MMSE results to Hadoop HDFS for bigdata analysis. HDFS is a distributed file system for Hadoop and useful saving tool for bigdata processing. HDFS consists of Master Node and multiple Slave Nodes to distribute load to multi nodes. In this manner, it not only makes up for the shortcoming of I/O-intensiveness and huge CPU consumption, but also makes Scale Out favorable.

In the Processing phase, HIVE is utilized to load data form HDFS to memory and process/refine them in the form necessary for analysis. HIVE is a tool processing SQL-based inquiry. Among patients' data saved in HDFS, personal information (ID, number of education years, age, sex) is inquired and processed through HIVE. Then in Step 3, Personal Recommend Service Component is employed to provide analysis/visualization service. In addition, based on the processed/refined data in Step 2, statistics and machine learning are implemented using Programming Language R and the analysis results are visualized in diverse graphs.

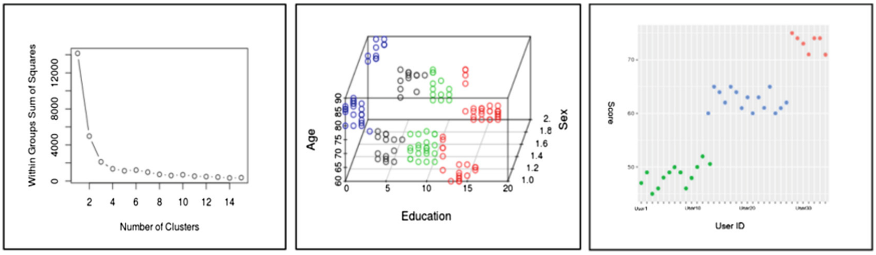
2.3 Personal Recommend Service Component

Personal Recommend Service Component is a bigdata-based recommendation component produced to provide personalized service to patients while avoiding simple repetition of cognitive rehabilitation training. The recommendation component, as in Fig. 1(c), employed Collaborative Filter Based on K-MEANS and Training Process Recommendation Based on Spiral Model. The Collaborative Filter Based on K-MEANS utilize similar personal information and patients with cognitive rehabilitation content results in order to predict the level and data of new patients or patients with not much information yet. Based on such prediction, Training Process Recommendation Based on Spiral Model is implemented for effective patient training.

Collaborative Filter Based on K-MEANS

Figure 3 visualized the analysis results of random data based on the MMSE average score distribution table. Figure 3(a) and (b) visualized the results of analysis algorithm utilized to predict the optimized number of clusters when clustering patient groups, showing change in the Within Groups Sum of Squares with increase in the Number of Clusters. The Within Groups Sum of Squares is calculated as in the Eq. (1);

$$\sum_{k=1}^{K}\sum_{i\in S_k}\sum_{j=1}^{P}(x_{ij}-\bar{x}_{kj})^2 \tag{1}$$

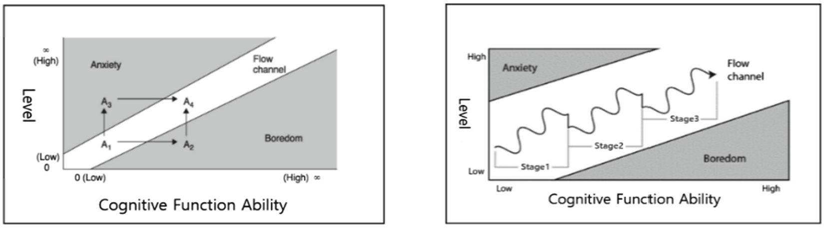


(a) Number of clusters (b) Personal information clustering (c)Result of cognitive rehabilitation contents clustering

Fig. 3. Data inference and clustering results (Color figure online)

S_k is the observed value of Kth cluster; $\bar{x}_{kj}$, Pth central point of variables; and x_{ij}, coordinate of data values. it is assumed that data set has K number of observed values for i number of variables. Initial center of cluster is randomly set up to implement the following steps; First, identify and randomly set up K number of clusters' centers. Second, if the distance between identified cluster and data is longer than that between another closest cluster's center and data, compare them and replace with the center of cluster with the shortest distance. Repeat the process. When reaching the maximum repetition number or change in within-cluster sum is smaller than the threshold in to consecutive times of repetition, repetition is ceased. Define the last updated cluster as the final cluster center.

In Fig. 3(a), it is found that the cluster with minimum change in within-group sum of squares has the central number of 4. Figure 3(b) is the number of clusters optimized in Fig. 3(a), visualizing by clustering patients' age, number of education years and sex into similar groups. They were classified into blue, black, green and red groups. The blue group represents patients aged 80–90 with 0–3 years of education; black group, those aged 65–80 with 3–6 years of education; green group, those aged 65–80 with 6–12 years of education; and red group, those aged 60–75 with 13–16 years of education. Figure 3(c) is the clustering of green-group patients' contents scores and the number of groups was set at 3. Then, based on such a group, the level and data of new patients or patients without much information yet are predicted by looking at other patients with similar personal information and cognitive rehabilitation content results using Collaborative Filter. In reflection of the prediction data, Training Process Recommendation Based on Spiral Model is implemented.



(a) Flow theory (b) Fractal pattern

Fig. 4. Spiral model

Training Process Recommendation Based on Spiral Model

Figure 4 visualized the spiral training model proposed in this study. it is found that a phased computer-based cognitive program is easy to use and allows personalized treatment for each patient according to their levels; thus, it is a suitable intervention method for treatment motivation reinforcement in patients whose treatment effect can hardly be generalized. Therefore, given the study finding that, when an occupational therapy program is provided in consideration of a patient's interest and ability, the patient can more concentrate on implementing the task; it is necessary to do the modeling of phased training structure through methods to apply computerized cognitive training to the clinical field as well as diversified study on motivation. The spiral model proposed in this present study allows to set up training order and training difficulty level and, to motivate patients and encourage interest and immersion into training, Csikszentmihalyi's Flow Theory and Jesse's Fractal pattern were applied [8, 9].

In this study, in order to set up the order of training, Flow Theory as in Fig. 4(a) was employed. The X axis represents a patient's cognitive functional ability; and Y axis, the difficulty level of challenge. Flow Channel means the status of immersion flow. In Fig. 4(a), A1 represents indifference; A2, boredom; A3, anxiety; and A4, flow. They respectively mean the status when a challenge difficulty level is low and patient ability is also low; when the ability is high but challenging spirit is low; when a challenge difficulty level is high, but ability is low; and when a challenge difficulty level is appropriate for ability. in this present study, A1, A2, A3 and A4 were repeated to maintain patients' flow status and, to stimulate their interest, Flow Theory-applied training process was modeled. For instance, if a patient's attention, of his or her cognitive abilities, is low, orientation is low, memory is high and concentration is high; low-difficulty attention content, low-difficulty memory content, high-difficulty orientation content and high-difficulty concentration content are recommended in order. Moreover, in modeling contents difficulty level, Jesse's fractal pattern based on Flow Theory was applied to provoke patients' spirit of challenge.

In lower stages, difficulty levels are set very low. Although this means indifference in Flow Theory, such a low level was intended in training content design for the tutorial purpose so that patients can become sufficiently familiar with the new rules. After that, the difficulty level gradually elevates from the point where the patient is expected to have acquainted themselves with the rules. Then, the difficulty level moves down at the point of stage change to provide new time to adapt themselves to changed rules, giving the impression to patients that their ability has improved. Such a practice could have a positive effect on patient motivation and induce active engagement of patients. In the graph, one period means one stage and patients' spirit of challenge can be reinforced by arranging tasks in relatively higher-than-average difficulty level in the middle. Or placing relatively lower difficulty levels give patients mental relaxation to ease their tiredness and reduce their sense of burden.

3 Conclusions

Computer-based cognitive rehabilitation programs have many benefits, compared with the conventional cognitive rehabilitation instruments. However, recently, such computer-based cognitive rehabilitation training faced limitation that simple training repetition cannot effectively help recover patients' cognitive function along with its financial, spatial and temporal limitations. This study, to overcome such limitations, employed 2 different approaches. First, to address the financial, spatial and temporal issues, we established a recommendation system for integrated cognitive rehabilitation training based on bigdata so that patients can training and evaluate themselves on their own at home using the provided contents. The contents in this system consist of highly sophisticated difficulty level structure. According to average response time and game performance results, its algorithm automatically adjusts the difficulty levels to require high accuracy maintenance in detailed evaluation items. Such training results consist of training time, number of responses, accuracy and response time; and accessible by desired date, allowing therapists, patients and guardians to easily check and understand for systematic rehabilitation management. Second, in order to overcome the limitation that simple contents repetition can hardly improve cognitive function, we employed the spiral model in the training process. Patients' status and characteristics found in training were compared and analyzed based on study that treatment effectiveness could be enhanced when a subject's cognitive ability is assessed, goals for his or her level are set up in a phased manner, provide feedback when the set goals are met, and set up next-stage goals. According to the conclusion that a patient can more concentrate on given task performance when occupational therapy is presented in consideration of the patient's interest and ability, Csikszentmihalyi's Flow theory was adopted in the training process to induce immersion flow through motivation and interest. In addition, Jesse's fractal pattern was utilized for the modeling of training process with appropriate difficulty level arrangement.

We worked to not only stimulate patients' challenging spirit but also provide mental relaxation to help ease their tiredness and sense of burden. In this manner, the training was designed for patients to follow continuously.

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Virtual Environment for the Treatment of Patients with Hemiparesis

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Abstract. This paper proposes the development of a Virtual Environment that facilitates the process of reeducation of the motor and sensory functions of a patient with hemiparesis, through the simulation of physiotherapy exercises. The methodology used for the development of the work was as follows: a characterization of the variables that affect patients with hemiparesis was realized, analyzing the factors that cause this condition, for the determination of the bases of the Virtual Environment; later a model of Virtual Reality Environment was designed that allows the interaction with the patient for its later implementation using a video game engine that leads us to obtain a prototype of applicability in the rehabilitation of patients. Finally, the results are validated with experts in physiotherapy using system tests to verify the rehabilitation of patients with hemiparesis, reviewing the acceptance criteria of the prototype.

Keywords: Hemiparesis · Virtual Environment (VE) · Rehabilitation Physiotherapy · Kinect

1 Introduction

A Virtual Environment is a graphic representation of a real-world model that is achieved through a rendering process, where a 2D image is generated from a 3D image [1]. On the other hand, Hemiparesis refers to the decrease in motor force or partial paralysis that affects an arm and a leg on the same side of the body. This condition can result from strokes (affecting the blood supply of the central nervous system such as: brain, cerebellum and spinal bulb). It is noteworthy that Hemiparesis deserves special attention within the field of physiotherapy due to the disability problems it causes in the patient and has characteristics in common with Hemiplegic (paralysis of one side of the body) that can also result from this type of accidents [2].

New technologies in the field of health represent a great contribution to the improvement of people suffering from brain injuries, which is why the development of a Virtual Environment (VE) is planned to facilitate the process of reeducation of functions motor and sensory features of a patient with Hemiparesis, through the simulation of physiotherapeutic exercises.

Based on the foregoing, this environment aims to encourage and improve the patient's environment, so that discipline is originated in therapy, thus providing a

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comfort zone, where the individual feels motivated to develop the exercises and recreates a set of enjoyable activities, which usually develop in a monotonous way.

This document is organized as follows: in Sect. 2, the characterization of the variables that affect patients with hemiparesis is presented; in Sect. 3, the design and implementation of the VE is detailed; in Sect. 4, the experiments and results are presented; and finally, the conclusions and future works are exposed.

2 Characterization of the Variables that Affect Patients with Hemiparesis

During the investigation, the variables related to this condition were analyzed, such as: the different factors and techniques for the diagnosis and treatment of a patient where the most marked symptom is Hemiparesis. Bobath [3] mentions that there are some special aspects and problems suffered by patients with this condition, such as:

- Body divided: The patient's body seems divided into two halves and one of them has nothing to do with the other.
- Postural tone: The postural tone of both sides is different. At the beginning the patient is limp and seems too weak to move the leg or arm.
- Relearning: The patient does not know how to move. You must relearn how to turn in bed, how to sit and lie down, how to stand, stand and walk.

Before starting the treatment, previously a Neurologist must have made a diagnosis to be later evaluated by the physiotherapist, in such a way that he can initiate a treatment; The first thing is to evaluate the level and capacity of the patient to perform certain exercises.

Given that Hemiparesis has characteristics similar to Hemiplegia (paralysis of one side of the body), Moreno [4], shows how it is a treatment of a patient with Hemiplegia (paralysis of one side of the body), where techniques are defined, which they are established depending on the recovery stages in which the patient is located, or the process in which the improvement has been stopped. These stages are:

1. Initial stage or stroke: in this phase it is possible to determine which hemisphere is affected, but its scope is unknown, it can take minutes, hours, days, months, etc.
2. Flaccid Stage: according to the affected hemisphere in this phase there is clear evidence of inhibition or flaccidity in the hemibody, such as, for example, the fallen shoulder. If the patient does not adequately control the neck, upper and lower trunk, it hardly controls the upper and lower trunk, thus passing to the next stage.
3. Stage of spasticity: if the patient reaches this stage it is because he managed to overcome the flaccid phase thus improving his reflexes a bit, but at this point, he may have muscular contractures so the activities must be adjusted to improve muscle tone to normal levels.
4. Relative recovery stage: to fight against the consequences that can occur due to the condition suffered, is the main objective of this stage, as well as to continue improving the functionality of the person so that he has the greatest possible autonomy, establishing a series of sessions and exercises.

This is why, in the developed Virtual Environment, the epicenter is located in stages 3 and 4 of Hemiparesis on the recommendation of an expert in physiotherapy, which indicates that in these stages there is already a diagnosis, a treatment started and with an initial advance, where the patient can train movements and responses, helping to strengthen their motor skills through software.

Fernándes [5] proposes a program of physiotherapy exercises for the rehabilitation of patients with Hemiplegic, which can also be applied for Hemiparesis in primary health care. Based on the variety, which are both for the treatment of the lower limb and the upper limb and that can be performed in the comfort of the house independently, although it is always suggested to be in the presence of a responsible adult, the following exercises are selected: for lower and upper limbs, according to Fig. 1.

Fig. 1. Selected exercises: for lower and upper limbs [5]

In the characterization carried out, the variables that can lead to the Hemiparesis condition were analyzed, as well as the stages by which a patient must pass to have a recovery. In order that the patient has interaction with the VE, the physiotherapeutic exercises are simulated and a pleasant environment is developed where the patient performs the exercises in a more dynamic and entertaining way that allows to continue, with the recovery process developing greater interest when interacting with the VE.

3 Development of the Virtual Environment

The VE design is performed, based on the characterized physiotherapeutic exercises and after that, a comparative analysis of the devices was carried out, to determine the most suitable for the detection of the patient's movements. Based on the above, the Kinect device was chosen, since it does not require controls, as well as, because of the possibility of detecting complete bodies and their movements due to the fact that the device has an RGB camera, also, it has a depth sensor that jointly allows to create a 3D map and the capture of the movement of the bodies.

The sensor has a limitation and consists in that being placed in a static position, it does not detect the complete movements of the body and all the extremities when it is located laterally, therefore exercises are chosen that allow the patient to be front or back to the sensor. One of the advantages of Kinect is that it is economically accessible for anyone.

To realize the design of this VE, we opted to use the methodology of video game design SUM [6]. The methodology aims to obtain predictable results, efficiently manage resources to achieve high productivity of the development team; It was designed to be adapted into small work teams and for short projects. This methodology was used, taking into account designs of attractive environments, characters and elements that allow interaction and entertainment with the Virtual Environment, because it aims to develop quality video games in low time and cost, as well as the continuous improvement of the process, to increase its effectiveness and efficiency.

With this methodology it was possible to evaluate the progress of the work, which allowed to realize changes in time and make decisions to comply with the planned deadlines. In addition, the experience gained allows to improve the way of working in each activity and increase productivity.

The software used are: Unity because it allows to use it in conjunction with other 2D and 3D design platforms; Flash for its ability to create animations with special effects and professional graphics; and Blender, for its capacity of modeling and animation, for the creation of video games.

For the construction of the bases of the prototype, Lanning [7] proposes a series of items, which must be developed for any design methodology in a Video Game. Supported in this, the configuration items, characters and environments, problems, resolution/objectives and actions were identified.

In the simulation, the patient performs exercises with the amount of repetitions that the physiotherapist previously recommended to the patient. The patient will observe a virtual trainer who will indicate the exercises to be performed. The Kinect detects the movements made from these exercises and simulates them through an avatar.

The chosen environment is a natural landscape, to reflect an open and calm space. In addition, there are some types or musical genres that can motivate people to perform exercises, therefore, music is included for the patient to feel motivated. Because it is intended that the patient enjoy the exercises.

In the design, 3D technology features were incorporated and taking into account the characterization, environments and characters were simulated that give a different focus to the environment in which the patient is, allowing the immersion and interaction with the simulated environment; in this way, it allows the patient to feel attracted to perform the exercises and complete the repetitions according to what was proposed by the physiotherapist.

3.1 Implementation of the Virtual Environment

Moncada and Mateus [8], highlight the use of video game engines for the creation of simulators and games, which are also tools that have allowed the design and rendering of contents based on 2D and 3D technologies, as well as providing environments that adapt to the needs of the game or its objectives, introducing elements of the engine for interaction with the platform, known as Assets, which contain all export models for the construction of animations, sounds, scripts, characters, among other contents.

Unity was selected as a tool for the construction of the animations and content in the video game prototype, since it provides all the necessary elements, such as: open spaces, land, textures and prefabricated models, which were taken into account for the development of each challenge and the necessary coding in order to achieve the objectives proposed in the work.

The Kinect Windows Software Development Kit (SDK) was used to create applications using Kinect sensor technology (for Windows 8, Windows 8.1 and Windows Embedded Standard 8), allowing the recognition of gestures and voice through C++, C#, Visual Basic or any other.NET language; in this specific case, C# was used. The integrated development toolkit includes sample applications with access to full source code, Kinect Studio and resources to simplify and accelerate application development, which was indispensable for VE development. This was downloaded from the Asset Store that comes in Unity for free.

In order to create the animations and contents of the VE prototype, to achieve the proposed objectives and to have a clear definition of the technical factors; Unity Software, was used to create the scenario (terrain, open space), movement of the characters and menu; while with the help of Software Blender, prefabricated models were implemented as characters and animations of them.

The VE for its execution requires few requirements in terms of video and processing, for which the rendering and performance properties were key points in its development.

- Main menu: A main menu has been designed that allows the selection of repetitions for the exercises as well as the start and exit options of the VE.
- Music Player: A rhythmic music player is designed on the main screen with the intention of motivating the patient and generating extra energy so that he is comfortable and can also practice the exercises driven by music. This includes buttons to play/pause, next and previous.
- Simulated Physiotherapeutic Exercises: The patient must initially choose the number of repetitions to perform in the session, before beginning to use the VE.

For the VE were implemented 3D objects that allow the movement of an avatar with the movements performed by the patient, the Kinect through the sensors throws information on the position of each of the limbs of the person in front of it, so that the information can be manipulated from a programming language that uses the SDK libraries.

In addition, the environment has a coach in which previously the movements that are executed have been created until the patient completes the exercises or wishes to move to a new one (to pass the exercise without completing the repetitions the patient must raise one of their two hands above the head) the screen where the avatar of the virtual trainer and the patient is located is shown in Fig. 2.

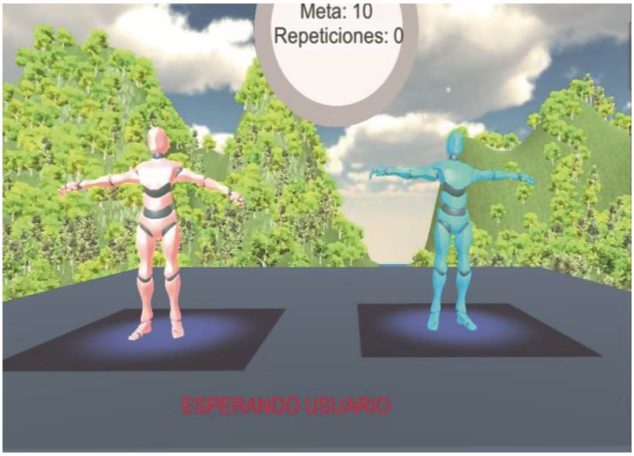

Fig. 2. Main view VE.

Based on the implementation, flexibility can be observed in the handling, export of 3D objects through the Unity Engine and integration with other tools, allowing to maintain an appropriate control for the coding of the necessary movements; likewise, the configuration required for the rendering of built environments does not require high levels of performance for the computer.

4 Experiments and Results

For the validation of the model, surveys were realized to experts, to a patient and not patients; On the one hand, the experts can consider, if the model and the VE are adequate and give the expected results; on the other, the patients are the people who benefit directly from the VE and also determine when interacting with it, if it is appropriate and of their liking. The surveys were conducted after these people interacted with the created VE.

4.1 Results of Surveys of Patients and Non-patients

The VE prototype is viable because patients find a new way to complement their treatment, whether implemented in consultation with the physiotherapist or at home, feeling attracted by the VE, dynamism and entertainment, with many benefits in the future. In addition to this, they found the VE of easy interaction and manipulation as a complement to their treatment to remember the exercises to be performed and how to perform them.

In Fig. 3a we observe a person who does not have this condition using the prototype, however, this person has interacted with a relative who suffers from hemiparesis, so he understands very well how is the treatment for these patients. In Fig. 3b a patient can be observed using the prototype.

a. b.

Fig. 3. Validation a. with non-patient user, b. with a patient.

4.2 Results of Surveys of Experts

The VE prototype is viable in an initial process of treatment for stages 3 and 4 (Spasticity Stage and Relative Recovery Stage) because patients constantly need to perform exercises with the amount of repetitions previously recommended by the physiotherapist and for this, it is not enough to only perform them in the consultations but also at home, so the VE serves as a complement to the treatment to be dynamic, as well as easy to manipulate, it is an option for the patient to feel attracted to execute the exercises.

5 Conclusions and Future Works

The Virtual Environments have been of great help in the field of medicine and physiotherapy, since it has been implemented in several areas with satisfactory results, both for the treatment of phobias, as well as diseases and physical conditions.

During the development of this work, it was necessary to investigate how patients can develop the condition of Hemiparesis and developed EVs, finding implementations of these in favor of reeducation, motivation and improvement of motor skills, which allowed to determine the video game engine to be used, the characteristics and the exercises to simulate.

It is for this, that, counting today with a variety of devices, motors of video games and tools with specialized features, can facilitate the construction of software for treating various diseases, illnesses and phobias, motivating the patient to perform the treatments when offering a practical alternative.

The VE prototype can be used as a complement to traditional physiotherapy, since it can define to the patient the number of repetitions to be made, either in consultation with the expert or in the comfort of the home.

As future work, it is possible to deepen and create a protocol (rules) for the patient's condition, in this way that is more personalized, because the rehabilitation process depends on the individual's progress. Therefore, it also considers the integration of other devices that allow greater interaction with the environment and, in turn, a greater sense of immersion.

The creation of virtual environments in areas of health and psychology among other areas is also proposed, where it will generate greater interest for the execution of certain activities in patients.

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Towards the Development of a System for the Support of People with Visual Disabilities Using Computer Vision

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Abstract. The visual impaired people requires being as much independent as possible to navigate indoor environments. The mobility of this kind of people is difficult and several times requires a companion. Therefore there are several methods for object detection and recognition based on computer vision techniques. This work proposes the use of these methods in the context of accessibility for people with vision problems.

Keywords: Accessibility · Blind navigation · Artificial vision

1 Introduction

According to WHO (World Health Organization) [1], in 2010, 39.365 million of people suffered blindness and there were 264,024 million people with low vision in area of the Americas (Central and South America) 3,211 million (8%) were blind and 23,401 million (9.5%) with low vision. Vision is one of the main ways humans develop most of their daily activities, due to that, people with affected eyesight suffer various difficulties dealing with everyday activities. Although governments and public agencies in different cities have implemented systems that include Braille and RFID (Radio Frequency Identification) labels in main sites to orient blind people, these methods are not widespread and not effective in all cases. As a result in most cases blind people depend on a companion to move towards their work, home or any indoor environment. Relying other methods in many cases is not feasible or practicable, for lack of time or resources. For this reason these people seek to be as independent as possible in order to integrate and become part of society. There are several applications that help navigation and mobility of people with visual disabilities [2–5], that can be divided into navigation support indoor and outdoor spaces.

Additionally, there are other methods based on the generation of mental maps for navigation using step to step actions in a virtual environment using portable devices [6].

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2 Developed Process

A system for support of people with visual disabilities must consider a set of different kinds of sensors, which provides as much as possible information about the environment. Such as a unit of processing (i.e. a companion computer), a method for feedback (tactile or auditory) and a correctly developed interface that receives the user commands and manage the inputs of sensors to return the required information to the user. In this work, a part of the whole system is presented, this part is composed of a visual system based on computer vision techniques. The computer vision techniques are in charge of detect objects of interest in the environment as signs that indicate which is the place where the user is located. For this purpose a machine learning method is used for object detection using a dataset obtained in first instance from a camera. In this stage a ROI (region of interest) is obtained. After that, a color based segmentation is used to improve the detection. Since the vision system obtain images with perspective distortion, a homograpy is computed in order to get a rectangular sign. Then, an implementation of OCR (optical character recognition) using neural networks is employed to obtain the data of the sign. After that, the information is processed in order to give a response to the user using a text to speech component.

3 Methodology

In the first stage a set of 50 images with resolution of 8 megapixels were obtained. These images allowed to test the system. The dataset different features that includes, images taken from different point of view, background and sign color as can be shown in Fig. 1. For the implementation of the system, the OpenCV library was used.

3.1 Object Detection

An object method based on HOG descriptors [7], that are computed by a sliding window is implemented for sign detection; the classifier is a support vector machine as is shown in Fig. 2.

3.2 Irregular Quadrilateral Recognition

After the sign detection, it is necessary to find the corners of the sign in order to apply a homography. This is done by computing the closest distance from the detected corners to the frontiers of a bounding rectangle as it is shown in Fig. 3.

The corner detection is necessary to specify a set of points that permits to create homography, the results are shown in Fig. 4.

(a) 1 (b) 2 (c) 3

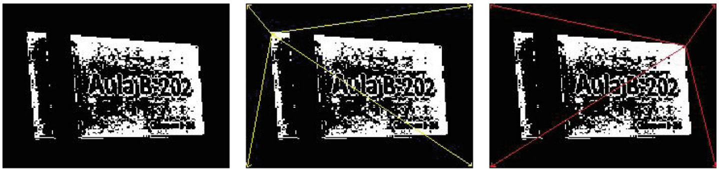
(d) 4 (e) 5 (f) 6

(g) 7 (h) 8 (i) 9

(j) 10

Fig. 1. Some examples of the initial dataset. (Color figure online)

Fig. 2. Object detection.



(a) 1 (b) 2 (c) 3

Fig. 3. Corner detection method.

(a) 1 (b) 2 (c) 3 (d) 4

(e) 5 (f) 6 (g) 7 (h) 8

(i) 9 (j) 10

Fig. 4. ROI detected and corrected.

(a) 1 (b) 2

Fig. 5. OCR process.

3.3 OCR Stage

It was necessary to use a database of characters in order to train a classifier that is able to recognize the characters that appears in the rooms signs. Before the optical character recognition (OCR) it is necessary to process the image in order to improve the contrast and binarize, obtaining a simplified input to the system as is shown in Fig. 5.

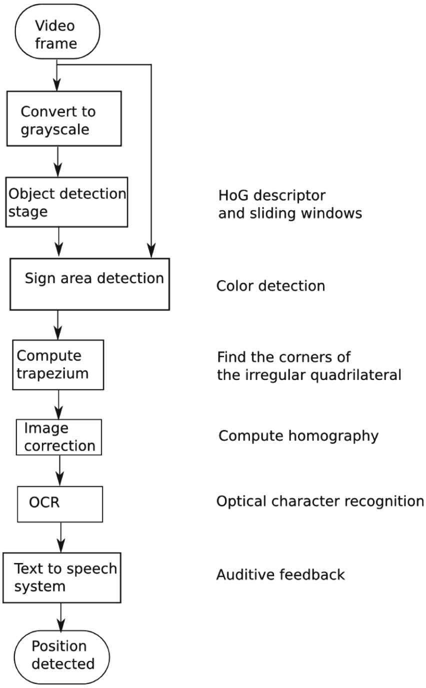


Fig. 6. Proposed process.

4 Results

After the object detection stage, the system is able to isolate the image of the sign using an image processing method, due to corner detection method a segmented rectangular sign is produced. A method for perspective correction based on homography is employed with good results. The proposed process is shown in Fig. 6.

5 Conclusions and Future Work

The actual system allows to distinguish the area where the signs are located inside the walls of the building. Moreover, it permits to detect the characters included in the sign.

In addition, a connection with a text to speech system is able to communicate the information to the blind user in an auditory feedback.

The study and development of an interaction method that improve the usability of the system is proposed as a future work.

Also the semantic relations that can be present in internal environments could be explored as a future work in order to improve the system.

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A Gesture Elicitation Study with Visually Impaired Users

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Abstract. Despite active research in input device development, the visually impaired community still find difficulty in interacting with computers. Braille and other conventional methods have limitations while inputting data to the computer due to their vision loss. Gesture-based interaction can offer them a new vista of computer interaction. However, one needs to consider their performance and preference towards hand gesture. So, a gesture elicitation study is done with 25 visually impaired users. A quantitative rating analysis is performed with them, and an optimal set of gestures is obtained. Further, a dactylology is proposed using which visually impaired users can interact with computers. In this work, we present an insight on the gesture selection method and reveal some key facts about the optimal gestures.

Keywords: Human-computer interaction · Gestural input
Visually impaired

1 Introduction

Gesturing is a natural phenomenon that is found even in individuals who are congenital blind [1]. Interaction using gesture is becoming more and more popular day by day. It provides a more natural and comfortable means of interaction. Recent advancement in gesture recognition algorithms and low-cost hardware development had made it possible to use gesture commands to interact with computer and other consumer electronics. Despite active research in gesture-based interaction and related user-elicited studies, much attention is needed to include visually impaired users [2]. It is equally important for them to interact with computers. The sighted user provide input using mouse and keyboard. However, visually impaired users find it difficult to use them effectively.

Keyboards like e-Brailler, SMART Brailler, etc. are available in the market to assist them. However, facts reveal that only 8–9% of visually impaired students in the United States use Braille [3]. The majority of their population (∼90%) lives in developing countries where the Braille literacy rate is as low as 3%. Hence, solutions based on Braille are not so popular for computer interaction [4]. Apart from Braille, interaction using data gloves is also proposed in the literature.

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But the data gloves approach needs the user to wear a special device which hinders the naturalness [5]. Speech processing is ineffective for the mentioned purpose as it depends on accents, dialects, and mannerisms [6]. Even, systems based on EEG are unsuitable because the received information is noisy and ambiguous [7]. Handwriting recognition via smartpens seems to be a potential technique. However, the letters like f, i, j, t, x, consists of two strokes wherein the second stroke is referential to the first stroke (dotting the j's and crossing the f's). Further, locating precise spots on the touch screen surface can be very difficult for visually impaired. Research [8] confirms that visually impaired users can draw and make some gestures on touchscreens with more or less difficulty. They face severe issues with form closure, line steadiness, location accuracy while drawing gestures [9]. Consequently, it is complicated for them to learn and use handwriting [10].

Fingerspelling in American Sign Language (ASL) or its subset have been used extensively in many HCI applications. However, these fingerspelling signs were devised with deaf and mute users. Visually impaired users do not know sign language. Additionally, they feel difficult to use it. Past studies [11] have suggested that including the target users in the gesture elicitation study will increase the usability of the system than just using gestures of ASL. Hence, a study [2] is performed with visually impaired users. Based on which a dactylology [12] is proposed for them to interact with computers. Work in [12] primarily focuses on the recognition aspect of the dactylology.

Before we proceed further, it is important to clarify the motive behind this work and its difference with that of the [2]. The motive of this work is to fill the knowledge gap and provide insight on gesture elicitation study with visually impaired users. Some of the key points are listed below.

– In this work, we explicitly answer following questions about the gesture elicitation study.
  - What design aspects/criterion are considered for the selection of optimal gestures?
  - How & why these set of gestures are further categorized into two-tier?
  - Which gestures are mapped to the most commonly used keys of the computer keyboard and why?
  - How is cognitive load reduced?
– Detailing of ergonomics aspects which were considered while performing the gesture elicitation study.
– Limitations and issues faced while the gesture elicitation study is also discussed.

The remainder of the article is organized as follows. Section 2 discusses the gesture elicitation study. Section 3 presents a glimpse of dactylology. Section 4 presents the result and discussion while Sect. 5 presents conclusion and future work.

2 Gesture Elicitation Study

The sense of touch in a visually impaired is stronger than normal vision. Hence, a tabletop set-up is provided in the proposed system. This set-up facilitates haptic feedback and support to the arms. One of the vital questions is what type of gesture should be used. Previous research shows that finger-based gestures cause less fatigue and are more comfortable as compared to arm-based gestures [13]. Visually impaired also find finger-based gestures are easy. Hence, only finger-based gestures are investigated in this work.

A finger is considered to be either in extension- or flexion- state. In extension state, the particular finger is stretch out, while the flexion state involves folding of the finger. We have assigned a number to each finger, i.e. thumb $\rightarrow$ 1, index $\rightarrow$ 2, middle $\rightarrow$ 3, ring $\rightarrow$ 4, little $\rightarrow$ 5. The naming convention of gesture used in the study consist of letter G that resembles gesture followed by the number of finger(s) in the extended state, e.g. G15, G2345, etc. G15 means a gesture with the thumb (1) and little (5) fingers in the extended state. Similarly, G2345 means gesture with index (2), middle (3), ring (4), and little (5) fingers in the extended state.

With the help of 5 fingers, 31 possible gestures can be formed. These gestures are divided into 5 classes. Here, a class is the set of gestures with an equal number of extended fingers. It is found that not all the possible 31 gestures are comfortable to the user. The physiological constraints and interrelation between joints of the finger cause fatigue. It is crucial to find gestures that are optimal for visually impaired users. Therefore, we performed a gesture elicitation study with 25 visually impaired participants. These participants were graduate students (avg. age $\simeq$22) with no prior gesture posing experience. While acquiring gestures, participants were asked to settle down themselves in a relaxed position. We have ensured that participants keep their forearm flexed with elbow at 90°. Additionally, there should not be any bent in the wrist as shown in Fig. 1.

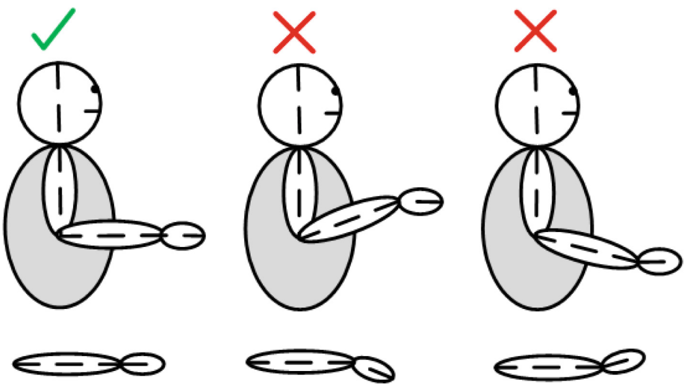

Fig. 1. Illustration showing correct hand posing based on ergonomics.

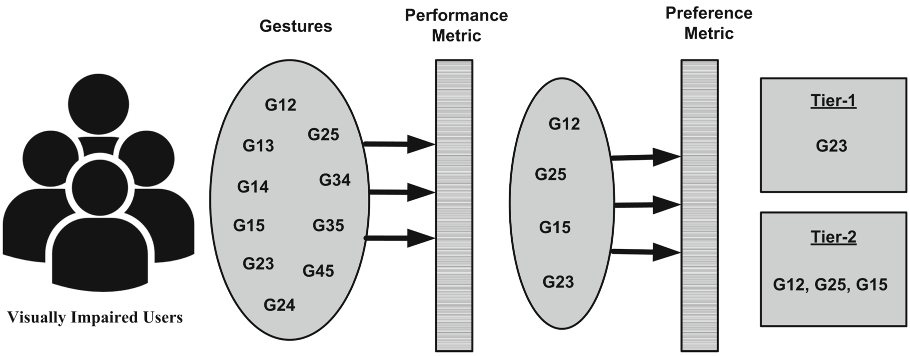

Fig. 2. Illustration of gesture selection method.

The forearms and wrists should be kept in-line with the shoulder to provide a comfortable experience to the participants.

Two important metrics—performance & preference—are considered to choose optimal gesture. Illustration of gesture selection method is shown in Fig. 2. In the first stage, optimal gestures are obtained on the basis of the performance metric. In performance metric, a user is asked to form a gesture and evaluate it on four subjective criteria defined as below.

- Easiness: A parameter to figure out the fatigue [14] while executing/posing hand gestures.
- Naturalness: It is a parameter which considers the likeness of the gesture being used in natural everyday human behaviour [15].
- Learning: Through this [14] criterion, we try to figure out whether a gesture can be learned and adopted.
- Reproducibility: A parameter to measure the reproduction ease of a gesture. We considered fist to be neutral pose and asked participants to repeatedly (4 times) produce the gesture from fist and finally, rate the gesture based upon its reproduction easiness.

The rating is done on a scale of 1–5 using a Likert scale. The overall rating of a gesture is calculated by finding the sum of all the criteria. Performance metric is obtained as the median of the overall rating. This is depicted as bar plot in Fig. 3(a). Gestures with the performance metric greater than 32 are considered to be optimal. Among the possible 31 gestures G1, G2, G5, G12, G15, G23, G25, G123, G125, G234, G345, G2345 and G12345 are found to be optimal. In preference metric, users are requested to pose gestures and ranked them based on their preferences. It should be noted that gestures are ranked on an ordinal scale within its class only. A preference index P_i is calculated using these preference ranking whose result is furnished in Fig. 3(b).

The above mentioned optimal gestures are further categorized into two grades: tier-1 and tier-2 gestures. Each class has a gesture with the highest

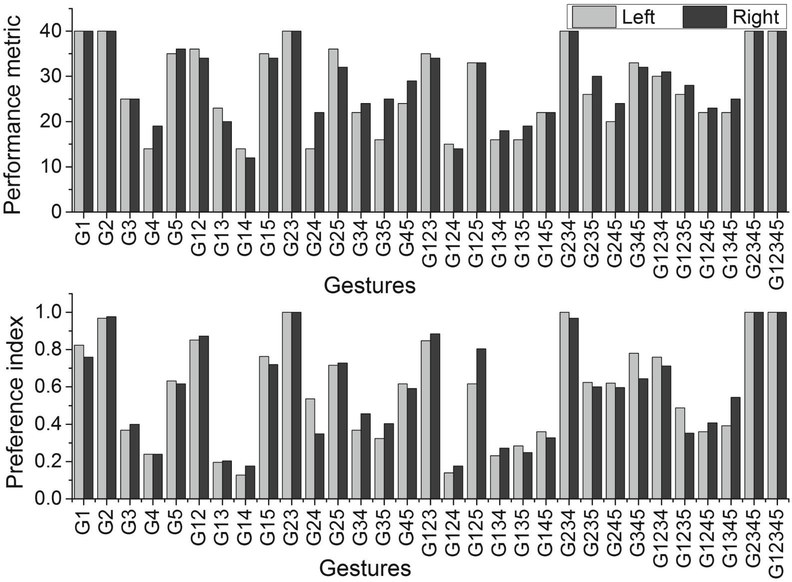

Fig. 3. Performance and preference metric (a) performance metric (b) preference index.

preference index which is included in tier-1 grade. Let us consider a class-2 case shown in Fig. 2. It can be observed from Fig. 3(b) that gesture G23 has the highest P_i among class-2 gestures. Rest gestures of class-2 (i.e. G12, G23 & G15) are included in tier-2 gestures. Similarly, analyzing other class, gesture G2, G23, G234, G2345, and G12345 are found to be categorized in tier-1 grade. Rest of the optimal gestures are considered as tier-2 grade gestures.

3 Dactylology

The dactylology [12] uses tier-1 gestures to map alphabets and numbers. It uses a combination of left and right hand to produce alphabets while single hand (i.e. either left or right) is used to produce numbers. The combination is formed according to the Table 1 as depicted in Fig. 4. Character A in the matrix is an element of the first row and the first column. The symbol for character A is formed by the combination of the left hand with one finger and right hand with one finger. Similarly, other symbols for remaining alphabets and numbers can be formed as shown in Fig. 4. The word is formed by concatenating the subsequent symbols. The dactylology illustrated in Fig. 4 is reproduced for the completeness and understanding of the article. For additional details, please refer to [12].

Table 1 Matrix

	Col-0	Col-1	Col-2	Col-3	Col-4	Col-5
Row-0	-	6	7	8	9	0
Row-1	1	A	B	C	D	E
Row-2	2	F	G	H	I	J
Row-3	3	K	L	M	N	O
Row-4	4	P	Q	R	S	T
Row-5	5	U	V	W	X	Y

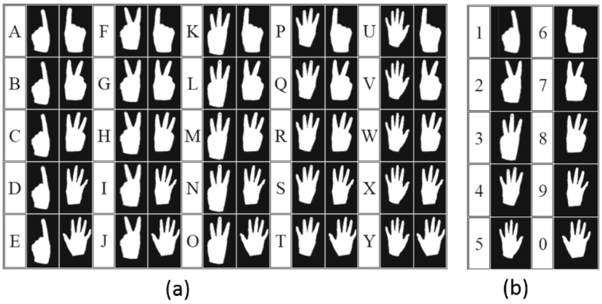

Fig. 4. Left: illustration of the matrix. Right: dactylology (a) Symbols for alphabet, (b) symbols for number. (©2017 Kishor Prabhakar Sarawadekar and Gourav Modanwal. All rights reserved)

4 Result and Discussion

The primary motive of this work is to provide detailed insight on gesture selection methodology considering visually impaired users. The study is done with 25 visually impaired participants. In this work four subjective criteria: easiness, naturalness, learning, and reproducibility are used. Users rated each gesture on a scale of 1–5 using a Likert scale. Performance metric of each gesture (refer Fig. 3(a)) is obtained from the user's responses. This metric indirectly tells about the goodness factor of the gesture. Based on the performance metric, an optimal gesture set is obtained.

The obtained optimal gestures of each class contain a gesture which is better than the others. In order to obtain the best gesture of its class, we calculated the preference index (refer Fig. 3(b)). Now the obtained optimal gesture set is categorized into two-tier grade. Tier-1 gestures are those gesture which has the best preference index among its class. Rest are Tier-2 gestures. The benefit of having two-tier gesture among the optimal gesture facilitate the option of mapping the most commonly used keys of the keyboard to tier-1 gesture. These are the most preferred gesture among the obtained optimal gesture set. More than 200 symbols can be created using tier-1 and tier-2 gestures. However, these symbols are required to be mapped to keys of the keyboard through a gesture command matching study.

Cognitive load is another vital parameter in the development of gesture set for a large set of task. Since a participant can remember 5 ± 2 gestures in short-term memory [16]. Hence, the number and type of gesture must be carefully chosen. The aforementioned cognitive load is reduced by reusing similar gesture under a different context. The reuse is done on the basis of the matrix shown in Fig. 4. This reuse of gesture will not only reduce cognitive load but also facilitate a larger set of the tasks with a smaller number of gestures.

5 Limitations/Issues Faced

We faced some issues during data collection. Few participants were unable to complete the study in one session. The remaining part of the study was done on the subsequent day. This may affect the ratings by the users. However, we have ignored this factor in the present study.

All the participants were male with average age $\simeq$22 years. School children and female participants were not considered in this study as there were issues while obtaining ethical approvals for them. It will be important to understand their view on an optimal gesture selection.

When analysing the questionnaires response, we came across the problem of treating Likert scale as either ordinal or interval. It is a long-running dispute. We have treated it as ordinal scale and computed the median of the overall score obtained as the sum of all criteria.

6 Conclusion and Future Work

In this work, we present insight and discussion on the gesture selection method. Based on the outcome of the quantitative rating analysis with 25 visually impaired participants, an optimal gesture set is devised. Further, a novel dactylology is proposed for them to interact with computers. Real-time experiments are also performed with visually impaired users, and motivating results are obtained. Clearly, further research work such as mapping of remaining tier-2 gestures, finding the effect of handedness, analyzing cognitive load, comparison with existing methods, etc. are required.

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Text Vocalizing Desktop Scanner for Visually Impaired People

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Abstract. There are many devices and applications dealing with text vocalization and some of them are easily accessible and implemented in mobile devices. These apparatuses are used to enable the access of visually impaired people to texts (without figures), in native or foreign language. However, there are too few devices that meet the deformity correction (typical of books), and picture improvements (enhancing the performance of the vocalization) requirements and low cost, really matters if the target group is found in the public Brazilian schools. From a domestic point of view, there is a gap in the products that fulfill these requirements. This work presents the development of a device that contributes to the autonomy of visually impaired people during their books and common documents reading. The equipment implements an Optical Character Recognition (OCR) process converting the textual content into speech, without the use of a computer, performing the task in an autonomous mode.

Keywords: Vocalizing desktop scanner · Assistive technologies
Visual impairment

1 Introduction

According to the Brazilian census of 2010, more than 35 million people have some visual impairment and more than 6 million are totally blind or have severe difficulties on this matter. There is a great demand for public policies that target these people enabling them to use assistive technologies.

The education of visually impaired children still suffers from the traditional concept found in the Brazilian general education. This situation could not be different since the visually impaired student has integrated into the regular educational system, with the same educational proposals, curriculum, and contents worked by the school. A conceptual review is imperative in the teaching-learning process not only for the children with visual problems but also with the other children which they will share their knowledge with [1].

Social inclusion is a challenge in Brazil that has for historical reasons, an economically and socially unequal society. Beyond the resulting exclusion generated by an unequal income distribution, impaired people also struggle against the difficulties to exert their citizenship [2].

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The Brazilian Board of Technical Help (*Comitê de Ajudas Técnicas*, CAT) states that assistive technologies aim to develop “autonomy, independence, life quality, and social inclusion” [3], being of critical importance in the lives of disabled people. There are several proposals both in the academic and commercial backgrounds of devices to assist visually impaired people in reading. The conversion of texts into the Braille [4], the identification of the captured texts and images in the context of the disabled student [5], and the reading of books with the aid of smartphones [6] are some examples of scientific research in this scenario.

In this context, this work presents a development of a device that aims to promote the autonomy of visually impaired people for books reading. Different from the speech synthesis for accessibility using computers and software, the goal of this proposal is a speech synthesis system for book texts, in a way that is both adequate and economically accessible. As a result, we expect to widen the learning opportunities and the professional performance improvements of people with visual problems, with a reduction of the limitations imposed during the reading of books.

This article describes the device created and the technical difficulties involved in its implementation, especially the text extraction from the document images.

2 General Description

The aim of this project is to produce an audio file that reproduces a specific text from its digitized image. In other words, the main goal is to enable the reading of simple texts in Portuguese to people with low vision or blindness.

In summary, the Fig. 1 presents the block diagram of the proposed device.

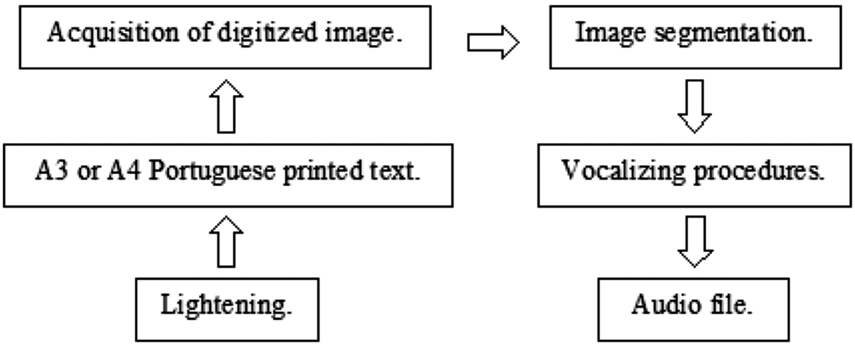

Fig. 1. Diagram block of the proposed device for vocalizing texts

In order to achieve this goal, some problems had to be faced:

Warping

Usually, when ordinary books had opened, the page shows a ripple due to its binding. Since a digital image is a two-dimensional representation of this page, the lines of the text might be mixed. Therefore, in the computational process of vocalizing, the enunciated words might not be understandable.

To solve this problem, a 90-degree glass book support has built. When the book is over it, its own weight eliminates the warping (Fig. 2).

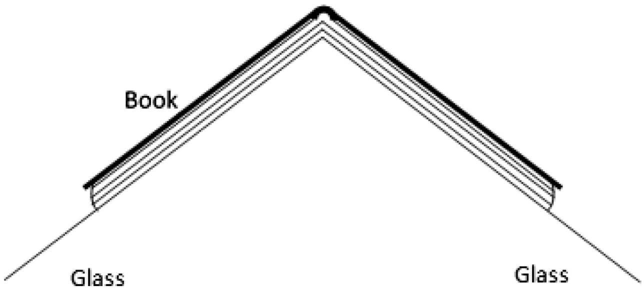

Fig. 2. Book suspended on glass surface

Lightening, Erosion, and Dilation

The uneven lightening of the surface of the text produces in the digital image morphological transformations called erosion and dilation. In the first case, the area of the characters is smaller than the original and the second one is larger. In both cases, severe misunderstandings may result in the computational process of vocalizing.

Figure 3 presents an example of dilation:

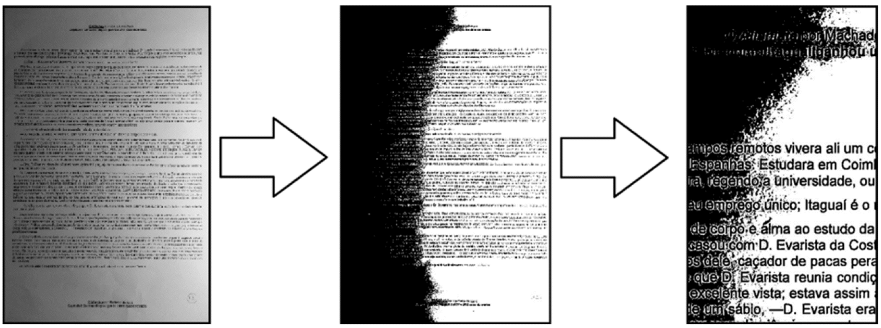

Fig. 3. Dilation example

In order to have a uniform lightening, LED strip and concave mirrors has used. The light beam emitted has reflected by the mirrors (Fig. 4) and all region has illuminated, resulting in a more balanced light distribution.

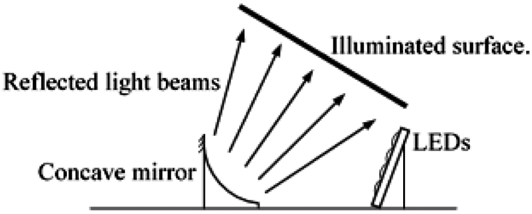

Fig. 4. Concave mirror and LEDs position

Threshold

Before using OCR, the text image must be transformed into a binary one: black and white. The simplest process is to choose a gray level as a threshold. Some procedures has shown in the corresponding literature [7–9]. The adaptive threshold produced satisfactory results.

After the image has digitized and segmented, technical difficulties of the OCR processes has investigated and tested. Commercial products have a better performance in the OCR process but are not cost effective for most of the visually disabled population in Brazil. On the other hand, the selected OCR software (Tesseract) is free and presented a satisfactory performance. However, it can be improved with more studies about the preprocessing, processing, and post-processing stages. The quality of the captured image is critical and this issue is somewhat solved, as well as the physical aspects of luminance.

The project expects to use the scanner in documents and books up to A3 size, which implies the need to position the cameras of the device in order to capture its whole area. Besides that, the design specifications of the apparatus define this as enough compact to be used comfortably by the user in a table. These two needs were the major obstacles to reach an acceptable performance: camera positioning and adequate illumination inside the dimensions of the scanner. Figure 5 shows the prototype of the project that is already being constructed. All the tests were made in an object of proportional dimensions and under the same conditions of the final product.

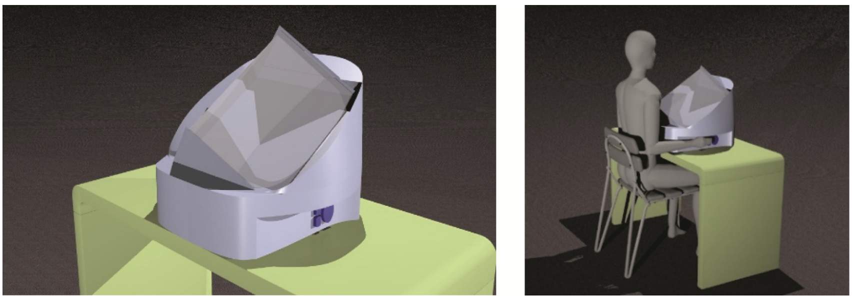

Fig. 5. Design of the developed scanner

3 Results

Several approaches for the illuminance has adopted until the proper illumination has reached. Different approaches has theorized, applied, and tested according to their performance in character recognition.

Among several tests, the penultimate attempt was to standardize the illumination using one developed software to remove the background of the page captured with the text. Therefore, the differences of illumination had eliminated (Fig. 6). However, for its implementation, different types of paper, colors, and textures database would be necessary. This precluded its use, despite the fact that the tests have shown approximately 95% of right characters.

Fig. 6. Image difference process (the last image already limiarized) (Color figure online)

A set of concave mirrors was used to optimize the illumination, widening and standardizing it, which was the biggest problem faced. The mirrors were positioned in order to reflect the light received from the LED stripes and reflected it in the glass that supports the book. Therefore, the image is captured and preprocessed with histogram equalization and adaptive limiarization. It was then possible to reach 98.54% of correctly detected characters, comparing the original text with that processed by the OCR.

From the results of the OCR, the remaining errors had evaluated by a software based on the algorithm Needleman and Wunsch [10], which verifies the number of differences (at the character level) between two texts; this algorithm was adapted to consider the most frequent errors generated by the OCR. To do so, it was necessary to manually obtain, for each image, a file with the corresponding exact text.

4 Conclusions

The text-to-speech process was composed of (1) image capture through the prototype, (2) image preprocessing, (3) OCR application, and (4) TextToSpeech (TTS) application. To evaluate this process, images were captured in different scenarios in order to verify how the process would react to different types of books and documents fonts. The dataset consisted of three pages of books from the Brazilian literature (one of these pages being an expanded font) and one biography book. The biography book intentionally had words from another language, just to evaluate how the OCR would behave in this scenario. Preprocessing was composed of adaptive thresholding and adaptive histogram equalization. The evaluation consists of gauging the number of characters that have been correctly identified by OCR. The exact text of each image was compared with its respective version obtained by OCR (Tesseract 3.05.01), generating the number of different characters between these images. The spaces of the texts were removed before this comparison. According to these differences, it was possible to estimate an amount of 1.085% and 1.825% of error (differences) for the Brazilian literature book, 2.679% for the page with extended text, and 4.77% for the text with words in a foreign language.

All difficulties faced such as warping, lightening, threshold have been solved. Ergonomic concerns have been taken in account, resulting in a product compact and comfortable to users.

The aim of the project was achieved with the development of voice scanner avoiding the use of a computer and peripherals hardware. The costs are low (mainly due to using free software like Tesseract), less than 50% of the similar equipment available in Brazil, so the equipment developed it will be ready to be used in Brazilian's public education system.

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Experimental Verification of Contents Usability for Upper Limbs Rehabilitation in Patients with Hemiplegia

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Abstract. Patients with hemiplegia with upper limb impairment have difficulties in performing coordinated bimanual movement of hands and activities of daily living (ADL) due to reduced performance in functional movements. This study developed a serious game for upper limb rehabilitation training using a balance handle specifically designed for patients with hemiplegia. Most current serious games designed for healthy people constitute difficulties for hemiplegia patients to use. For this reason, the simple game interface adapted to accommodate patient disabilities and the content tailored to the needs of these patients are warranted to provide gaming environments according to each patient's condition. Therefore, this study designed the tailored content that offers an environment appropriate for each patient by evaluating range of motion (inclination of a balance handle) of hemiplegia patients, movement speed and others. This game content is designed based on extension, flexion and movement assessment guidelines for the Fugl-Meyer Assessment (FMA), and measures muscle activities of triceps, biceps and deltoid muscles which demonstrate changes in upper limb motor function while performing the content. The experiment results revealed that triceps, biceps and deltoid muscles were activated. This content is expected to be utilized for rehabilitation purposes in hemiplegia patients with upper limb impairment.

Keywords: Hemiplegia · Limbs rehabilitation · Serious game · EMG · FMA

1 Introduction

Hemiplegia refers to the status of hypotonia in face or upper or lower limb on the affected side of brain damage. It causes muscle regulatory ability impairment, muscle tone weakening, etc. to develop paralysis or synergy symptom where one cannot move one single muscle but a group of muscles simultaneously [1]. Most of the hemiplegia patients have upper limb functional disorder from minor to severe degree and its accompanied functional movement weakening that undermines not only the coordinate movement of both hands but also activities of daily living [2]. In general, hemiplegic patients can enjoy high efficiency of rehabilitation treatment if received within 7 days of disease occurrence before muscular rigidity. Particularly, to help reduce the aftereffect from

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cerebral nerve rearrangement due to neuro-plasticity or restore exercise function, rehabilitation treatment is necessary in the initial stage [3]. To facilitate neuro-plasticity, patients' active participation is required in addition to repeated exercise. Rehabilitation treatment methods known to many include Fugl-Meyer Assessment (FMA) and Motor Assessment Scale (MAS). Most of them rely on therapists' supervision to make patients follow repeated moves for functional damage minimization and damaged brain nerve recovery [4]. Other effective rehabilitation treatment research methods include Constraint Induced Movement Therapy, Mirror Therapy, Bilateral Upper Extremity Training, and Rehabilitation Robotics. These are to improve the ability to control the upper limb muscles on the affected side of hemiplegic patients for enhanced exercise function on the affected side [5–8]. However, even the patients with the same impairment can still show mutually different results depending upon the subjective evaluation method of therapists. Therefore, an objective evaluation method is necessary, which can represent qualitative results. In addition, rehabilitation training requires continued participation, and, for this characteristic, it is also demanded to explore how to stimulate patients' interest for their active participation [9]. Against this backdrop, research has been actively made on quantitatively measuring or analyzing physical movements during rehabilitation exercise by attaching miniaturized inertial sensor, electromyogram sensor, etc. to body; and on functional games capable of stimulating activeness and interest [10, 11]. Most of the known functional games are generally made for normal people, posing plenty of difficulties for hemiplegic patients to use. But they are more interesting than conventional rehabilitation training methods by utilizing a lot of devices capable of somatesthesia or movement, reinforcing patients' will to participate. In this sense, when producing a functional game for hemiplegic patients, it is necessary to develop a simple interface and tailored contents to implement according to each patient's status. In this present study, for reinforced upper-limb muscular function and improved range of motion of hemiplegic patients, an acceleration sensor-based bilateral rehabilitation exercise device (balance handle) was employed as the functional game interface [12]. The triceps, biceps, and deltoids activation status of the developed functional game was measured to see if it could be utilized for hemiplegic patients as a rehabilitation content. Moreover, tailored contents were produced, which measure the range of motor (balance handle inclination) and movement velocity according to patients' hemiplegia degree, then, configure an appropriate contents environment for each patient.

2 Materials and Methods

2.1 Balance Handle and Electromyogram Measurement Location

Balance Handle employed in this study is shown in Fig. 1(a). For hemiplegic patients with restricted movement due to weakened upper-limb muscle, the device was designed to support their upper limbs. Balance Handle consists of 3-axis acceleration sensor, MCU, Bluetooth module, etc. inside. For the acceleration sensor, Analog Device's ADXL335 model was employed to acquire the inclination to the x, y, and z directions. In MCU (ATmega16), the acquired 3-axis data voltage values of acceleration sensor were sampled with 100 Hz. Not to disturb Balance Handle operation movement, Bluetooth module (Firmtech's FB155BC) was employed and, by doing so, the inclination data transmitted to PC were utilized to control the developed contents. Among the upper-limb rehabilitation movement assessment methods checking the degree of recovery of upper-limb motor function of hemiplegic patients, the developed contents based on FMA flexion-extension motion to operate Balance Handle. Balance Handle basically moves to the top, bottom, right and left up to the maximum inclination of 22° to the top; 28°, bottom; 16°, left and right. To check the muscle activation of triceps, biceps and deltoids according to Balance Handle move, EMG electrodes were attached at certain intervals from about 2 cm away along the muscular grain from upper-limb muscle center as in Fig. 2 ①, ②, and ③. A reference electrode was attached on the outer side of elbow of ④ without any change in muscular activation.

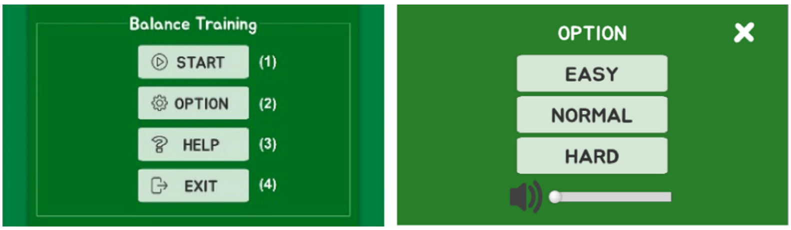
(a) (b)

Fig. 1. Balance handle and EMG sensor location and a balance handle

2.2 Production of Tailored Upper-Limb Rehabilitation Training Contents

The developed content is to gain a high score by avoiding obstacles or vehicles appearing while driving a car on a highway; earning events (refuel coin); and refueling the car to run a longer time.

Figure 2(a) shows the game start page. (1) is game start button. (2) allows to adjust game difficulty levels or sound volume as in Fig. 2(b). Difficulty levels were adjusted to change the frequency of obstacles (vehicles), vehicle types, fuel consumption, etc. At the difficulty level, Easy, a single vehicle appears less frequently for all people to get used to the game easily. As the difficulty level moves from Normal to Hard, cars running



(a) Game start page (b) Setup page

Fig. 2. Game user interface

on the highway appear irregularly in different types and speed. User car consumes fuel faster so, to game for a longer time, users have to earn a lot of events (refuel coin) appearing on the screen. The help button in (3) explains simple operation method and game details.

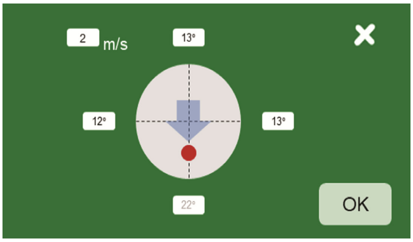
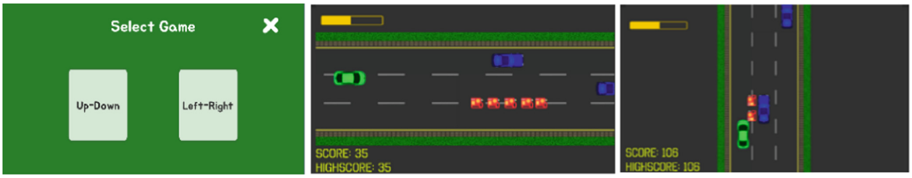


Fig. 3. Inclination and movement speed of a balance handle by user

Figure 3 shows the screen to measure the max up, down, left and right-directional inclinations and movement velocity of Balance Handle as each patient has different degrees of range of motion according to their disease status. Based on the information obtained here, the game environment is tailored to each user. At the basic difficulty level set up previously, the relative speed of car and obstacles, inclination, obstacle frequency, initial fuel amount, etc. are additionally set up in line with user characteristics so that mild through severe case patients can enjoy the game.



(a) Game model selection page (b) Flexion-extension training (c) pronation-supination training

Fig. 4. Game execution page (Color figure online)

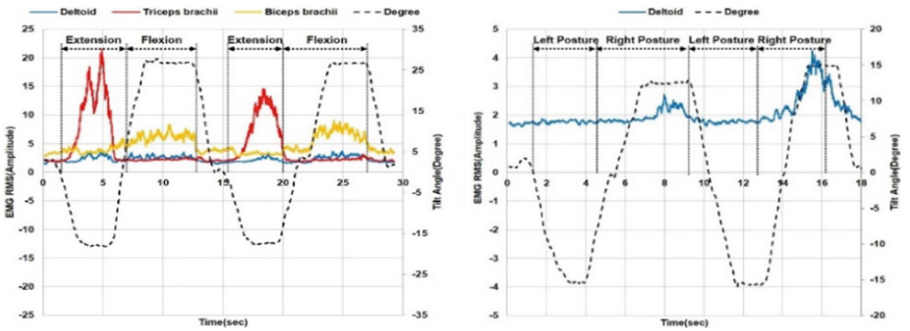
Figure 4(a) is the page to select the up-down exercise mode for flexion-extension training as patients wish in their rehabilitation training and the left-right exercise mode for below-elbow pronation and supination.

In Fig. 4(b), as a user moves Balance Handle to the top and bottom (flexion-extension move), the green-colored car moves up and down in the game. The yellow fuel gauge on the upper left side of the screen shows remaining vehicle fuel amount, which decreases slightly as while gaming. On the lower left part of the page, a user's present score is displayed in SCORE and the highest score of users so far, in HIGHSCORE, to stimulate their competition and encourage voluntary participation. SCORE increases with game hours and drops if collided with an obstacle. Since the fuel gauge gradually decreases while gaming, users have to gain events (red-colored refuel coins) to continue their game and score more. Figure 4(c) shows the left-right mode (pronation and supination training) which is progressed identically to the top-bottom mode.

2.3 Experiment Method and Results

In the experiment of this study, 7 normal men aged between 24 and 27 without any hemiplegic history were investigated. As they were gaming, change in their triceps, biceps and deltoid EMG signals was measured. The subjects were sufficiently told about the experiment method. To avoid any difficulty in placing their arms on the Balance Handle device, a height-adjustable chair was utilized to ensure they were in the most comfortable position in the experiment. Before game start, the subjects' Balance Handle range of motion and inclination velocity were measured but, since they had no big difference, it did not have any special effect on game environment setup.

Figure 5 shows the muscular activation measurement results in the up-down and left-right modes of the car game developed in this study. As shown in Fig. 5(a), in the extension move, the triceps show the largest muscular activation; and, in the flexion, the biceps. Since the left-right mode experiment of this study collected data when the EMG sensor was attached only to the left-side upper limb, the muscle activation of left-arm deltoid was found increase when the subjects took a motion to the right. Such a result is consistent with that of previous study measuring muscle activation in Balance Handle up/down, left/right exercise [12]. In other words, the car game developed in this study makes users follow up/down, left/right exercise using Balance Handle to induce change in the activation of triceps, deltoids and biceps, by which the muscular function recovery in patients who need upper-limb rehabilitation is evaluated.



(a) Up-down mode (b) Left-right mode

Fig. 5. Results of muscle activation measurement

3 Conclusions

In this study, a functional game (Serious Game) was developed for rehabilitation training using Balance Handle developed for the purpose of supporting hemiplegic patients' upper-limb muscle function reinforcement and range of joint motion recovery. The functional game was basically for upper-limb motor rehabilitation while allowing visual, auditory physio-feedback to increase patients' motivation and voluntary participation in the training process. Since people with restricted movement such as hemiplegic patients have difference in the range of joint motion and movement velocity according to their disease status; their range of joint motion (Balance Handle inclination), and movement velocity were measured to configure an appropriate content environment for each patient. In this manner, the game sought to include hemiplegic patients to perform the contents for rehabilitation training without special difficulty. To check the effect of the developed contents, patients' triceps, deltoid and biceps activation status was measured, which are relied upon to evaluate patients' muscular function recovery, while they perform the rehabilitation contents structured based on the evaluation items of FMA (Fugl-Meyer Assessment) extension and flexion exercise. As a result of the experiment, in the up-down exercise, biceps and triceps were found activated; and, in the left-right exercise, deltoid activation was found. The findings are similar to triceps, biceps and deltoid muscular activation in hemiplegic patients' conventional upper-limb rehabilitation training moves using other devices [13, 14]. That is, while performing the functional game developed in this study, it can be utilized as a content of rehabilitation training for hemiplegic patients with upper-limb functional impairment.

Since this study experimented normal subjects, change in pre/post-training range of motion and movement velocity could not be identified. These will need to be investigated in an experiment in cooperation with a hospital capable of performing a clinical test on actual patients. Moreover, through game type diversification and difficulty level sub-fragmentation, tailored functional games should be researched, which are capable of adjusting difficulty levels or recommending contents to follow according to each patient's present status.

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Using Libras to Support People with Communication Disabilities: An Alternative Communication Tool

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Abstract. Communication is accounted as one of the main abilities related to humankind development, as it allowed people to pass on acquired knowledge. However, conventional communication favors those with great communication skills, i.e. reading, writing or typing skills summed up to oral language; thus, part of the population is excluded from conventional means of communication. Using assistive technologies such as Augmentative and Alternative Communication (AAC), IVA prototype was developed, enabling communication between patients with motor or cognitive difficulties and health professionals. In addition to their basic needs such as hygiene or food, patients were able to express their wishes, for example to choose which type of food they preferred or which activity they wanted to perform. During the validation and testing of the prototype, healthcare professionals considered that learning LIBRAS would be valuable for patients and other professionals. Thus, the prototype was expanded so that it includes LIBRAS resources, allowing patients and professionals in education and health to use a form of communication through gestures and facial expressions. This new prototype was called LIVA. LIVA assumes the use of communication boards, in which the user selects by click what they want. When selecting an option to express patient's desire, the information is presented in synthesized voice and the sentence is written in Portuguese; in addition, a pre-recorded video with a LIBRAS expert is presented, showing the same information in LIBRAS. Thus, user can understand what the sequence of gestures and expressions represents. The objective of LIVA is that when viewing the word, phrase or expression in LIBRAS the user reproduces the same signals to express themselves and this may allow greater autonomy for individuals with communication difficulties.

Keywords: Communication process
Augmented and alternative communication
Communications technologies · LIBRAS · Sign language

1 Introduction

The main role of technology is to approximate people. It is common to observe technology playing this role through social networks, instant messaging tools, tele-calls, and other forms of communication. Technology allows people to be together by transposing

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physical distance. However, most tools are developed for users with broad communication skills, specifically users with reading, writing and/or typing skills and oral language, and are not intended and appropriate for individuals with communication difficulties or cognitive and motor restrictions.

To support the communication process of people with communication disabilities, assistive technologies provide mechanisms and resources that extend the communication skills of these people, and this area of assistive technologies is called Augmentative and Alternative Communication (AAC). AAC is defined as other forms of communication beyond the oral communication, such as the use of gestures, sign, facial expressions, use of alphabet boards, graphic symbols, use of sophisticated computer systems with synthesized speech and others [3]. AAC support people who has no speech, or who has a lag between their communicative need and their ability to speak or write.

In order to allow communication between people with communication disabilities, who may have some cognitive and motor restrictions too, it is proposed a tool that helps the communication process using technology and sign language. The presented tool proposes, besides the communication through voice and image, the use of Brazilian sign language.

This paper is organized as follow: Sect. 2 presents contextualization and motivation. The proposed tool LIVA is presented in Sect. 3, as well as the results of the usability tests. Finally, Sect. 4 presents the conclusions and future work.

2 Contextualization and Motivation

2.1 Augmentative and Alternative Communication

According to [1] Communication is a basic need of human beings. It is required in professional, social and personal relationships, establishing a fundamental aspect for survival. Communication can be considered a set of signs that refers to behaviors that occur among two or more persons and which provide a way to create meanings between them. When individuals have no forms of communication or have some form of communication, but this is not enough to maintain communication links, establishing social relationships, it is necessary to use some resources to promote communication, integrating this individual in social life.

Silva et al. [7] define as cruel the quality of people's life with communication difficulties. The greatest existing barrier in the communication of individuals with some disability is the verbal language and this causes other communication techniques to be adopted. Radabaugh [5] says that for people with communication difficulties technology makes things easier and for people with communication disabilities makes things possible. Thus, some alternative ways of communication can be used as writing, sign language, images, symbol boards, etc.

When we use different technology resources and alternatives to adapt or create a form of communication, we are entering the area of knowledge called Assistive Technology (AT), which proposes to promote or extended skills in people with all types of disabilities. When AT is used specifically to solve problems with access to knowledge, writing production, information exchange, etc., which is directly related aimed at expanding communication skills, they are called Augmentative and Alternative

Communication (AAC). The AAC is intended for people who are not speakers or have only a non-functional speech, or people who are in the gap between their communication needs and their ability to speak and/or write [3]. The term “alternative” is intended for individuals with no communication resource and the term “extended” those who have it, but insufficiently to establish socializing. Thus, the AAC is a term that is used to describe some communication methods that can help people who are unable to use verbal discourse to communicate, creating adaptations and communication alternatives that help them in this process, through expressions, images, gestures and signs.

In this way of communication, it is common to use many different learning tools, such as the alternative communication board, which uses the intuitive graphic images (photos, symbols, figures) with characteristics common to the real objects and actions. These figures have the purpose of representing actions through according to individual’s needs and feelings, in order to further expand the communicative repertoire of these boards, using vocalizers that produce pre-recorded messages, which are accessed by keys through the images in the boards.

2.2 LIBRAS

The Brazilian Sign Language (LIBRAS) is a language in its full concept, with morphology, syntactic and semantics and uses gestures and facial expressions in the communication process. Albres [2] emphasizes that LIBRAS is composed of linguistic universals, because it presents phonological, morphological, syntactic and semantic-pragmatic aspects. In addition, the Brazilian government, by means of Federal Law No. 10,436, of April 24, 2002 effective LIBRAS as the second official language in the country. In this work, it was adopted as an alternative communication technique, whose communication process occurs through gestures, facial and body expressions, allowing the exchange of information between individuals and therefore allows people with oral communication disabilities to interact socially.

The LIBRAS had influence of the Portuguese language because they are in contact, but had as fundaments, the French sign language. Some of the Brazilian individuals who have LIBRAS as their native language do not know Portuguese and, consequently, feel difficulty due to the structure of the sign language, which when it is translated to the written language does not resemble to Portuguese language structure. Many words, concepts, expressions in Portuguese do not exist in LIBRAS, causing difficulty for the native individual in LIBRAS to understand texts in Portuguese [4]. Thus, to assist these individuals, assistive technologies can be used as ways of communication, to providing the inclusion of these individuals in society.

2.3 Motivations

Previous works carried out by these researchers with Augmentative and Alternative Communication tools [1, 6] showed that technology helps the communication process and allows the inclusion of individuals in society, facilitates the process of learning of children in the classroom [1], sharing information and learning new ways of communication.

The development of the IVA tool [6] allowed to these researchers lots of knowing, and we realized that using a sign language, associated with IVA would increase the usefulness of the tool, presenting a new form of communication to the individuals with communication disabilities. Also, during the researches we have identified several tools that use LIBRAS to help the communication for hearing impaired, applications that reproduction prerecorded videos with real people or even digital characters, but with limited resources to translate oral communication to gestural one. However, we did not identify any tool or research that uses communication boards and LIBRAS to foster the communication of people with cognitive and/or motor disabilities. Thus, the motivation for this work was the development of a tool that joins the two techniques of communication: boards and signs to broaden the ways of communication.

3 LIVA Tool: Communication with LIBRAS

The prototype of LIVA - Accessible Interaction with LIBRAS was developed to individuals that need to learn another form of communication besides oral communication, or because they do not have it or because they need to communicate with those who do not have it.

Therefore, through functions of the LIVA tool, in addition to the resources for alternative communication with images and sounds, users can use signals to communicate. The tool also serves as an option in learning the sign language LIBRAS, since it shows in a simple way the use of signs, facial and body expressions in the communicating.

We use an integrated development environment to create and develop the LIVA prototype. The prototype was evaluated through usability inspections performed by usability specialists and, at the end of this evaluation, the requirements were validated.

Considering the difficulties of communication, we seek to develop the prototype with the adoption of images and sounds to help and facilitate recognition and memorization, facilitating the adoption of the prototype.

It has the following features: on the main screen (Fig. 1), the user has options to express what he wants to do: choose a food, a drink, a song, a game, express a feeling or write a message to be spoken or transformed into signs. Still in this main screen, the user can access specific LIBRAS functionalities: button at the bottom of the screen.

Fig. 1. Main screen

By accessing the specific functionalities of LIBRAS on the main screen the functionalities are presented, as in Fig. 2. The user can select what he would like to learn in sign language: the alphabet, the greetings, days of the week and months of the year, colors, numbers and other options that have not yet been developed but can be created.

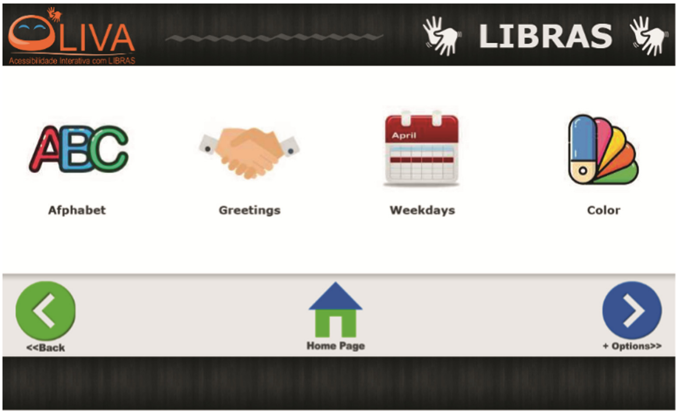

Fig. 2. LIBRAS functionalities. (Color figure online)

For the evaluation of the LIVA tool, the usability inspection technique was used to verify the usability and functionalities, concentrating on the Nielsen heuristics. And as it can be done at any stage of development, this type of technique has become suitable for the work, in the prototyping phase.

The analysis of heuristic evaluation shows us that LIVA is simple to use and the user can recognize where he/she is without having to remember the path he/she have been navigating. Furthermore, the use of metaphors and patterns provides greater ease in recognition of the objects to interact. Besides that, this tool minimizes number of click's (actions) to perform a task, based on user's needs who have deficits in motor coordination.

4 Conclusion

We present the prototype LIVA that's support the communication process in an alternative and Augmentative way for people with little or no oral communication. And we used as a resource of this alternative communication, the Brazilian Language of Signs - LIBRAS.

Other existing tools were tested, but they did not meet the needs of individuals with cognitive and/or motor deficits, besides the difficulty of communication, using signals as an alternative in this process. During the usability inspections, we realized that the integration of the signals with other resources so common in such tools proved to be a great differential and provided users with or without communication difficulty to learn a new language.

We understand that people with multiple disabilities need specific technology to support communication and that these resources must be tailored to each user. Our prototype is constantly evolving and adapting to meet the different users with their various differences in the communication process.

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Development of Serious Game and Integrated Management Service Model for the Cognitive Rehabilitation

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Abstract. Cognitive impairment that can be caused by brain disorders or aging affects quality of life by interfering with abilities to perform activities of daily living (ADL). For this reason, this study developed serious games for the purpose of rehabilitation and proposes an integrated management service model that can recommend the difficulty level of games and manage changes in serious results according to user's cognitive function ability during rehabilitation. The areas of cognitive training are designed in consideration of game elements in relation to attention, concentration, memory, orientation, executive function and ADL. Based on the analysis results, we established a database for recommendation of game level in the next training session. Attention is further subdivided into selective, sustained and divided attention. Memory is subcategorized into topological memory, associative memory, verbal memory, immediate memory, visual short-term memory, working memory and recall memory. Executive function is classified into inhibitory control, cognitive flexibility and working memory. ADL includes physical ADL and instrumental ADL. This model comprises a total of 19 serious games for cognitive rehabilitation and each game consists of 3 levels of increasing difficulty. Game interface is created with a user-centered design which focuses on visualization for elderly-friendly use. Our integrated management service model for cognitive rehabilitation can provide training on cognitive function in different areas as a single program and recommend the difficulty level of games depending on player's ability.

Keywords: Cognitive rehabilitation · ADL · Dementia · Memory Serious game

1 Introduction

Computer-based cognitive rehabilitation programs such as PSSCogReHab, RehaCom, and COMCOG have been developed since the 1980s and utilized in many neuropsychological tests. Although they are useful in proving mild cognitive impairment, they

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are limited in identifying normal aging, mild cognitive impairment and dementia separately from each other as there are many common aspects among those. The possibility, however, has been presented that cognitive rehabilitation therapy is capable of not only slowing the progress of cognitive dysfunction, but also improving concentration and memory, enhancing cognitive functions such as daily living activity [1, 2].

In memory training, in particular, the therapy was found effective in improving working memory capacity, processing speed, etc. It was found as one of the factors capable of preventing or, at least, minimizing memory functional weakening to learn memory strategy necessary for information encoding and retrieval. Activities seeking brain stimulation such as learning a new language or gaming were said to function as a protective factor against degenerative dementia or Mild Cognitive Impairment (MCI). It was also reported that the cognitive perceptual factor of stroke patients was highly correlated with their activities of daily living [3, 4].

Such computer-based cognitive rehabilitation programs allow to change rehabilitation training items and computerized the test taking and scoring procedures, easing the comparison between the present and past results through the qualitative scoring of task outcomes. In addition, they can store and convert data, measure and analyze responses to each area, and easily reproduce the measurement. However, most of the computer-based cognitive rehabilitation programs proceed game in a consecutive and repeated manner to dampen user interest and hardly inducing their voluntary participation for the thought that they are receiving repeated evaluation.

Against this backdrop, this present paper developed a functional game (serious game) encompassing diverse cognitive functional areas for patients with degenerative dementia or MCI by taking the merits of the computer-based cognitive rehabilitation programs; and suggested an integrated cognitive rehabilitation management service model capable of recommending an appropriate game based on the results while user training. The functional games proposed in this paper are centered on the frequently utilized neuropsychological test of RehaCom and divided the cognitive functional areas into 5 areas under hierarchical classification. They were further developed again by subdividing the training areas. Moreover, since most of the users are the elderly, the system interface was designed with the focus on their convenient use.

2 Cognitive Functional Area-Specific Contents Building

In this paper, the main cognitive functional factors were categorized into 5 areas – attention, memory, orientation, executive function and activities of daily living (ADL). According to the categorized areas, contents were produced as shown in Fig. 1.

2.1 Contents for Attention

In the contents of Selective Attention, letters are presented at the center of contents based on the color and word test utilizing Stroop effect designed by J. R. Stroop, an American psychologist; and users are made to select colors appropriate for the meaning of the word, regardless of its colors [5]. With respect to the difficulty level structuring, figure forms were made in quadrangle, pentagon and hexagon to increase nontarget stimulation to users, helping amplify semantic interference effect [6].

In Sustained Attention, based on the existing SIMON game, users remember the order of colors of figures in diverse colors presented in random order then, recall them and touch the button of colors in the same order. This is an effective method to increase the working alliance referring to the relationship between a therapist and patient [7]. With respect to contents progress, in the case of positive response, the number of presented colors increases continually and, in the case of wrong response, the game is ended.

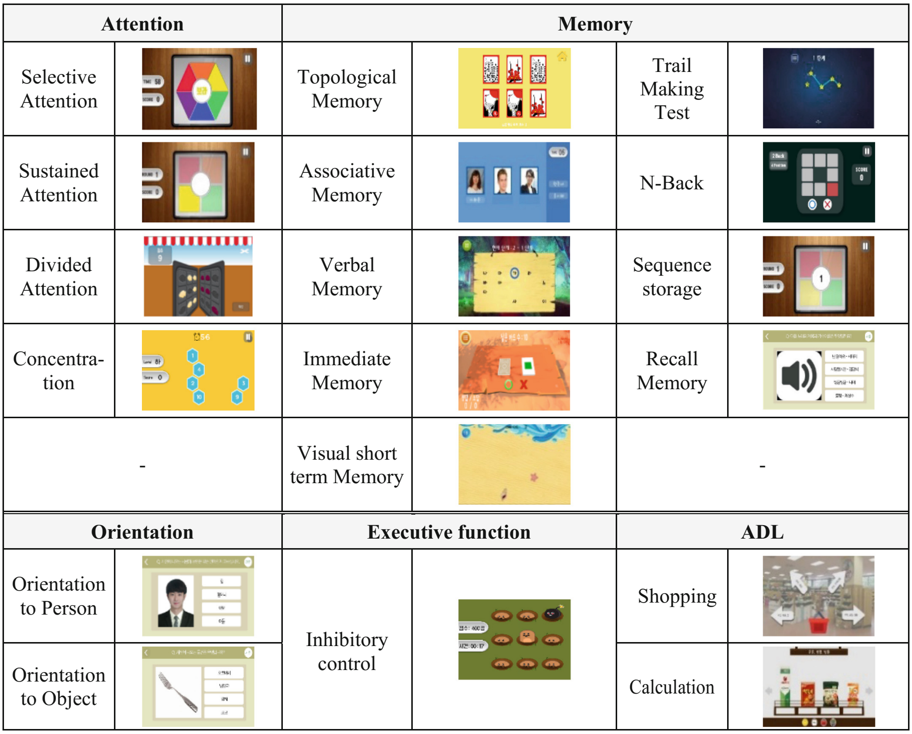


Fig. 1. Produced contents of each cognitive functional area (Color figure online)

Divided Attention is the highest level among the three types of attention and means the ability to perform multiple kinds of tasks simultaneously in a certain condition [8]. In this paper, users were made to cognize spatial pattern by assessing symmetry of both sides; remove it; and remember the number presented upon the removal to perform multiple tasks at the same time. If a user enters filling on the right side of the screen to mirror the dough pattern on the left side, a well-baked fish-shaped bun is made. If there is no filling in the symmetrical place or filling is placed in a wrong spot, a burnt fish-shaped bun is made. Additionally, users were instructed to remember the number of fish-shaped buns their guest wanted to buy so that they can perform divided tasks as well.

Attention is to select randomly-presented numbers following the rules such as the ascending order or descending order, and even or odd number. Difficulty level was differentiated according to the digit of presented numbers or their size or number change.

2.2 Contents for Memory

Memory is the ability to store and maintain information such as perception or experience at a certain point and recall it as necessary. In general, memory consists of four steps of attention, encoding, storage and retrieval. These processes are known to be intercorrelated [9]. In this study, based on the preceding study results on memory, 7 areas were recognized.

Topological memory is the ability to remember the location and space of a perceived target. A card matching game was included, which is a main topological memory content where players find out the location of identical figure. For the card matching game, flower cards were utilized as they are familiar and easily understood by Korean elderly people. Multiple pairs of flower cards are shown for a certain time in random locations; then they are flipped over for users to find out the same pairs within the shortest time possible.

Associative memory refers to the ability to encode and store visual and linguistic stimulations then, retrieve the other stimulation through one of the two stimulations. The content for this was set up to make users remember the faces, names and characteristics of many people shown for a certain time then, match the randomly-rearranged faces with the names based on their memory.

Verbal memory is the ability to recall information at verbal stimulation. This study employed the Cerad-K word list memory test and word list recognition test protocol in producing the content [10]. Random syllables and words were presented for a limited time and users selected the previously-presented syllables and words on the list of mixed words. Since the object to remember is words, difficulty level was differentiated according to the number of presented syllables and words.

Immediate memory is part of short-term memory to keep the information received from sensory memory for a while. The content was set up by letting users remember the forms and colors of figures in cards presented first and judge if they were identical to the forms and colors of figures in card presented subsequently.

Visual short-term memory is the ability to recall information on visual stimulation within a short period of time. The content in this paper was structured based on Change Detection Task [11]. An object is shown for a certain time at a random location on screen. After it disappears, a user detects and selects another kind of added object to a new location in this game.

Working memory is the ability to remember information for a few seconds, utilize for operation information remembered in the process of thinking. The content consisted of three activities – star sign marking, N-back training and sequence memory [12, 13]. Among the trailing marking test, the star sign marking bases on visual and motor detection functions. When stars with number marks are shown in random spots on screen, users should connect the stars in the ascending order from number 1. N-back consists of the 3 aspects of color, voice and location for visual, acoustic and spatial recognition training. Users recall their response to the stimulation N times earlier back in sequence. Difficulty levels are adjusted according to the increase in N, representing how far a user should remember back in sequence.

Sequence storage is similar to SIMON, the Sustained Attention content mentioned above. It is to remember the order of colors shown in a random order and choose the color of figure appropriate for the number presented at the center of screen.

Recall memory is the ability to communicate one's past experience to another person through the cognitive process, emotional process and verbal process. It is to recall again the information on things once experienced. The content was structured to make users recall once well-known persons, events, songs, etc. in the past.

2.3 Contents for Orientation, Executive Function and ADL

Orientation means to perceive the three dimensions of time, place and surroundings of oneself at the present time. The content was established with questions on things and jobs easily accessible from surrounding people and daily lives. Orientation on surrounding people, in particular, is in the form that a guardian or therapist enters the photographs and information on people around a user; multiple choice questions are established based on it; and the user answers the questions. Since orientation is the training of long-term memory, no time limit was set so that patients could have enough time to recall and think.

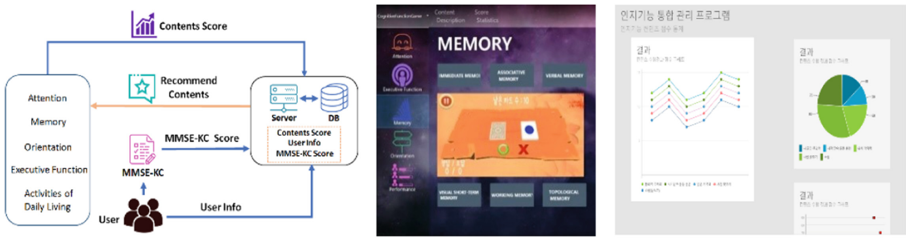
Executive function is a high-level cognitive ability to adjust one's thoughts and behaviors in line with environment. Executive function can be divided into working memory, inhibitory control and cognitive flexibility or shifting. As in Fig. 1, response inhibitory ability content was established with the mole catching game based on Go, No-Go Discrimination Task [14].

Activities of daily living (ADL) means the ability to independently perform the basic daily activities to take care of oneself as well as the complicated daily activities to maintain social life. The content consisted of grocery shopping, calculating, etc. In the grocery shopping, when a list of random items to buy is presented, users have to buy the right items accordingly. Difficulty level was adjusted according to the number of items to purchase. In the calculating, a receipt is presented, and users have to choose the right bills and coins shown in the bottom of the page accordingly and receive the right amount of change. Difficulty level is adjusted according to the number of items on the receipt.

3 Integrated Management Program

3.1 Composition of Integrated Management Program

In this paper, an integrated management program was designed to reflect the cognitive function level of users according to cognitive function evaluation results in recommending cognitive functional areas to train and detailed training contents. Computerized mini-cognitive function test was constructed based on the MMSE-KC (Mini-Mental Statue Examination-Korea Child). To this end, users were instructed to enter their name, sex, age, academic background (number of education years), etc. [15]. A total of 19 sets of question text were included on orientation, memory registration, attention and working memory, delayed recall, verbal ability, constructional praxis and judging ability. The results were reflected in the contents of 5 areas recognized in this paper to recommend content difficulty level to users. The results are visually presented in pie chart and line graph for users to easily understand their score distribution. The block diagram of integrated management program, produced user interface and result pages are shown in Fig. 2.



(a) (b) (c)

Fig. 2. (a) Diagram of integrated management program (b) user interface (c) result page

4 Conclusion

Computer-based cognitive rehabilitation programs have been researched in many studies so far and their effect and usability have been proven and developed in various forms. However, they have not assessed different levels of people's cognitive function and provided games simply in a consecutive and repeated manner to lose users' interest and face limitation in inducing their voluntary participation.

In this paper, the areas of cognitive rehabilitation programs were categorized into 5 areas of attention, memory, orientation, executive function, and activity of daily living with the focus on RehaCom, a frequently-utilized neuropsychology test. Each of the 5 areas were further divided for more effective training. In general, contents were made to reduce user impression of being tested while encouraging their interest in participation. Moreover, in order for therapists to more conveniently perform the cognitive functional test and management, MMSE-KC-based cognitive function evaluation tool was computerized and, based on its results, an integrated management program was designed, which is capable of recommending contents for cognitive functional areas with low scores. In particular, the contents produced in this paper were constructed by focusing on the followings to help enhance users' interest and engagement.

First, in developing a functional game, Korean cultural elements were applied to contents so that the program users feel familiar. Second, each game has different background music and sound effects to give acoustic feedback inducing user engagement in the contents. Third, as most of the users are elderly, touch screen-centered visual screen composition was constructed in the user interface for their convenient use. Forth, for their easy reading and understanding of change in results according to the number of content taking, it was visualized in pie chart and line graph to help improve users' achievement. Fifth, in reflection of users' cognitive functional test scores and training result scores, sub-area-specific contents were recommended to users in a non-consecutive way to help ease the sense of being bored from repeated task implementation.

It can be stated that the integrated cognitive function management program developed as such has the strength of checking a user's cognitive function level and training him or her with contents suitable for own level any time if user cognitive functional test and training contents are available. Moreover, since most of the cognitive rehabilitation training contents are, so far, those in a few cognitive function areas only; the 5 areas presented in this paper are expected to support cognitive rehabilitation training in further diversified areas.

To expand the cognitive rehabilitation training effect, further study can make use of big data to analyze plenty of result data in recommendation for more effective and user-customized service provision.

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We Care: Integrated Helping System for People with Physical Limitations

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Abstract. This project introduces a simple device as a passive social medium with the purpose to create an inclusive smart city for all its citizens. Often while designing a smart city, people facing physical limitations aren't perceived as the target users. Systems and designs lack empathy due to the lack of humanistic data.

To remedy this, our idea of an integrated helping system, "We Care", connects people in public areas to people with physical limitations while also collecting data for the government. This system strengthens community collaboration and human to human communication through the use of digital devices.

Our proposed solution includes: Wearable band for disabled people provided by the government. Physical device that receives nearby stress signals in the installed shops. Mobile application that notify nearby people for the given stress signal and also emergency contacts in a crisis Database that stores the location of the signal.

This solution aims to drive efficient policy-making and programs especially by the government while fostering empathy amongst the public. It also boosts independence and mobility amongst the people with limitations.

This project will establish a direct and more humanistic way of collecting data. It is an opportunity to collect insightful data while creating empathy and social inclusion. With the proposed system, we enable mobility with greater independence amongst people with limitations. For the shop, it improves their economy with increase in potential clients. This becomes an alternative to easy accessibility without infrastructure remodeling and investment. Moreover, this device in the shops can be replicated in different domains such as transportation modes, public buildings etc.

Keywords: Smart data gathering · Social inclusion · Community development Digital connectivity

1 Introduction

Smart cities as defined by Cisco are those who adopt "scalable solutions that take advantage of information and communications technology (ICT) to increase efficiencies, reduce costs, and enhance quality of life" [1]. With rapid influx of people into cities every year, there is a growing interest in Iot investments by companies and the need to deploy smart city solutions. Being smart is about redefining processes and engaging

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citizens. And this includes all its citizens, especially people with physical limitations. Our proposed solution of inclusive smart cities is targeted towards the city of Milan in Italy with government help. 6.6% of the Italian population faces physical limitation [2]. The government provides assistive technology to its citizens on national, local and municipal level. It also has a list of approved appliances that are distributed and recommended for use. The city of Milan has taken positive steps to make public spaces and facilities friendly for people with physical limitations. But the lack of accessibility and navigation still largely persists with an inherent stigma in the Italian population.

2 The Present Landscape

We observed and spoke to people with physical limitations about their routine and experiences. According to our findings, they are plagued by fear of deviation from a fixed routine, are hesitant to ask help from strangers, reliant on dedicated caregivers, have a feeling of exclusion and unwelcome, with dependence on tangible or intangible navigation guides. Compared to general public, their tendency to go out is considerably lower with a frequency of less than 20% to go to shops for buying necessities and goods. Moreover, they feel that their opinions are unheard with minimum to no participation in decision making.

These concerns arise due to the inability to record and use the real problems because of unavailable tools. Social interactions are almost non-existent leading to misconstrued perceptions. The city administration also faces geographical and budget constraints in changing the existing infrastructure. These can be overcome by incorporating digital technologies and using different connectivity solutions (LoRA) to develop participatory mechanisms for co-designing smart city solutions.

With the above considerations, we have designed the We Care system focusing on their accessibility for basic requirement of visiting shops. Our focus on the shops stems from the fact that out of 11000 shops in Milan, only 2,000 meet the accessibility standards. The key participants of our solution are the people with physical limitations, their caregivers, shop-owners and the general public with government as the regulatory body at the centre.

3 The Solution System

We Care system starts in the government offices where the users are given the We Care devices. All of the users (people with physical limitations, caregivers and shop-owners) have to fill a form that states the agreement terms for privacy and usage of their information. We envision to follow the secure and efficient solutions/protocols deemed fit for a smart city [3]. After this, our primary user (people with physical limitations) would receive the wearable band with the emergency button. Each band has a unique serial number that identifies the user. On pressing the button, it signals for help which gets transmitted to nearby shop devices and mobile applications and is stored by the government for data collection.

The We Care shop device is a small box with led lights, thermal printer and a push button. Through this, shop-owners receive notifications of help as the leds emit lights in two different colors (green and red) indicating the proximity of the person. Red light indicates the person is less than 25 m away and green light indicates that he/she is 50 m away. On pressing the push button, the shop-owner accepts to help the person and receives the printed specifications of estimated time to reach, distance, location (printed map/turn-by-turn navigation). The personal details of the person in need to assistance is not divulged with only type of disability mentioned. As the shop-owner accepts to help, the person in need is notified that the helper is on his way through vibrations in their wearable device.

To collect, preserve and identify problematic areas for the users with physical limitations, the information gathered from the wearable devices is stored in the government database, mapping the city according to the type of limitation.

The mobile application, includes two different sections: one for the designated caregiver and the second one for the citizens. For the caregiver, it provides intimation in case of a sudden attack(fall) or when the user long presses the 'help' signal on the wearable. Whereas, citizens are informed if there is someone nearby who needs assistance mobile application notifications (Fig. 1).

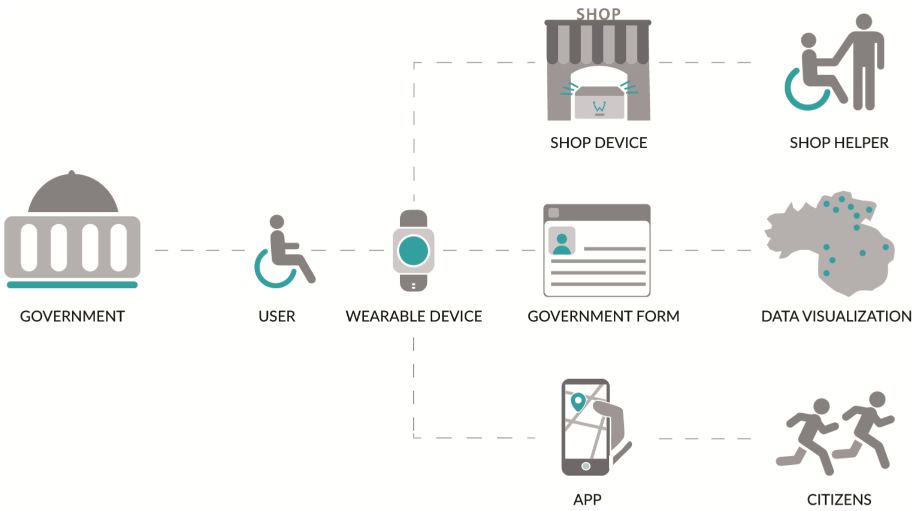

Fig. 1. We Care system map

4 Digital Connectivity

The connectivity of the We Care system is powered by connection with LoRaWan as it is being used by governments of Europe. It metes the requirements for the connectivity with the (IoT) internet of things.

The location signal from the wearable device embedded with GPS chip can be connected over a wireless network by the LoRaWan MQTT which with IP connection goes through LoraWan Gateway that acts as a bridge allowing the access to internet. Here, the information goes directly to the data base server, that processes and converts the information (algorithm calculation) provided by the device.

In the cloud the information is distributed using internet in the shop store device, government data base and mobile application. These devices receive the information and send it back using internet that connects to the server forming a bi-directional communication that facilitates processing of small data (Fig. 2).

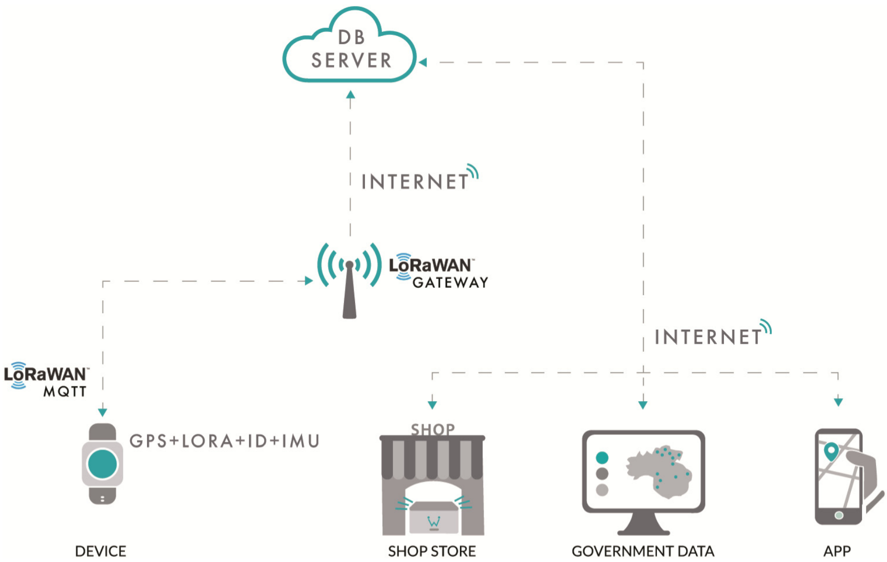

Fig. 2. We Care connectivity between devices

5 Implementation and Results

We prototyped and tested the We Care devices with the real users in context, i.e., the people with physical limitation on their way to the shops. The following are the built prototypes (Figs. 3, 4 and 5).

Fig. 3. Render and prototype of the wearable band

Fig. 4. Render and prototype of the shop device

Fig. 5. Information visualization of collected data

The initial test users had a warm response to adoption of this solution. The average mean time response time for help providers was of 3 min that we are trying to improve as a work in progress. While the wearable device lacks advanced and personalized features of other wearable devices in the market for people with physical limitations, it becomes a generic solution to city accessibility (Figs. 6 and 7).

Fig. 6. Mobile application for the citizens

Fig. 7. Mobile application for the caregivers

6 Value and Potential

Our solution proposes collection of data from direct sources, the users making it humanistic. The information gathered by the government will help in the profiling of problems based on geography and limitations while promoting accurate and innovative solutions. By the way we manage city data and infrastructure; we will co-create an improved living environment.

This solution also relies on community participation that creates empathy and supports social inclusion. The people with physical limitation have greater independence with easy access to shops and increase in their social interaction.

For shop-owners, it comes with possible tax benefits, increase in potential clients and an option to alternate accessibility without infrastructure remodeling and investment.

With more research and iterations, the device in the shops has the potential to be replicated in different domains such as transportation modes, public buildings etc. As a whole, it is an affordable, collaborative, digital smart city digital solution with a high market potential that can be replicated on the guidelines of Sharing Cities [4].

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Evaluation of Accessibility of Course Websites for Foundations of Engineering Classes

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Abstract. Many programs around the nation are starting or have already implemented digitally mediated courses. Since this form of learning is somewhat new, there is still room for improvement in many areas of this digital learning system. Based on student responses, there could be "better features to better enable interaction and communication." Also, there has not been much improvement on assisting or helping students with any sort of disabilities. This literature culminates in the research questions: "Does the types of webpage created influence the number of accessibility errors on a webpage?" and "Does the individual instructor who created the content for the webpage influence the number of accessibility errors?" To properly understand and answer these research questions, it was necessary to take both a qualitative and quantitative approach to the research questions. Qualitatively, scales and numeric classifications were applied to qualitative aspects such as page type and teaching experience. Quantitatively, regression models were complied to predicted which independent variables are impactful for total accessibility errors. Additionally ANOVA tests and post hoc tests were utilized to understand if there was significance within the independent variables presented. All p values for all three of the experiments were found to be highly significant. Additionally the post hoc tests denoted that there are significant differences between particular types of web pages and the instructors who produce the content for those pages.

Keywords: Human computer interaction · Learning management systems
Accessibility · Engineering · First year · Disabilities

1 Introduction

Most courses in engineering rely on the Internet to disseminate information, and this is typically done through a Learning Management System (LMS). This project involves the examination of course LMS pages to examine the digital accessibility of course websites for foundational first year engineering classes. Specifically, the project examines compliance to the Web Content Accessibility Guidelines. Pages are examined for level of compliance and trends are noted: compliance over time of creation, based on instructor experience and type of page are examined. Finally, recommendations are presented for common occurrences of compliance difficulties along with general trends in digital accessibility compliance within different level of teaching experience in engineering.

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2 Literature Review

Since 2014 digitally mediated courses have become prominent within both higher escalation and secondary education. These pages can be user-created or presented within a Learning Management System. These LMSs are prominent: 99% of all colleges use some sort of learning management system (Dahlstrom et al. 2014). While this is only one way of digitally mediating courses, this number still provides significance. Further, the business need and, proportionally, the market share for learning management systems have grown exponentially, as shown in Fig. 1, within the last decade partially due to the heavy collegiate utilization of learning management systems to facilitate digitally mediated education. However, despite the universities' heavy reliance and investment in learning management systems, nearly 50% of students, disabled and nondisabled, ask for "better features to better enable interaction and communication" within the learning management systems. This is shown in Fig. 2 along with other student recommendations for learning management systems (Dahlstrom et al. 2014).

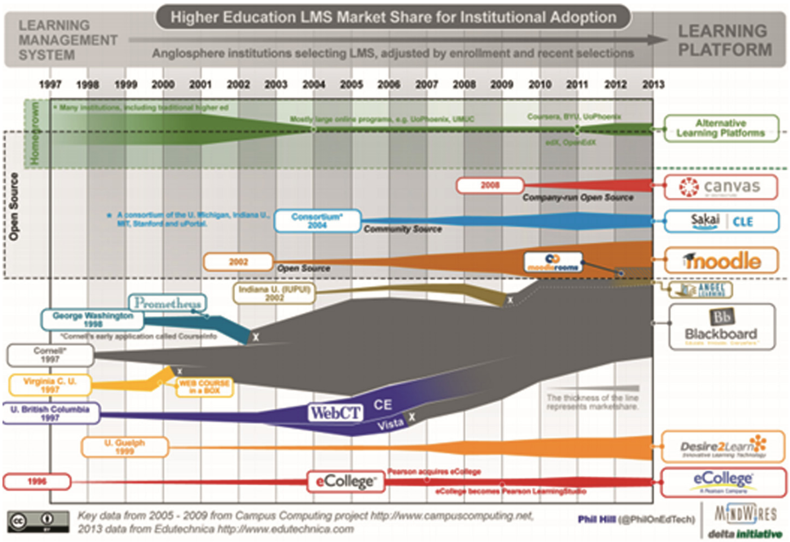

Fig. 1. Higher education LMS market share 2013

While many students need to access online LMS, research and student responses state academia is "lagging behind" in their online institutional support for disabled people, especially those who have cognitive and learning disabilities (Straumsheim 2017). Many large national studies on higher education digital learning environments only briefly mention disabilities or fail to mention any data on disabilities, physical or cognitive. It is vital for disabled engineering students to be able to access their digital educational content with the same ease as typically-abled engineering students. Lack of training for engineering faculty and lack of knowledge about the needs of cognitively

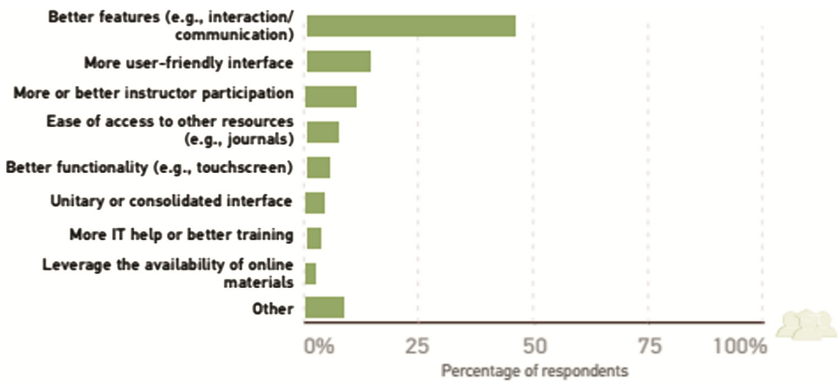

Fig. 2. Student recommendations for improving the LMS

disabled engineering students provides an environment in which engineering faculty do not have the knowledge they need to create accessible and inclusive environments.

3 Methods

For this research study both qualitative and quantitative research methods were invoked. A mixed method approach was utilized to gain both exploratory and explanatory data about the accessibility of engineering course websites. First, an app and web browser extension was used to evaluate and help calculate the number of compliance errors for each level of WCAG accessibility. Out of the 67 total sections of the Foundations of engineering course, 27 of these sections were analyzed. Each course website contained an average of 32 sub pages that were, in turn, analyzed for compliance. This sample included course websites from 9 different faculty members and instructors. The app used within this study is called UDOIT is called and the web extension that was used is called Siteimprove. The UDOIT app created a report of the accessibility errors within the entire course site, however, there were aspects that were unreadable by the app. Therefore, the information from the app was supplemented by the information provided by the individual accessibility readouts by individual web page by the Siteimprove web browser extension. This data was stored in a spreadsheet with classifying information for the engineering faculty members and instructors. The qualitative data for this study was collected through the use of targeted focus groups and interviews with the engineering faculty and instructors who created their course websites. A semi structured interview guide was created and utilized within the focus groups and interviews to have targeted and pointed conversation concerning faculty compliance barriers and faculty support needed to equip faculty and instructors with the knowledge and tools to create accessible course materials and websites.

4 Results

The quantitative results of this study were imported into R and analyzed using ANOVA and regression. Significant results were found when comparing different levels of compliance, teacher experience, and type of page on the website. These results were further understood through the analysis of the qualitative data. The qualitative data was analyzed through the use of keywords and thematic coding. Through these results the researchers were better able to understand the difficulties that the engineering faculty and instructors encounter when creating content for their engineering course websites. Additionally, the faculty and instructors were able to identify support that would be necessary to aiding the process of creating accessible engineering course websites for all levels and types of disabilities.

The most significant predictors for total accessibility violations and access errors were "logistical organization and flow", "non text images", and "non contextualized links to pdfs and and external websites". When these three independent variables were put into the regression model predicting total accessibility errors, 97% of the variation was explained. With this model explaining such a large amount of the variance, allows for the informed development of targeted workshops for informing instructors and GTAs as to the most common and impactful accessibility errors that occur on their course websites and how to remedy these errors.

Beyond the regression model, the different types of pages that the instructors posted within their course websites were significantly different with the lecture type pages having the most total errors on average. Additionally, there was no significant difference in the average accessibility errors per page between GTAs and faculty instructors. However, there was a significant difference between instructors, GTAs and faculty instructors, that have and have not taught the first year engineering course before. The instructors that have taught the first year engineering courses had more accessibility errors than the instructors that have not taught the course before. The researchers predict that this is because there are more resources and information posted on the course websites, on average, for instructors that have taught the first year engineering course before.

5 Conclusion

While the results of this study has limitations and are preliminary with their generalizability, the regression model predicting total accessibility errors per page within learning management systems is useful nonetheless to help inform and start to shape accessibility training for faculty and instructors. Additionally, this research helps to promote best practices for accessibility training and where accessibility training can truly create and impactful and genuine.

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Flexible Keyboard for Everyone

Tailored Software Keyboard for the Better Touch Typing

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Abstract. A user has hard time doing touch typing with a software keyboard. As these senses highly contribute to allow a user to recognize the layout of the keyboard, a user often feels disoriented to cause more mistypes once the user loses the senses with a software keyboard. We think that an appropriate key is typed in touch typing with a hardware keyboard. A user approximates layout of the keyboard through feeling of the finger tips, and relative distances between fingers. But hardware keyboard has a problem. This problem is a user can't approximate layout of the keyboard. A current software keyboard provides no straight forward solution. One more fact to be discussed here is that the size of the keyboard matters for the better touch typing. This paper proposes "flexible keyboard for everyone" to tackle this problem. "Flexible keyboard for everyone" is a tailored software keyboard for every single user. "Flexible keyboard for everyone" learns a user's habit with two major strategies and tries to help the user the better touch typing. This method allocates wider area for a weak key to pick up unintentional mistypes and increase the rate of appropriate types of the weak key to accomplish the better touch typing.

Keywords: Software keyboard · Touch typing · Input method editor

1 Introduction

Tablet devices have infiltrated our everyday life. One writes with a software keyboard quite often on a tablet device or smart phone, and this situation leads a problematic phenomenon. A user has hard time doing touch typing with a software keyboard. We think that an appropriate key is typed in touch typing with a hardware keyboard. A user approximates layout of the keyboard through feeling of the finger tips, and relative distances between fingers. But hardware keyboard has a problem. This problem is a user can't approximate layout of the keyboard.

A user approximates layout of the keyboard through feeling of the finger tips, and relative distances between fingers. Therefore, the key input in the home position and the relative position of the user is recorded in advance.

This paper proposes "flexible keyboard for everyone" to tackle this problem. "Flexible keyboard for everyone" is a tailored software keyboard for every single user.

We can expect users to touch typing easier using Flexible Keyboard than a general keyboard.

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2 Related Research

2.1 Study to Fit the Hand Shape

Hisano and Shiduki [2] suggests a "software keyboard easy to touch typing" on the touch panel. Hisano point out that touch typing is not easy because "the position of the key does not adapt to the shape of the hand of the user". Hisano's method relies on the vision of the user when matching the keyboard to "hand shape", and the user can arbitrarily change the position of the key. In order to make typing easy, it is important to match with the shape of the hand, but I think that shape change relying on vision cannot be said to facilitate touch typing which does not rely on visual sense. So, in this research, we use a method to change the shape of keyboard which does not rely on visual sense.

2.2 Improve Input Speed

In the research by Endo and Go [1], when inputting with a software keyboard, "input speed reduction" is a problem due to "move line of sight". Endo are approaching problem solving from both key shape and visual aid in order to improve the input speed. In addition, the method of Endo refers to the input position of characters and the number of inputs when matching the shape of the key to the user. In creating a keyboard, the input position can be said to be indispensable information, but considering the ease of striking each key, we think that creating a keyboard with the number of inputs will hurt ease of eating.

Because Endo's method changes the shape of the key by moving the center of gravity of the key according to the number of inputs when matching with the user. Indeed, by moving the key's center of gravity. However, with this method, there is a difference in easiness of striking with keys with a small number of inputs and many keys. Therefore, in this research, even with keys with different number of inputs, ease of striking Is difficult to differ.

2.3 Change Determination Position

The research of Karashima and Yanai [3] improving "input of performance" without changing "layout of QWERTY". Karashima are doing the approach of changing the judgment position of the input without changing the shape of the keyboard.

The method of Karashima refers to the data of the actual input coordinates for the user who can perform the touch typing. Based on the input coordinates, the actual judgment position is created, and the keyboard is adapted.

It is also based on the input coordinates other than yourself that you can touch typing when creating the judgment position of the keyboard. In other words, it is a judgment position which is generally easy to strike, but I think that small hands or big people who do not match the shape of a general hand, for example, cannot be said to be easy to strike.

It is important that keyboards are easy for general people to enter. But I think that a software keyboard which is not a physical keyboard can make it easy to use persons with characteristic hand size. This is because keyboards that can be easily struck by anyone can be reproduced as they are adjusted from the software side because software is used to display them. Therefore, in this research it is important to match with each user We propose a possible software keyboard.

3 Method

3.1 How to Obtain Coordinate Data

What is important for creating a keyboard is the touched coordinates. If you use the touched coordinates, it becomes data dependent on the appearance frequency of characters. For example, when acquiring touched coordinates from a word such as “apple”, a keyboard biased toward “p” is created. An unfair keyboard is created in ease of striking from data in which characters with high and low occurrence frequency are mixed.

As a solution, touch panel coordinates are divided into blocks. Then, the coordinates that can be input are replaced with the block. When multiple identical characters are input to the same block, the number of inputs is 1. As a result, data with a dense character input frequency is approximated to sparse data.

Figure 1 shows inputs in areas partitioned into blocks and input coordinates on the touch panel. In the area divided into blocks, the input becomes 2, and the input becomes 4 on the touch panel. By dividing the touch panel into blocks, it is possible to make inputs with close coordinates as one input. It can be expected to approximate to sparse data regardless of the input frequency of characters.

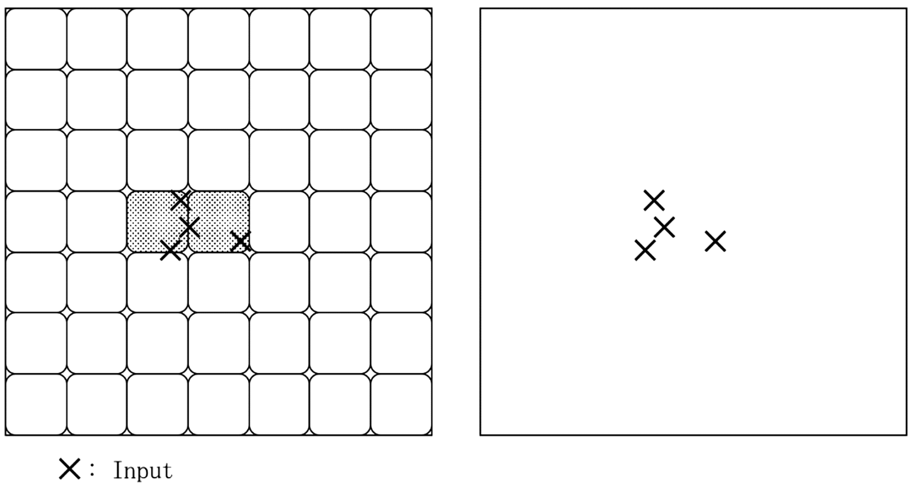

Fig. 1. Input of divided keyboard and touch panel

3.2 Step

In this method, the key is placed at the position recognized by the user. And "Flexible Keyboard" is a tailored software keyboard for every single user. For that purpose, the step will be explained first.

1. Read the home position of the user.
2. Read the relative position of the home position assumed by the user.
3. Create keyboard based on the data read by step (1) and (2)
4. The user inputs text with the keyboard created in step 3. (Count mistypes for each key)
5. Increase the size of key with many mistypes.

3.3 Processing of Input Data

There is creating keyboard based on data input by user. However, when making a keyboard from data input at a point, it is difficult for the user to input. Because the keyboard made with dots is distorted. Figure 2 is the keyboard (QWERTY) that the actual keyboard and the user think are desirable. Software keyboard must be a territory like this ideal keyboard. Therefore, we add work to make certain distance a single input as shown in the Fig. 3. By increasing the input coordinates, the distortion of the keyboard created is reduced. A keyboard that is easy to input is created.

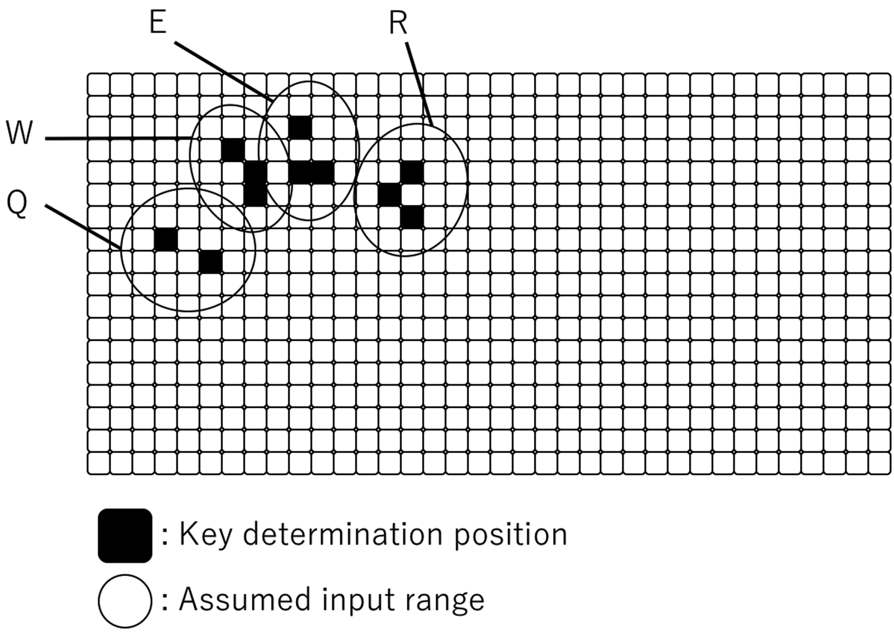

Fig. 2. Actual and ideal keyboard

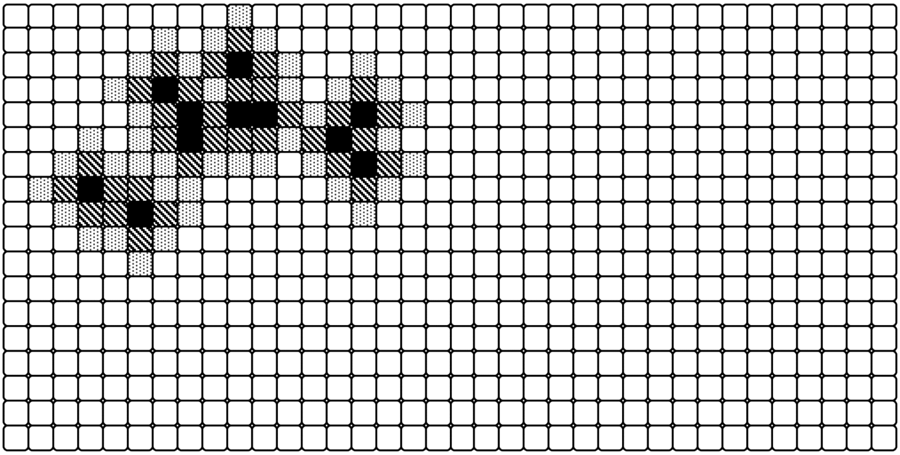

Fig. 3. Input after processing

3.4 Decision of Key Placement

Based on the data acquired in steps 1 and 2, arrange the keys in the divided coordinates. Combine all the data of A to Z on the divided coordinates. (Figure 4) However, when synthesizing on divided coordinates, there are cases where data overlap at the same coordinates. We solve this overlapping problem by weighting keys and comparing the weight values.

As shown in Fig. 5, the distance of the input center coordinates is converted to weight. Compare the given weights and determine the key placement as A to Z keys. Therefore, the keyboard reflects the relative position of the key assumed by the user.

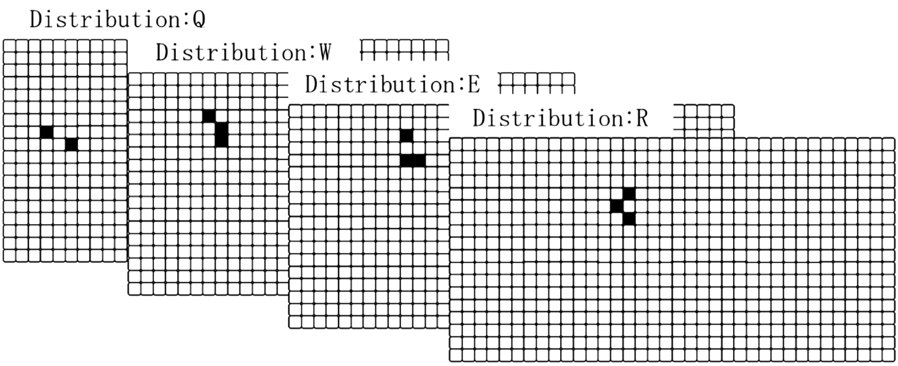

Fig. 4. Combine input data

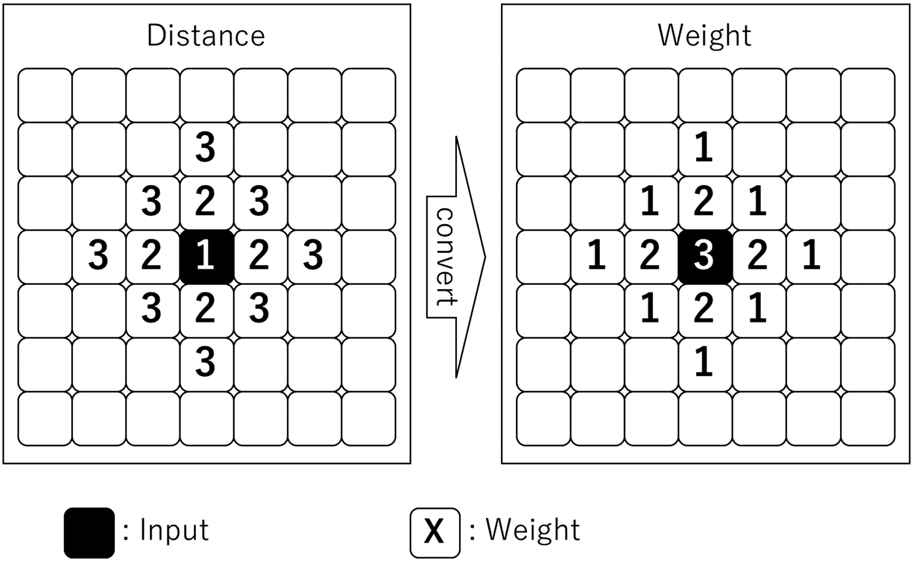

Fig. 5. Convert from distance to weight

3.5 To Correct of Keyboard

A user inputs the home position key and other keys to create a software keyboard. In this chapter, the user uses the created keyboard and corrects it based on the number of mistypes.

In this method, keys with more than a certain number of mistypes are increase size. (Figure 6) Increasing size of the key makes it easier to push the target key and reduces the number of mistypes.

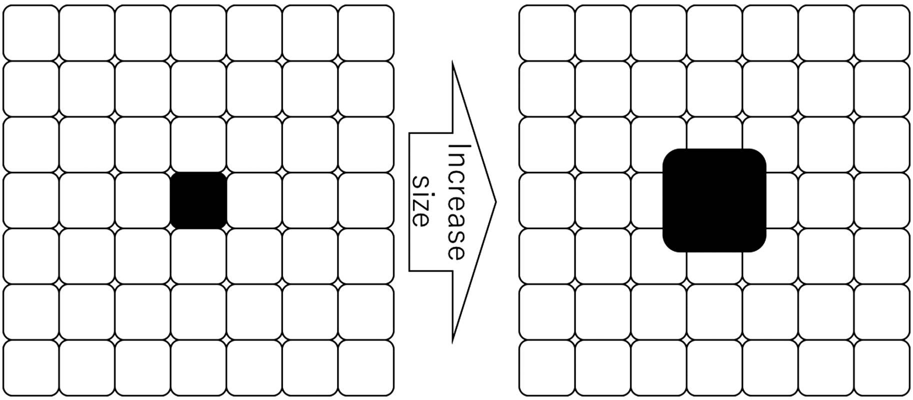

Fig. 6. Increase size of key

4 Results

In the experiment, we cooperated with 10 engineers by part time job. They can all touch typing.

Table 1 showed the comparison result with touch typing of the number of mistypes. The proposed Flexible keyboard has a lower average number of mistypes than the general Google keyboard. In addition, the number ratio of mistypes was 3: 6, Flexible and Google.

Table 1. Comparison of the number of mistypes

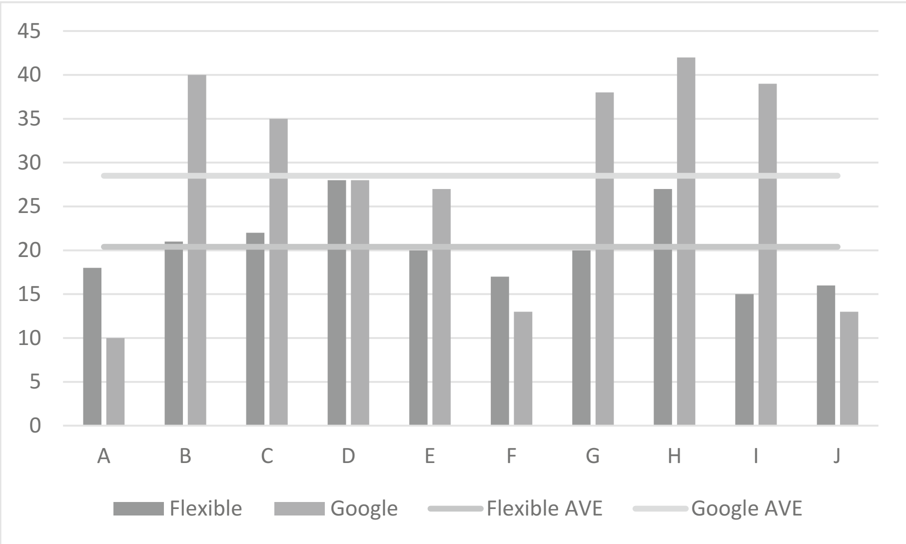

Table 2 showed that dispersion of Flexible is smaller than Google.

Table 2. Mistype of average and dispersion

	Flexible	Google
Average	20.4	28.5
Dispersion	18.93	153.61

5 Discussion

It said that Flexible Keyboard is ease of use for various people and Flexible Keyboard has few mistypes in touch typing. Therefore, users have easy time doing touch typing with a software keyboard than general keyboard.

However, only six people out of ten have achieved miss type reduction. Three people have few mistypes in the conventional keyboard, so it seems that some problems exist. For example, he is accustomed to the size of a conventional keyboard for the user.

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Medical Dictionary Using Sign Language Animation for Hearing-Impaired Persons

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Abstract. This paper is about creating a sign language dictionary for use in medical, which shows three-dimensional animation to find expressions in sign language. The dictionary is aimed at standardizing and spreading sign language expressions for use in medical, one of the fields that require sign language interpretation. Many medical terms have no corresponding or standardized expressions in sign language. Therefore, it is hard to correctly communicate disease names and more. We have created a sign language dictionary that has 3D animation so users can learn sign language expressions for use in medical. The dictionary mainly includes terms required for an examination/visit at a hospital. For 1,112 Japanese words, a total of 1,272 sign language expressions are included in the dictionary. All of the sign language expressions can be represented as 3D animation.

Keywords: Sign language · Medical dictionary · 3D animation

1 Introduction

One example of a setting in which sign language interpreting is needed is the medical setting. In the medical setting, important exchanges that are a matter of life and death sometimes take place, requiring accuracy of expression. However, in the medical setting, specialist terms are often used, making translation difficult. One reason for this is that there are no fixed sign language expressions for certain medical terms such as the names of diseases and tests. While books introducing medical sign language expressions do exist, they are not very satisfactory, for example, there is no unity of expression even within the same book and expressions that are not widely used are introduced.

We therefore created a medical sign language dictionary with the aim of standardizing and spreading medical sign language expressions. We began by gathering the medical terms necessary for treatment and examined sign language expressions corresponding to these terms. For difficult terms, we prepared explanations in sign language. Then using an optical motion capture system, we filmed the sign language for the terms and the explanations, we created 3D animations of the sign language. The sign language expressions for all the terms and explanations in the dictionary can be verified using the 3D animations. The use of moving images gives people who are learning sign language expressions a more accurate understanding of the sign language expressions than if they learned them using static images only. This dictionary has been designed so that it is

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easy for anyone to use, offering not only a keyword search function but also functions that enable users to search by category or from a list of terms.

2 Medical Terms and Explanations

To determine the terms included in the dictionary, we first gathered the terms considered necessary for treatment in hospital and used frequently in hospital. We then examined sign language expressions for the gathered terms, aiming to ensure that the sign language expressions would be easily understandable to anyone. We also added explanations in sign language for terms that might be difficult to understand.

2.1 Medical Terms

Table 1 shows an example of the Japanese terms gathered for inclusion in the dictionary. We gathered mainly terms necessary for treatment and in addition to key “parts of the body,” “names of organs and bones,” “names of diseases,” “symptoms,” “names of departments,” “names of tests and equipment” and “drug names,” we also provided terms believed to be frequently used in hospitals such as “doctor” and “reception.” We did not, however, include dentistry-related terms.

We gathered 1,113 Japanese terms. For these Japanese terms, we examined sign language expressions. We examined sign language expressions in cooperation with sign language interpreters, including medical providers, and persons who use sign language as their primary language. While being careful to ensure that the sign language expressions were easily understandable to anyone, we paid attention to the unity and consistency of expressions and determined sign language expressions through verification. Consequently, the number of repetitions and preservation of hand shape are also unified in the dictionary. As a rule, we provided one sign language expression per Japanese term, but, in view of factors such as individual differences in expression and ease of expression, there are some terms for which we provided more than one expression, enabling adaptation to the future popularity of the sign language expressions in the future. This resulted in 1,272 sign language terms in total, compared to 1,113 Japanese terms.

Table 1. Examples of gathered medical terms

Category	Examples of terms
Parts of the body	Head, Face, Body, Skin, Eye
Names of organs and bones	Stomach, Skull, Spine, Intestine, Lung
Names of diseases	Cancer, Myopia, Mouth ulcer, Pneumonia
Symptoms and conditions	Cold, nausea, Shortness of breath, Fatigue
Names of departments	Department of Surgery, Department of Internal Medicine, General Department
Names of tests and equipment	Ultrasound, MRI, Endoscope
Drug names	Mouthwash, Antibiotic, Powder, Pill
Others	Doctor, Reception, Medical history, Recurrence

2.2 Medical Explanations

Since medical terms are not routinely used and are often specialist terms, there are many terms that lay people do not understand. Therefore, we also prepared explanations in sign language to explain the meanings of terms considered difficult to understand through sign language expressions alone and terms that generally tend to be misunderstood. This also removes the need to look up the meanings of terms in another dictionary. Furthermore, among those who have difficulty hearing, there are many people who are not good at Japanese. We, therefore, prepared the explanations in sign language rather than Japanese text to make it easily understandable to persons without good Japanese.

The terms we explained are terms that are difficult to understand because they are rarely heard, for example, the names of diseases such as “Crohn’s disease” and “collagen disease” and words like remission, and terms that are difficult to distinguish from each other such as “virus” and “bacteria.” There are 122 explanations compared to 141 terms because we explained related terms together. Again, we prepared the sign language for the explanations in cooperation with sign language interpreters, including medical providers, and persons who use sign language as their primary language.

3 Creation of 3D Animations of Sign Language

Since sign language is a language expressed through movement, it is preferable to check expression in moving images rather than static images such as pictures or photographs. We, therefore, prepared 3D animations of the sign language. Figure 1 shows the created sign language animation. Use of 3D animations enables the image rights of sign language signers to be taken into consideration.

To reproduce sign language movements in 3D animations, it is necessary to acquire 3D movements corresponding to the bone structure of the models. We, therefore, made recordings of the 3D movements via an optical motion capture system. Table 2 shows details during recordings. The sign language signer wore a total of 112 retro-reflective markers all over her body, including her face and hands. This enabled us to create highly accurate animations. In sign language, facial expressions are also important. Through the attachment of markers to the face, animations with facial expression were created. It is also possible to view the sign language from all directions (360-degree view) to acquire the 3D movements. The right side of Fig. 1 shows the screen of the animation when the sign language signer is viewed from the left. Even if it is difficult to understand the sign language based on an image taken from the front alone, it is still possible to view the sign language expression from another direction, allowing users to properly verify the movement in detail .

We asked a person who uses sign language as her primary language to be the sign language data model to acquire the Japanese sign language. We have already confirmed that this resulted in expression in more natural movements.

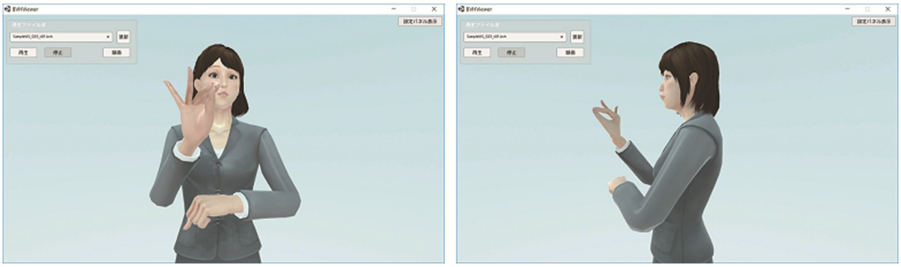

Fig. 1. The screen of the animation

Table 2. Motion capture information

Installation	Detail
Camera type	VICON T-160
Number of cameras	42
Installation range of the cameras	2 m × 2 m × 2 m
Frame rate	120 fps
Number of retro-reflective markers	112

4 Functions of the Dictionary

The dictionary features a "keyword search" function, a "category-based search" function, a "list of terms" and "sign language expression-based search" function. Besides searching for terms, it is also possible to search for explanations using the "medical term explanation" function. The top screen of the dictionary has search buttons for each of these functions. Clicking on the relevant button will cause the corresponding search screen to appear.

4.1 Keyword Search

In terms of the GUI, the "keyword search" function has a larger button than the other search methods on the basis that it is the most frequently used search method. Users can use the keyword search function to quickly find the term they are looking for. When users input any character they choose into the search box, the relevant term will be displayed. A "yomigana" search (search in kana indicating the pronunciation of kanji) and a partial match search are also possible. The keyword search screen also has panel with the 50 characters of the Japanese syllabary. Characters can be entered into the search box by means of mouse operation only, without using the keyboard buttons. This makes the dictionary easy to use even for people who are no good at operating computers.

4.2 Other Search Methods

The category-based search function enables users to search for applicable terms based on each category. The terms are put into categories which are more specific than the categories shown in Table 1 and are divided into categories besides "names of departments" or "drug names" such as "facility" or "reception" according to the situation in which they are used. The "term list" function displays all the terms recorded in the order of the Japanese syllabary. This makes it possible to search for terms simply by clicking, without the use of a keyboard.

The "Medical term explanation" function allows users to search for the meaning of sign language terms. The terms that have explanations are displayed in a list and users can search from the list.

4.3 Search by Symbols Describing Sign Language Expression

The words contained in the dictionary are described using the "NVSG element model [1, 2]" that was proposed by the authors. This description method was proposed to describe the complex morphological structure of sign language. It describes the morphological structure of each element of sign language such as hand shape and movement. Using this description method to describe the expression of each sign language term will make it possible to conduct searches based on an element such as the hand shape or movement and will make it possible to search for sign language based on sign language expression. Therefore, someone enable to look the term up in this dictionary even when users do not know how sign language translates into Japanese. This feature is currently being development.

5 Conclusion

We created a medical dictionary that allows users to view sign language in the form of 3D animation, thus enabling sign language interpreting to be used in a medical setting where its use is important. To record the dictionary, we examined sign language expressions of medical terms in cooperation with persons who use sign language as their primary language. To ensure that the examined sign language expressions will become widely used in the future, we also paid attention to the creation of terms. We also added explanations in sign language for terms considered difficult to understand. We created sign language animations for all the sign language expressions created and created 3D animations of the sign language. The use of 3D animation enables users to view the sign language from all directions (360-degree view).

To make the dictionary easy for anyone to use, we considered the GUI in the dictionary design and ensured that word searches can be performed without any keyboard operation. Besides keyword search, it is also possible to search based on category and search from a term list.

In the future, we plan to add a function for searching based on sign language expression. Sign language can only be looked up in a dictionary based on a Japanese translation. However, we are currently building a "reverse lookup" type function that enables anyone who sees sign language which they do not know the Japanese translation for to look up the meaning in the dictionary and to search based on the hand shape and movement of the sign language.

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A Mathematical and Cognitive Training Application for Children with Autism: A System Prototype

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Abstract. Some empirical studies showed that children with autism spectrum disorder (ASD) may have similar mathematical competences compared to their typically developing (TD) peers, but deficits in social communication or interaction skills. To date, a number of commercial applications are available to children with ASD for practicing mathematical and cognitive skills, yet few of them intended to promote social interaction and equipped with analytical tools for evaluating their cognitive and social development. Our current project aims to fill this void by developing an educational tabletop application to strengthen the capabilities of mathematics and cognition for children with autism. It provides several practices on counting, recognition, and measurements and could be played either alone or together with other children. It could also serve as edutainment tools to lessens the burden of special education teachers from repeatedly teaching mathematical and cognitive knowledge.

Keywords: Autism spectrum disorder · Math learning · Cognitive learning · Tablet application · Data collection · Behavioral data

1 Introduction and Background

Some research surveys have estimated that the prevalence of ASD reached 0.62–0.70% in 2013 [1]; and early behavioral and educational intervention could enhance autistic children's functional and living skills in their future [2]. A report also showed that autistic youths have a mean discrepancy of 4 to 5 grade levels on readings and mathematics [2], although empirical studies showed that preschoolers with high-functioning ASD (IQ > 80) may perform as well as typically developed (TD) peers in mathematics [3]. Meanwhile, a study indicates that students with ASD are more likely to enroll in science, technology, engineering and mathematics (STEM) fields [4], which infers the importance of mathematical and cognitive training in their early childhood.

In this paper we present a mathematical training application for preschool children with ASD. It is intended to be played alone or with peers to enhance both their cognitive and social interaction skills. At this moment, the application is intended for Chinese children, therefore, all instructions and feedback (speech and words) are in Chinese.

In the next section we will discuss some related works and then our design in Sect. 3, followed by concluding remark in Sect. 4.

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2 Related Work

Some applications have been developed to enhance applied mathematic skills of children with ASD [5–11]. Hansen [7] has provided a comparison of several math applications for students with ASD. Browder et al. [9] categorize mathematical components into five: (a) numbers and operations; (b) measurements; (c) algebra; (d) geometry; and (e) data analysis. They argued that numbers, operations, and measurements as the most important components referred in mathematical applications. Moreover, along with the concern of autisms' reading skills, the hypothesis of "thinking in pictures" in Kunda and Goel's research [11] suggests that thinking visually is crucial for cognitive model design.

According to our observation in two learning centers in China, we found that some children had difficulties of memorizing things, hence, require repeated reinforcement in one-to-one sessions; consequently, teachers were frequently facing difficulty of teaching a class of students with varying learning skills. Therefore, an interactive educational application may help to solve such problems. For the discussion on the benefit of such assistive learning technology in the classroom, the readers are referred to [12].

3 The Game-Based Math Training Application

3.1 Design Goal and Framework

One of the advantages of our proposed application is to lessen teachers' burden and offers children more opportunities to practice their mathematical and cognitive skills after class. However, since children with ASD need more opportunity for social interaction, our design shall support one to three children to play together at the same time. Also, to motivate their learning, the activities should be fun in the form of games.

Basically, the game is aimed to teach children rudimental math skills, which can be categorized into five groups of activities: (a) counting numbers; (b) comparing size or length; (c) discriminating shapes; (d) distinguishing colors; (e) classifying circles with different colors. Every category includes one to three playable activities and each activity consists of three levels of difficulty.

3.2 Game Design

Players are allowed to play the game in random order or select a specific game and its level of difficulty. Figure 1 depicts the screenshots of each activity. The instructions for the activities are shown in Table 1.

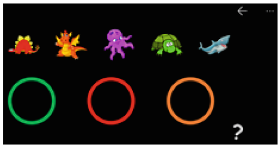
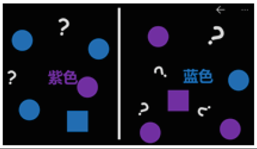
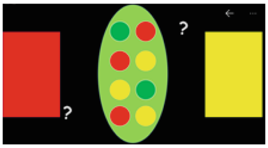
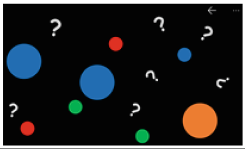
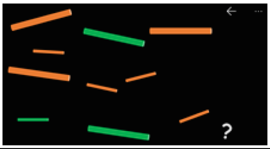
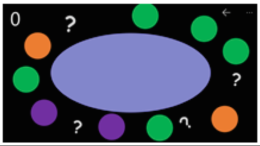
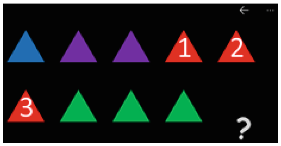
Activity Names	Questions	Activity Names
Colorful Circle 	(Left) "Please tap all **blue** circles." (Right) "Please put rings on the images with same colors."	Matching Color 
Shape 	(Left) "Please tap all **triangles**." (Right) "Please move stuff into corresponding area."	Left or Right 
Organizing Circles 	(Left) "Please move circles into corresponding baskets." (Right) "Please tap all big circles."	Circle Size 
Stick Size 	(Left) "Please tap all long sticks." (Right) "Please tap the highest building."	Size in Life 
Circle to a Basket 	(Left) "Please put all **green circles** into basket and count numbers at the same time." (Right) "Please count all red triangles."	Counting Stuff 

Fig. 1. The screen short for each activity (Color figure online)

Image Component Consideration. Children with autism are having some difficulties on differentiating similar things [13], so we will avoid any ambiguity among shapes and colors. The common shapes such as circles, triangles, squares, pentagrams, sticks and familiar cartoon characters are used in this application. In addition, only familiar colors are presented in the images.

Speech Generation. Considering that children with autism have lagged ability to recognize written words [2], verbal instruction is more frequently used since it is more user-friendly to them. The speech includes game instruction and feedback (reminder, warning, and praises).

Table 1. Activity description and its categorized domain.

Domain	Activity name	Description
Color recognition	Colorful circle	Various circles are displayed on the screen, and players are required to click all circles with certain color. With the growth of difficulties, the amount of circles will increase and more colors will be presented
	Matching color	Several cartoon images and rings are shown in the screen, players are required to 'catch' all cartoon images using the correct (same-color) ring
Understanding size	Circles	Users are asked to click either big or small circles. A larger number of circles and colors will be presented when the activity becomes more difficult
	Sticks	Users should click either long or short sticks according to the instructions
	Size in life	In this activity, three scenes will be displayed, and each scene has three common elements (trees, buildings, people, and animals). The user should distinguish which one is in tallest, shortest, or middle size
Recognizing shape		This activity requires cognitive skills to distinguish different shapes, circles, pentagrams, triangles, and squares
Classification	Left or Right	In this activity, users are required to move circles into correct areas matched their color
	Organizing circles	Users are asked to sort circles into the areas matched their color. If a circle is placed in a wrong area, the application will alert the user to put it back to its original location
Counting	Circle to a Basket	Users are required to put circles into a basket according to the instructions. The game will count the number of circles in the basket
	Counting Stuff	Users will learn to count the number of the shapes in the same color

3.3 Data Collection Module

Since the game is intended to support classroom activity, we record every user's manipulation and store it into a local CSV file. Figure 2 shows the sample of collected data. The last column shows whether the user correctly tapped a square or not (recognizing shapes). Since, at present, the system does not support multiple players, therefore, each user's data in multiple sessions will be uniquely stored (Fig. 2); user log-in is required to facilitate further analysis. The collected data is an essential reference for teachers to assess the math and cognitive ability of children. Additionally, it may also be used on the behavioral analysis of children with ASD.

In order to protect user privacy, the real name of children will be encrypted using one-way hashing algorithm, and the encrypted identity (the left-most column) is used to distinguish different users.

User	Level	Start Time	Step	Time	Container	Color	PositionX	PositionY	Status
dz5J2vSvlg7wuE1	3	2018/1/27 22:42:06.9	1	2018/1/27 22:42:09.6	square	orange	1013.342	687.3196	T
			2	2018/1/27 22:42:12.2	square	green	659.9892	341.9843	T
			3	2018/1/27 22:42:15.8	triangle	orange	1002.003	369.3102	F
			4	2018/1/27 22:42:17.9	circle	yellow	1329.314	708.6362	F

Fig. 2. Data sample

4 Conclusion and Future Work

In our present study, our aim is to build a mathematical and cognitive training software for children with autism. We have already designed 10 activities in 5 categories, and we are preparing to develop additional activities in the future. We also plan to build a recommendation module that can propose the next activity and the difficulty based on children's past performance. Moreover, we tend to collect user behavioral data for the evaluation of their performance and further analysis. Our future work includes the comparison between children with ASD and TD children, that is, the response time of each step, positive and negative attitude towards the game difficulty, number of failure in the game, manipulation habits, etc.

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Aging and HCI

The Research on the Application of Incentive Mechanism in Interactive Design of Rehabilitation Products for Elderly Stroke Patients

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Abstract. The challenge of aging has become increasingly serious in today's China. Among the elderly population, stroke is a disease with characteristics of high incidence, high morbidity and high mortality. Based on the understanding and analysis of aging users and stroke rehabilitation status in China, this paper discusses the way to improve the interaction between the users and the product, so to provide the elderly patients with more convenient, relaxed and interesting experience, as well as a positive and optimistic atmosphere through focusing on their emotional experience and the real needs. To achieve these, the incentive mechanism is introduced. The aim is to help the elderly restore activities of daily living and return to society soon through a more scientific and humane way. Moreover, this paper attempts to explore the interaction design approach and application measures based on the incentive theory, and provide reference for the design and development in this field.

Keywords: The aged · Stroke · Rehabilitation · Incentive mechanism Interaction design

1 Introduction

China is facing an increasingly serious challenge of aging. 241 million Chinese people are aged 60 and above, accounting for 17.3% of the population [1]. Stroke is a cerebrovascular disease with a high incidence among the middle-aged and the elderly. It is predicted that, by 2030, China will have 31.77 million stroke patients. Besides, inadequate prevention and intervention lead to high incidence of disability. Compared with the recovery rate of over 80% in developed countries, 70% to 80% stroke patients in China cannot live independently because of hemiplegia, aphasia and different levels of disability. Patients with Severe disability accounted for about 40% of the total [2, 3]. A large number of patients with stroke will generally have one or more kinds of obstacles, such as motor disorder, speech disorder, cognitive disorder, psychological disorder, etc.

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Yet Medical science has proved that timely, continuous, standardized and reasonable rehabilitation procedures and rehabilitation programs suitable for the patients can reduce the disability rate of patients, reduce the incidence of complications, promote rehabilitation [4]. This can also improve patients' quality and satisfaction of life, reduce potential nursing costs and save social resources. Therefore, the question of how to provide better rehabilitation treatment and services for elderly stroke patients is of significant meanings and challenge.

2 User Needs Analysis of Rehabilitation Process and Rehabilitation Products for Elderly Stroke Patients Based on Incentive Mechanism

2.1 Incentive Mechanism and Its Basic Process

Motivation Mechanism is also called Motivation System. It was originally a western management mode, guided by the motivation principle of psychology, with management psychology and economics as the core. According to the theory of incentive mechanism, the incentive subject takes the corresponding incentive measures to the incentive object in order to achieve the established purpose, so that the motivation of the incentive object can be produced, maintained and reinforced. An effective incentive mechanism emphasizes endogenous motivation rather than simple external motivation [5]. It is an excellent and important way of motivating people to achieve their stated goals, and continuous improving work efficiency.

In modern rehabilitation medicine, the rehabilitation exercise therapy based on central nervous system restoration has been proved to be the most basic and active rehabilitation therapy for stroke by clinical rehabilitation medicine. It is also the most widely used treatment in rehabilitation medicine at present. The stimulation mechanism can achieve better rehabilitation effect by strengthening the central nervous system.

The basic process and mode of the Motivation Mechanism are driven simultaneously by several factors, namely, need, internal driving force, inducement and purpose. Incentive mechanism reflects the interaction between incentive subject and incentive object through a set of rational system.

2.2 Analysis of Treatment and Rehabilitation Process

2.2.1 Rehabilitation Process of Elderly Stroke Patients

Generally, the rehabilitation process can be divided into five stages: early stroke, stroke palsy, stroke spasm, relative recovery and sequelae. Wheelchair, orthodontic appliance, etc. will be needed during the sequelae stage 6 months after the rehabilitation. Therefore, the main rehabilitation recovery training focuses on the early three stages. During early stroke period, retarded body position and simple passive or active training should be applied. During the stroke spasm period, basic control training, coordinated training, muscle strength and endurance training should be applied. During the recovery period, limb control, exercise training, speed and refinement are required.

2.3 Analysis of Product Requirements for Elderly Stroke Patients

In September 2015 and October 2017, the research group investigated the rehabilitation departments of three Shanghai general hospitals, a rehabilitation department of a community hospital, a rehabilitation center and some elderly people from communities in Shanghai. In total, 380 questionnaires were distributed, and 354 valid questionnaires were collected. In this survey, the ratio of men to women are roughly equal, with 53% men. 10% of the respondents are over 80, 47% are over 70, and 43% are between 60 to 69 years old. Because some elderly patients with stroke have limited ability in movement and language, some of the questionnaires were completed by family members or rehabilitation doctors. The relevant findings are as follows.

2.3.1 Treatment Methods for Elderly Stroke Patients

The data shows that only 22% elderly stroke patients use the instruments, 32% uses comprehensive treatment. The rehabilitation treatment is mainly hospital counseling. The proportion of patients with continuous rehabilitation training is very low, while the workload of medical staffs is very large.

2.3.2 Evaluation of Rehabilitation Products

36.5% Rehabilitation users believe that variety of products cannot meet the needs of the rehabilitation, 54% believe that the rehabilitation products are not effective, 57% believe that the products are too heavy, 42% believe that the products are inconvenient in operation, 20% believe that the function is too simple, 56% believe that the products look like unfriendly machines. In majority, the elderly stroke patients believe the existing rehabilitation products lack variety and cannot meet the demand, with unsatisfactory effect, inflexibility, complex operation and there is a sense of panic, and dislike the appearance of the product. Some believe that the price is too expensive.

2.3.3 Expectations of the Elderly Stroke Patients

50.4% of the patients expect products to have timely feedback function. 58% expect illness records, 72% expect to use at home, 50% expect to have timely alarm or notification, 52% expect to promote family feelings and entertainment, 58% expect to receive instructions in the usage process. 38% expect the price to be not too expensive, 42% expect to improve loneliness and have more communication.

2.4 User Characteristics of Stroke Rehabilitation Products

2.4.1 Physiological Characteristics of Elderly Stroke Patients

The elderly patients in tardy period (that is, the early stage of stroke and the period of palsy) have features like loosen muscle, low muscle tension, weakened sensory functions, decreased intelligence, mental disorder and impaired autonomic nerve function, etc.

The elderly patients in spastic period begins to recover muscle strength. Part of the limbs can start to move, can drive the whole range of joint movement under the condition of weight loss, can complete the motion like turning around and sitting up in bed. The main purpose of rehabilitation treatment at this stage is to reduce and suppress spasms.

The elderly stroke patients in recovery period have less spasms, separated movements can be achieved by limbs. The patients can could walk, while there might be abnormal gait, namely cognitive ability obstacle, causing perception difficulty to live independently.

2.4.2 Psychological Characteristics of Elderly Stroke Patients

Stroke patients will be nervous, panic, depression at the early stage of rehabilitation. When the progress of rehabilitation is not obvious, they will be impatient and constantly complain as their willpower decline, and their dependence will increase. They will abandon themselves and refuse to participate in rehabilitation training. When the patient can gradually face up to reality, admit their physical defects and understand the rehabilitation process, there will be less negative emotion and psychological disorder. The patient will begin to cooperate with rehabilitation treatment actively, with active idea of striving for self-caring.

Stroke patients need more care and positive support from doctors, family members and society to help them recover soon. But it is not enough to guide and adjust patients' the negative psychology. It is also necessary to keep the elderly stroke patients in a positive environment in order to promote their optimism.

3 Analysis on Incentive Factors in the Rehabilitation of the Elderly Stroke Patients

The incentive factors of stroke rehabilitation for elderly patients are mainly divided into three aspects: elderly patients themselves, rehabilitation products, and rehabilitation medical staffs and family members (it will not discuss in this paper due to the limited words).The incentive factors of the elderly patients themselves are the center of the interaction between the product and the user. The incentive factors of the rehabilitative medical staff and the family members, and the incentive elements of the rehabilitation products are the external. They will stimulate internal factors based the cooperation between the two. Only the combination of internal and external incentive elements can promote the effective advancement of the complete rehabilitation process of the elderly stroke patient.

The qualitative research on users in interactive design generally includes five aspects: Activities, Attitudes, Aptitudes, Motivation and Skills. According to the inspiration of incentive mechanism, the use of stimulating rehabilitation products is a persistent reinforcement of rehabilitation in terms of Activities, Attitudes and Motivation for the elderly stroke patients. According to the incentive theory and the particularity of the elderly stroke patients, the interactive design should adopt both the means of positive reinforcement and negative reinforcement, and map them to the incentive elements in design.

3.1 Internal Incentive Elements for Elderly Stroke Patients

The internal incentive elements mainly include: expectations and confidence, recognition, rights, attribution and inclusion, attention, satisfaction, sense of achievement.

Elderly patients hope to return to normal life and society through rehabilitation. In the rehabilitation process, they hope to understand the progress of rehabilitation. After completing the rehabilitation task, they hope to get the affirmation and guidance of the medical staff. Timely feedback and guidance will encourage them to be more confident and concentrate on rehabilitation training, and get a sense of satisfaction and achievement. It will help them to restore the confidence of surviving and overcoming the disease.

3.2 External Incentive Factors Based on Rehabilitation Products

The external incentive factors mainly include: physical characteristics,control, fault-tolerant and feedback. The appearance, color, texture and other external physical manifestations of rehabilitation products make it easy for elderly patients to accept and adapt. The operation should be simple and easy to use. The controllability is strong, and timely feedback of rehabilitation information can be corrected for misoperation without friendly measures. There will be failures, letting them feel that they are respected. All these can weaken or even eliminate their fear and conflict of rehabilitation to a certain extent, trigger their interest, and increase their expectations for rehabilitation.

4 Application of Incentive Mechanism in Interactive Design of Rehabilitation Products for Elderly Stroke Patients

4.1 The Implementation Framework of Incentive Mechanism in the Interactive Design of Rehabilitation Products for Elderly Stroke Patients

On the basis of clarifying the elements of rehabilitation motivation for the elderly stroke patients, the author divides each rehabilitation training process into three stages: initial, development and end, and analyze along the timeline. The framework is separated into internal and external motivational factors, and the factors influencing the rehabilitation effect on elderly stroke patients. These correspond to the three levels of initiation, maintenance and strengthening of the incentive mechanism. The model of the rehabilitation incentive mechanism for the elderly stroke is put forward in Fig. 1.

Since stroke rehabilitation for the elderly is a long period of treatment, rehabilitation training also needs to be carried out continuously, from passive treatment to active movement. Therefore, the three stages of rehabilitation training in this model are continuous circulated until the patient is fully recovered. Only when the internal and external motivating factors work together can they bring stronger incentive effect, so that the elderly patients can recover their mental and physical functions happier and faster.

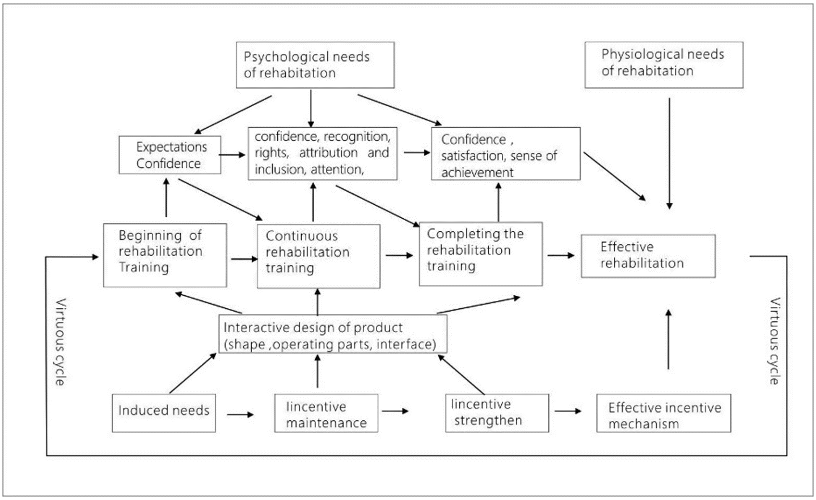

Fig. 1. The model of incentive mechanism of rehabilitation products for elderly stroke patients (Source: author)

4.2 Interactive Design Measures of Rehabilitation Products for Elderly Stroke Patients Based on Incentive Mechanism

The design measures mainly follow the incentive mechanism and revolve around the goal of creating a virtuous circle, from analyzing users' demand to strengthening their self-rehabilitation consciousness and behavior.

4.2.1 Meet Individual Rehabilitation Needs with Scientific Orientation

Reasonable rehabilitation orientation can make the patients accept it quickly, and can recover their mental and physical functions more effectively. It can be reflected in two aspects:

Firstly, rehabilitation doctors can provide users with personality rehabilitation training goals according to the elderly stroke patients at different stages of rehabilitation, specific symptoms, impaired function or limbs, so to deliver professional rehabilitation guidance to patients.

Secondly, rehabilitation doctors can provide the patients with functional- and environmental-matching rehabilitation products according to the rehabilitation plan for elderly stroke patients.

4.2.2 Stimulate Rehabilitation Needs with Reasonable Semantics and Safe Functional Structure

According to the psychological characteristics of the rehabilitation phase of stroke patients, the shape of the product,as an external incentive element at the demand-inducing stage in the model of incentive mechanism should reflect as far as possible the sense of affinity, trust, science and technology, and security. For example, the shape should be round and concise, with warm or clean color. The materials should let the users feel the warmth and caring. In the design of functional components and operating methods, it should be clear, concise, accurate, so that patients benefit from receiving information and trust the product, and their need for rehabilitation can be simulated. Safety is an important feature of medical products. The stability of the hardware and the software interface should be ensured to avoid unnecessary shock or other negative effects on patients.

4.2.3 The Rehabilitation Behavior Guided by a Hierarchical Rehabilitation Model

Rehabilitation treatment is a long-term, continuous process, following the incentive mechanism from initiation, maintenance to reinforcement. Correspondingly, the settings of rehabilitation product function and interaction design should follow the steps from simplicity to complexity, from completely passive, assisted-active, to completely active anti-resistance exercise, so to prevent elderly patients from falling self-confidence, inferiority and abandonment of the rehabilitation due to difficulties and failure in operation. Therefore, the design of rehabilitation products should be based on the rehabilitation plans and rehabilitation needs of different patients, and set the multi-level functions, order, duration, frequency and intensity of the products. This can keep the patient in the virtuous cycle of taking the challenge, proof of competency, taking further challenge, thus enhance the difficulty of training, as well as maintain and strengthen patients' confidence in rehabilitation. Based on the types and means of rehabilitation, a variety of functional models can be set up in the product design of rehabilitation products. Even for the same rehabilitation condition, multiple types of detailed training models can be set up for selection and setting, so to improve the pertinence and practicability of the rehabilitation program.

4.2.4 Maintaining the Incentive Process in a Multi-channel Interactive Manner

By utilizing multiple sensation channels and movement channels, it allows the users to implement rehabilitation training be convenient, quick and accurate. For example, interaction ways like easily-identified pictures, comfortable lighting and material, or friendly and clear sound can communicate information clearly. These methods are designed and used to coordination with the patient's operating behavior and psychology as much as possible, to avoid users' tension, anxiety and lack of concentration. Feedback content is reinforced by a variety of interactive means and forms. This can offset the elderly stroke patients' deficiency in the body and perception ability, and fully mobilize and balance the patient's'physiological resources'. When the patient is at a loss, light, sound and other information reminders to guide the patient to solve the problem. When the motion slows down, or when the patient is at a low exercise speed due to the low muscle strength, the motor can provide driving force to assist the patient to complete the training. Rehabilitation product design needs to express humanistic care and respect for elderly stroke patients and fully meet their special needs in order to maintain the use.

4.2.5 Simplified Interaction of the Operating System and Increased User Motivation

The muscle strength, body coordination and cognitive ability of the elderly stroke patients in rehabilitation stage decreased significantly, so the response speed of the product system of rehabilitation in the elderly stroke should be coordinated with the response speed of the nervous system of the elderly. The reaction speed should not be too fast; the operation interaction should conform to the life experience and thinking mode of the elderly patients, try to be concise and clear, intuitionistic and clear, reduce the part that patients need to think when using the product, Take instinctive action or habitual behavior, easier to master the operation. Keys and forms of operation semantic precision; operating parts controllable, easy to control; high product fault tolerance; data rendering graphical are all to give users a sense of accomplishment. Stimulate continued use of possible effective means.

4.2.6 Introduction of Entertainment and Fun Interaction to Increase Incentives

The elderly stroke patients lack patience for long-term rehabilitation training. This is unfavorable for them to return to social life later. The integration of entertainment and training meets the emotional need, and can temporarily divert patients' attention. This can improve the relationship between doctors and patients and the rehabilitation status effectively. In the design, games can be adopted to combine the rehabilitation process and actions with the scene, process and operation behavior, to encourage the patients to participate in the rehabilitation and thus improve recovery efficiency. It also has a good effect on post-stroke depression. It can also be set up as multiplayer games or entertainment, such as music activities, sports competitions, art shows, etc. The form needs to be decided based on patient's psychological needs.

(1) Task-oriented entertainment games

Among the many rehabilitation training forms, game is the most popular and attractive one. It also meets the needs of the elderly patients for the fun and quantification of rehabilitation goals. The variety of interaction and communication forms in games can reduce the learning cost and enhance the participation of the elderly stroke patients. These meet the requirements of the incentive mechanism model.

For example, simple rehabilitation games can be set up according to the flexion and extension of the patients' lower limbs. The plasticity and the brain function can be stimulated by the combination of interactive training and exercise. A wide range of types and content with regular updates can maintain patient's freshness and sustained attention.

(2) Participatory and collaborative

The characteristics of the elderly determine the fact that they love to participate in mass and cooperative activities. There is such a need among the elderly stroke patients, and they hope for the care. The rehabilitation games can adopt the double player training mode, so that the patients and patients' families can get involved, especially the young generation. This can not only improve patients' social communication and language ability, but also bring comfort psychologically, enhance the kinship communication and stimulate the recovery enthusiasm.

4.2.7 Providing Evidence for Sustained Rehabilitation Through Systematic Data Monitoring and Evaluation

Elderly stroke patients have longer treatment and rehabilitation cycles, and may also suffer from many other related chronic diseases, which require long periods of observation and recording. Intelligent rehabilitation products can track and record patients' actual rehabilitation data. After storage and analysis, more concise and accurate expressions such as curves and histograms are fed back to patients intuitively to let them understand the progress of rehabilitation. At the same time, these data are fed back to rehabilitative medical staffs, so that they have a better basis to develop a follow-up rehabilitation plan for the patients.

5 Conclusion

With the progress of economy and technology in China, the improvement of living standard and humanistic accomplishment, the rehabilitation medicine and aging industry will certainly develop rapidly, and the rehabilitation medical system will be more complete. As the link of interaction among the elderly stroke patients, their families, the rehabilitation institution and the medical staffs, the rehabilitation products for elderly stroke patient will be optimize in terms of its functional system, feedback mechanism and interaction mode, to bring relaxed and happy recovery experience. For the product design of the elderly, cooperation in design, medicine, psychology and other fields are needed to achieve real humanistic care, so to make the life better for the elderly.

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Study on the Layout and Function Allocation of Community Home Care Service Center in Nanjing

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Abstract. As a new type of pension model, community home care has developed rapidly in China in recent years. But at present, the domestic community home care service system is not perfect. There are many problems in the community home care service system, such as the lag of market development, the imbalance of demand and supply, the backward consumption level and the low quality of the service personnel etc. This paper studies the layout and function allocation of community home service centers in Nanjing, and compares two home care service centers in different communities. By analyzing the layout situation and the key factors affecting its functional configuration in two cases, this paper suggests that the community home care service center should integrate their resources and complement the functions with other centers in order to meet the needs of different elderly people, can not only improve the quality of their life, but also can improve the utilization of resources.

Keywords: Community home care service center
Layout · Function allocation

1 Introduction

China's aging level reached 14.9% at the end of 2013. With the sharp increase of the number of empty nesters and elders, the traditional family pension and institutional pension have been unable to meet the increasing needs of the elderly [1]. In the Construction of social old-age service system "12th Five-Year", China explicitly proposed the establishment of "community home care service system". The model of community home care provides a new way to solve the diversified needs of the elderly service. Taking the community home care service center as the carrier, it can not only enable the elderly to live in familiar environment, but also make full use of community resources, providing relatively professional pension services for the elderly [2].

Nanjing has carried out a lot of beneficial exploration in the construction of social home pension system. Such as "love table" "benevolence supermarket", "elderly activity room" etc. The elderly do not need to get out of the community to accept the elderly service, this greatly relieves the pressure of family pension [3].

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There are also many problems during the development of the community home care system. In 2006, the China Aging Research Center surveyed the needs of elderly for daily life care, health care, spiritual comfort and other services provided by the community home care service centers, and concluded that the elderly have great demand for these services [4]. For example, many community home care centers often serve young elderly, healthy elderly, self-care elderly, but lack of the services for elderly people who cannot take care of themselves. The pension facilities in some community home care centers do not conform to the size of the elderly, which leads to the low utilization of the pension facilities. Although some centers provide facilities and services for the elderly with different disabilities, but there is a big gap between the fees and the actual economic conditions of the elderly. There are also some centers lack of the services to the spiritual needs of the elderly, and can not provide relevant services such as cultural entertainment, education, and re employment [5], The quality of the service staff is also uneven [6]. In order to provide better service for the elderly, improve the utilization rate of resources, improve the quality of life of the elderly, Through the investigation of 8 community home care centers in Nanjing Gulou District, this paper study the layout and functional configuration of the community home care center, and at last give some suggestions.

2 The Current Situation of the Layout and Function Allocation of Community Home Care Service Center in Nanjing

2.1 Research Data Sources

This research data is from the questionnaire survey and in-depth interview last from September 2016 to November 2016, which is for 1014 elderly people who receive service from the community home care service center of 8 communities in Gulou District of Nanjing. The research includes the desire of the elderly and the layout of the community home care center, the content of service supply and the utilization ratio and etc. The 8 districts include the old district, the high-grade district, the district of staff and their family, the commercial district and so on. A total of 816 valid questionnaires were collected, and analysis the data by SPSS and EXCEL. *The following* Table 1 *gives t*he pension willing of elderly of different lifestyle. *The pension willing means that the elderly prefer the style of community home care.*

It can be found that there is a strong demand for the elderly in different life forms. Among them, the oldest old, the healthy and the low-income groups choose to receive services more than the others. Although the elderly in 8 communities showed strong demand for the elderly services, there was a significant difference in the needs of the elderly in different backgrounds, educational level and economic level. For example, the elderly with low income and low education level hope for more beds in centers, faster home delivery, more door-to-door care and so on. But the elderly with higher income and higher educational level hope to have more activities, more equipment, more learning activities, and so on. At the same time, the needs of elderly people in different types of community are not the same. The elderly in old districts often have a high

Table 1. The pension willing of elderly of different lifestyle (N = 816)(%)

Variable	Classification standard	Proportion	Pension willing
Gender	Male	48.5	84.5
	Female	51.5	86.5
Age groups	60–69	48	84.8
	70–79	42.1	84.7
	80+	9.9	85.7
Physical condition	Healthy	31.2	84.4
	Moderate inability	54.1	82.3
	Severe inability	14.7	81.6
Source of income	0–9600	21.6	87.3
	9600–36000	61.2	85.2
	36000+	17.2	83.3
Degree of education	Illiterate, primary school	52.5	83.3
	Junior school	25.5	83.5
	High school or above	22	85.4
Living environment	The old district	19.4	83.5
	The high-grade district	32.8	86.2
	The district of staff & their family	27.6	81.2
	The commercial district	20.2	82.8
Living condition	Living with spouse	54.1	85.9
	Living with children	30.8	82.6
	Living with others	2.4	82.6
	Living along	12.7	83.2

demand for living care, while the district of staff& their family has a greater emotional demand.

The survey of the layout of community home care centers showed that most elderly people were not satisfied with it. They think that the regional division of the center is not reasonable and the functional area is not clear. The problems show like the personal area is too small, which leads to difficulties in protecting personal privacy. The lack of partitions between public activities and restaurants often results in functional conflict. The low utilization area has larger area, and affects the utilization of functional space with high utilization rate. These problems make it impossible for the elderly to receive community services though they need them, and also cause a waste of resources.

2.2 Research on Community Home Care Center

This research investigated the services provided by community home care centers in 8 communities, including 20 items, such as food service, service facilities, and personal cleaning, etc. The study mainly investigates the demand for services and facilities, the supply situation, and the utilization of these services and facilities for the elderly. Table 2 shows part of the needs, supply and utilization of different services and facilities for the elderly. Use the service demand ratio (D) minus the service supply ratio (S) can be the difference between demand and supply, is called “Difference of demand”, the greater the difference shows the greater the gap between supply and demand. Similarly, service supply ratio (S) minus the service utilization ratio (U) is called “Difference of Utilization”, which shows the oversupply of service.

Table 2. Demand supply and utilization of community home care center project (N = 816) (%)

Service items	Service demand (D)	Service supply (S)	Service utilization (U)	Difference of demand (D-S)	Difference of utilization (S-U)
Food service	58.4	62.5	19.3	−4.1	43.2
Doing housework	49.6	62.5	12.1	−12.9	50.4
Bed supply	68.3	45.0	14.3	23.3	32.9
Supply of sports equipment	60.7	50.0	24.6	10.7	25.4
Emotional counseling	26.8	37.5	6.9	−10.7	30.6
Medical care	25.8	25.0	1.2	24.6	23.8
Agency agent	11.5	50.0	4.2	−38.5	45.8
Accompany chat	14.3	25.0	1.9	−10.7	23.1

Table 2 shows that the elderly have the highest demand for the Bed supply of the community home care center, up to 68.3%, followed by the demand for supply of sports equipment, which is 60.7%. The difference of demand and supply shows that community home care system currently exists the problem of oversupply of service. Although these community home care centers have a comprehensive, diversified service supply, but the demand and the utilization rate of the elderly for these services are not high. From the difference of service supply and service utilization, we can know that the service provided by the community home care center usually more than the service utilization. But in the process of investigation, it is found that due to the uneven distribution of resources and the mismatch of resources, the real demand is not satisfied, and the supply of existing services is far from being utilized.

3 Comparison of Two Community Home Care Centers

3.1 Comparison of the Elderly with Different Life Styles

This paper choose two community home care centers from A and B community as a comparative case, for A and B community are close and the elderly from two communities have different life style. This paper makes a series of comparative analysis and research on the layout, service supply and utilization rate, elderly service demand and service satisfaction of community home care center.

Most of the elderly in A community are retired workers in a shipyard, their education level is not high and have low income level. Their demands are mainly reflected in life care and medical care. The services they receive are relatively simple and think that basically meet the basic needs of life is enough. Most of the elderly in the B community are retired faculty members in a university, who have a high level of education and a better economic situation than the elderly in the A community. Their needs are not only the basic needs, but also the spiritual needs.

3.2 Comparison of the Community Home Care Centers

The community home care center of A community is not large, can only make 4 elderly living. (see Fig. 1) The living form is close to the housing, make the elderly communicate with each other easily, and can also reduce the resistance to the community home care service center.

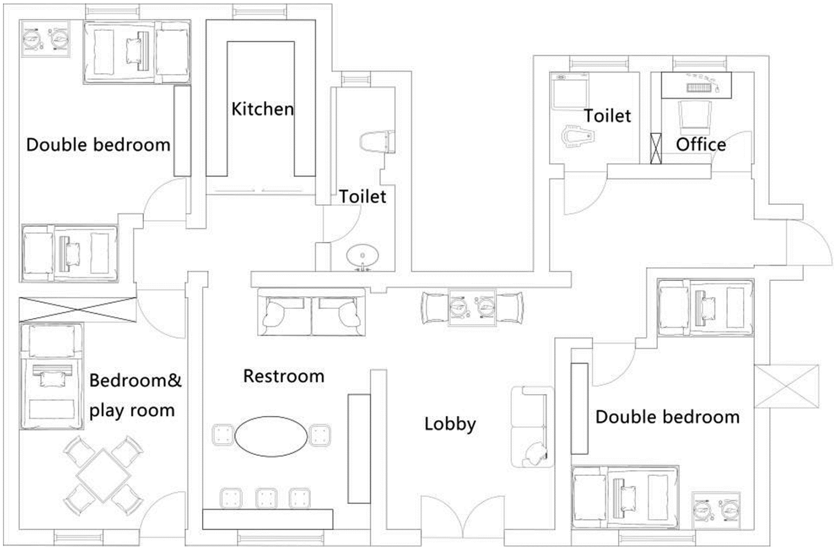

Fig. 1. A community home care center.

In addition to long-term care, the center also provides daytime care for the elderly, with up to 20 elderly could stay here during the daytime. In the leisure area, hall and recreation room are separated, the recreation room is set to a semi public space.In addition, the center has a chess and card room. In this chess and card room, the elderly can play cards or have a short rest in it. Because the area is too small, it can not provide more services for the elderly. The layout of the center is difficult to meet all kinds of needs of different disabilities, and the service content is single, and the pension function is not perfect. But in the actual survey, it is found that the elderly people in the A community have a higher satisfaction with the community home care center. The reason is that the service accepted by the elderly is the service they need. The service utilization rate is high, the supply and demand is matched.

B community home care service center is larger than the A community. The building is divided into three layers, which can accommodate more elderly people. (see Fig. 2) The service it provide include life care, entertainment, health care, and so on. There are many kinds of service content and professional staff, which belong to the medical and health care unit. Although the facilities of the B community home care center are more perfect and the nursing staff are more professional, the satisfaction of the elderly in the B community is low. For example, the high density of living reduces the personal privacy. The lack of consideration of the physiological state of the elderly in different situations has also caused a lot of inconvenience. Part of the functional area is large and empty, and it also increases the loneliness of the elderly.

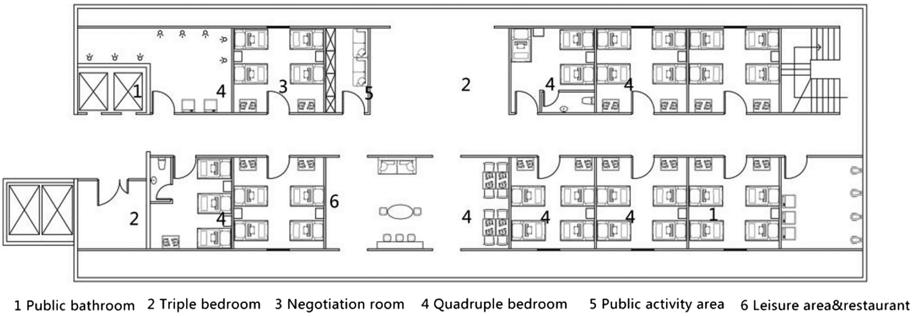

Fig. 2. B community home care center

3.3 Suggestions for Promotion

Through the comparison of the layout and functional configuration of home service centers in two different communities, we can find the phenomenon of the mismatch between the supply and demand of the service. In order to improve the utilization rate of service resources and enhance the satisfaction of the elderly, we need to start from the actual needs of the elderly, plan the layout suitable for the elderly of different life-styles and fit the functional configuration of the elderly in the community.

First, Classify the elderly in different life forms in the community, and provide community characteristic service content supply according to the service demands of the elderly in different communities. According to the characteristics of the whole community, we should make reasonable allocation of resources and improve the utilization rate of services, so as to avoid the problem of low utilization rate happened in the community home care service centers.

Second, merge the functional areas of low utilization into a new multifunctional area and make full use of the limited space. In this way, it is possible to avoid unused functional partitions with low utilization, can change the function of space flexibly.

Third, the pension resources should be allocated according to the needs of several communities in a certain range. The flow of service resources can not only achieve resource interchange, efficient utilization, reduce idle and waste, but also help the elderly to communicate between different communities, so as to achieve shared economy and shared service resources. For example, in two adjacent communities, the A community lacks a pension service, while the B community's service resource is just idle or the utilization rate is low, which allows the elderly in A community to accept the services provided by B community, so as to achieve the mutual flow of pension resources.

4 Conclusion

Based on the study of community home care service centers in 8 communities in Gulou District, Nanjing, Jiangsu, we found that there are more or less the current situation of community home care centers, which do not conform to the different life styles of the elderly. The content of service supply can not keep up with the demand for the elderly, and the utilization rate of service is far below the content of service supply, the phenomenon of lagging development and contradiction between supply and demand is formed. Then, through the comparison of two home care centers in different communities, it is found that the functional allocation of community home care centers should be classified according to the different life styles of the elderly in the community, so as to provide services for the elderly with practical needs and improve service utilization. In addition, the layout of the service center should be miniaturized, diversified and scattered. Through cross regional resource integration, complement functions with other service centers, can we make the centers miniaturized and specialized, so as to meet the different needs of the elderly.

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ABLE: An Arts-Based, Interactive Physical Therapy Platform for Seniors with Dementia and Frailty

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Abstract. ABLE is a gesture-based interactive platform that transforms physical therapy into game play or art creation – for example, virtual painting or digital music creation. ABLE targets older adults with dementia and fragility, employing art and gaming to encourage playful, physical interactions with family members, peers and care providers. The project aims to forge synergy between physical interaction and creative engagement to produce a range of positive effects; the platform aims to reduce boredom, agitation and social isolation while enhancing physiological, affective and cognitive health. Our interdisciplinary team of medical and health scientists, computer scientists, humanities scholars and artists together contribute the aptitudes required to develop ABLE with attention to the specific needs of these users, to design wearable biometric sensors for data capture, and to develop the app in a consumer-friendly interface appropriate for independent use in residences and homes. We are also developing ABLE with physical therapists, to create a menu of scalable physical therapy exercises designed to enhance strength, balance, and agility for variable populations with frailty and dementia presenting with low to severe impairments. As well, we are co-developing the platform with a range of participants (hospital patients, supported housing residents and home residents) to ensure that the experiences are pleasurable and encourage sustained use of over time. Offering a host of physiological, affective and social engagement benefits, ABLE aims to assist older adults, as they age, to stay mobile, active, and engaged with community and the people they love.

Keywords: Physical therapy · Gerontology · Performance art

1 Introduction

ABLE is a collaborative project, uniting researchers across health science, computer science, neuroscience and humanities to design experiences for frail older adults to enhance cognitive, physical, and emotional health. In this project, we employ a design thinking approach to develop an interactive exercise platform to tackle the growing needs of community and home dwelling older adults and their caregivers. Our targeted populations are frail geriatric outpatients, many of whom also experience dementia, at

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St. Peter's Hospital, Hamilton, Ontario (Canada) and frail seniors in need of home-based rehabilitation services.

Frailty can expedite the pathway to disability due to physical deconditioning, impact objective and subjective health, and can reduce social participation. Art, music and game play are powerful therapeutic activities that motivate participation in physical activity and may have synergistic effects, enhancing cognitive, physical and emotional health. We are creating a variety of arts-based movement experiences using gesture based and biometric capture technologies to translate physical therapy into art engagement. In this experience, seniors with dementia and/or fragility will engage in physical therapy exercise with a care giver or family member that produces an effect; in other words, interactive movement produces a live digital painting, a musical composition or engages players in digital gaming with peers and family members. The project aims to advance the design of the Movement and Biometric Feedback Platform ("the Platform") to produce artistic expression, gaming, movement, and interactions for frail seniors and to assess how the Platform impacts cognitive, physical, and emotional parameters in this population. In engaging these seniors in art-based practice and interaction, we anticipate the interface will offer physiological or rehabilitation therapy experiences that are pleasurable, which in turn, will be self-initiated and sustainable. In engaging participants in shared peer and intergenerational experiences that employ arts and play, we also seek to counter social isolation and enhance family and community bonds. Employing an interdisciplinary, design thinking approach, we incorporate diverse frail senior participants in the research design of movement and aesthetic solutions to ensure the platform is easy to use, pleasurable and effective.

2 Background

Frail, older adults with mobility impairments or who have fallen often receive a referral for home care physiotherapy to improve functional independence. Physiotherapy can help older adults improve their mobility through therapeutic exercises, enhancing strength and balance. [1] However, delivery of home care physiotherapy is often limited to three to five visits where the physiotherapists teach exercises and leave written instructions on how to complete them. Afterwards, older adults and their caregivers (e.g., personal support workers, spouses, family members, friends) are expected to continue exercising on their own. Consequently, older adults may stop exercising because they and their caregivers do not know how to do the exercises, are not motivated to exercise independently, or do not know how often to exercise to gain maximum benefits. As well, older adults residing in retirement homes increasingly experience significant cognitive and physical impairments. A recent study revealed that in retirement homes in the Hamilton-Niagara region, over 45% of residents had mild to moderate dementia. Many residents also had greater physical impairments than those living at home, had fallen recently, and demonstrated aggressive and wandering behavior. As a result, retirement home residents are at high risk for institutionalization in long-term care.

ABLE invites older adults with dementia in retirement and home residences to engage in physical exercise as meaningful art experience, that produces a virtual painting or sound score. Promising recent research suggests a synergistic effect arises from combined movement, social engagement and art practice. Engaging clients in dance and movement has been shown to improve emotional wellbeing, depression or anxiety [2], and art and dance stimulate memories in dementia clients, minimizing feelings of distress and disorientation, and improving health outcomes [3]. Making art creates more dramatic outcomes than simply viewing [4], enhancing agency and lessening social withdrawal and poor communication. [5]. A systematic review showed that using virtual reality games had significant positive effects on balance and mobility, and benefits for fear of falling, reaction time, and muscle strength compared to traditional exercise programs.

The ABLE platform responds to research showing that physical activity and movement reduces functional decline. As well, creative and social engagements have been shown to improve depressed mood and poor quality of life and decrease social isolation, all of which are associated with risk of functional decline and institutionalization. ABLE seeks to confront these problems by facilitating interaction with family members and care providers, reducing seniors' boredom and agitation. With these objectives, ABLE aims to facilitate older adults to remain independent, while maximizing quality of life within their location of choice as long as possible, whether that is a retirement home or their own home.

Our initial ABLE prototype has been tested in various settings including Baycrest Hospital, Toronto. Our group employed participant feedback to develop arts-based experiences that engaged seniors with both fragility and dementia. The research revealed the seniors' enthusiasm for engaging in the platform, in sustained physical engagement, and interest in varied digital art experiences. In this final iteration of the project, ABLE will provide (with video instruction) professional, scalable physical therapy exercises to address the needs of populations with fragility and dementia, to decrease pain, increase mobility, improve mood via an exercise experience that is social, pleasurable and packaged in a consumer-friendly plug and play form.

3 Hardware and Software Networking Interface

The project development occurs in Pulse Lab, McMaster University, which is outfitted with a movement space, and the ABLE Platform, including, biometric inputs, data projector, projection screen, speaker system and private Local Area Network (LAN). This wireless mobile Platform will also be set up at St. Peter's Hospital (Hamilton, ON) for on-site client engagement and feasibility testing or in at home environments, by simply opening the app on a mobile phone and connecting it to the family television screen.

3.1 ABLE Platform Technical Specifications

The ABLE Platform has several component categories that work symbiotically. The flow of this data generation and feedback can be seen in Fig. 1. The biometric sensor arrays contain wearable wireless connectivity through Wi-Fi or Bluetooth that use principles of ergonomic design and wireless charging for increased ease of use (see Figs. 2 and 3). Data sonification and visualization is accomplished via several data processing programs that generate real-time audiovisual feedback for the participants to aid in their exercises and create an enjoyable experience. The LAN network created in a participant's living space creates a seamless system that integrates a main television, and the participant's, a caregiver's or therapists' mobile smart device. The mobile device is used as an interface for interaction or a secondary source of information for therapists and caregivers, revealing real-time data and other information to aid in rehabilitation.

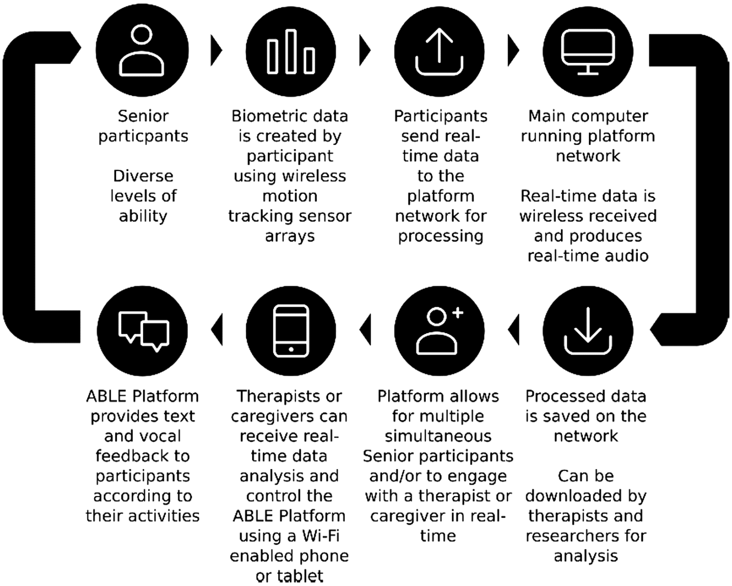

Fig. 1. An outline of the participant experience when using the ABLE Platform

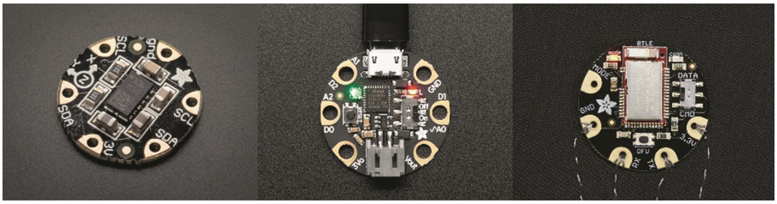

Fig. 2. Adafruit flora series hardware to create a Bluetooth, Arduino based, motion tracker using an accelerometer and compass module. Photos: Adafruit.com

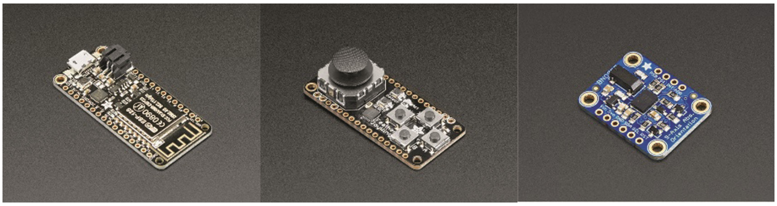

Fig. 3. Adafruit feather series hardware to create a Wi-Fi, Arduino based, motion tracker and joy stick based controller using a high accuracy 9-DOF (Degrees of Freedom) board to track the subtle movements of a user in 9 degrees of motion. Photos: Adafruit.com

4 Designing Rehabilitation for Motivation and Sustainability

ABLE takes into consideration barriers to exercise participation for frail, older adults with mobility impairment, and the lack of safe and accessible exercise facilities for this population. [4] While interactive technologies offer promising potential solutions to overcome these barriers, uncertainty remains around the feasibility of implementing interactive technology within the homes of frail, older adults. While it has been suggested that interactive technology can be used to easily engage hard to reach populations in exercise, [6, 7] few studies have explored the feasibility of using interactive technology with frail, older adults in their homes. Indeed, a recent systematic review identified that there is insufficient evidence to generate recommendations for using virtual reality games exclusively at home. [8] Another 2014 systematic review of Wii games8 identified only two studies that were conducted in the home environment. [9, 10] The authors called for a need to consider age, balance performance, comorbidities, and cognition when examining future interactive technology applications in the home environment. [11] Our study will fill this gap, by testing the feasibility of using interactive technology in the homes of frail, older adults.

Researchers have discovered interest by older adults in digitally based exercise programs. Research shows that computer-based, interactive technology, such as virtual reality and video games, and interactive technologies can improve adherence to, enjoyment, and outcomes of exercise. One study demonstrated 30% more attendance at exercise sessions when interactive video games were used compared with conventional exercise programs. [12] Researchers posit that interactive technology makes exercise more enjoyable since participants are directing their attention to the experience rather than the physical impairments they may be experiencing, [13] and suggests that motivation is key to improving functional outcomes. Indeed, interactive technology has also shown superior benefits to physical performance when compared with standard exercise programs. For example, a recent systematic review revealed that participating in computer-based virtual reality games had significant positive effects on balance and mobility, and helped to prevent fear of falling, to improve reaction time, and to lower extremity muscle strength compared to traditional balance and resistance exercise programs.

Finally, most interactive technology applied in the rehabilitation context offer sports-related activities not appropriate for most seniors; a 2014 systematic review showed that the most common Wii programs were soccer heading, slalom ski, and tight rope walking. [11] ABLE, differently, seeks to harness research showing that art and music are powerful therapeutic activities that motivate participation in physical activity and may have synergistic effects, enhancing cognitive, physical and emotional health. [5, 14] In engaging participants in art and music experiences created by physical movement (i.e., exercises), we expect to see added benefits, especially for older adults who identify more with and are better suited for arts-based (versus sports-based) experiences. The ABLE platform will provide opportunities for artistic expression in conjunction with physical movement, potentially increasing pleasure in, and in turn, the efficacy of this exercise platform for older adults in their homes.

5 The Interface Experience and Platform Advancements

The ABLE software application innovates by offering older adults with fragility or dementia a selection of engaging exercise and rehabilitation experiences. The ABLE platform consists of a wireless (clothes-clipped) sensor, a tablet, a mini-computer, and a screen (e.g., television). When the older adult moves, the wireless sensor transmits data to the mini-computer which produces visual effects (on the screen) or sound (on speakers) or game responses (on screen and speakers). A digital tablet is used by the older adult and/or family members to begin the interaction and to choose their desired exercise and art/game experience (e.g., painting, music making, or game play).

The app menu is designed to be clear and user friendly. The app will allow users to choose the type of physical therapy experience they wish to use and take part in interactive video training with their therapist of caregiver. The app will allow users to choose the numbers of users in the space ranging from one, to two players, or a team/gaming experience. The ABLE menu will also offer four types of interactions: musical or sound creation, digital painting, hybrid music/painting experience, and multi-person/intergenerational game. The app will feature a touch-based interface, offering a simple menu packaged in a clean visual design.

ABLE is an advancement in existing digital exercise systems, providing physical therapy regimes designed to meet the targeted physical and affective needs of seniors with fragility or dementia. Exercise experiences on the Nintendo Wii and games offered by Xbox Kinect, and other rehabilitation platforms provide sports experiences that are not designed or able to meet this population's needs.

As users engage in their physical therapy experience in the space, the ABLE platform captures (and stores) gesture, exercise and movement data and transforms it into art and game "feedback." Distinct therapy movements (raising arms, standing up, squatting, pressure ball use) create an effect—a brush stroke on a painting, adds percussion to a musical score, or enables interactive gameplay. Biometric sensors (e.g., heart rate monitor) can be added, capturing heart rate or breath data allowing less mobile individuals to trigger effect, for example, creating rhythm in a musical score or a painting stroke. ABLE can be used alone or interactively; it makes physical therapy engaging—in each "move", the "player" makes a contribution in an art creation or a move in a game play. Finally, the app will capture the data from each physical therapy experience, enabling the participant to gauge and understand personal improvements in varied metrics (strength, mobility, agility, etc.) acquired with the use of ABLE over time. Finally, ABLE is affordable and has a low barrier to access, reducing the cost of physical therapy, allowing users to accurately remember exercises and practice them with caregivers or family. With its easy to use interface, ABLE will allow any family member or caregiver to click visual icons on a computer or tablet screen to select a desired exercise and art experience or game and get on with playing.

6 Data Capture and Analysis

Our in-progress, proof-of-concept study focuses on the development and feasibility of the Platform for frail older adults. A test cohort of approximately 20 older adults will be recruited and will pilot this platform over 6-months. Each older adult will receive three visits with a physiotherapist in their home. The first visit will be to prescribe the home exercise program and to familiarize the older adult with the technology. The exercises will be designed to improve functional mobility via challenging lower extremity strength and balance in a multicomponent exercise program. The most effective exercise programs for preventing falls for older adults include balance and lower extremity strengthening exercises. The exercises will be scaled to the physical functioning level of the participant, as determined by their performance on the baseline measures of balance and strength. For example, a squat exercise, which strengthens the quadriceps and hip extensors, can be scaled for lower functioning participants by having them start with standing up out of a chair using their arms. Scaling of this exercise would be standing without using their arms, standing from a higher chair to a standing from a lower chair, and doing a squat without weight and then adding weight. The physiotherapist will then visit one week, and one month later to troubleshoot any technological issues, and to progress the exercises where appropriate.

The ABLE platform is designed with gesture-based sensing and a wearable device able to capture a range of biometric data (heart rate, heart rhythm, breath, appendage placement, acceleration and speed, EEG, etc. In testing ABLE at-home and in clinic patients, physical therapists and our designers will use the platform to capture user data, and to chart progress in physical therapy regimes toward achieving greater balance, strength, agility, speed, range of motion and cognitive abilities. In forthcoming data capture and analysis, we will evaluate outcomes that measure improvements in frailty, lower extremity function, mobility, cognitive and emotional function, and activities of daily living, as well as user's experience and pleasure in engaging in the exercises and the art-based experience.

7 Anticipated Outcomes and Benefits

Primarily, we seek to gauge adherence to the prescribed exercise protocol by participants recruited and retained in the pilot study. Secondary outcomes are physical performance and balance measured by The Short Physical Performance Battery (SPPB) [15], and the Balance Outcome Measure for Elder Rehabilitation (BOOMER) [16, 17]. The SPPB assess lower extremity function through measures of balance (timed static stance in feet together, semi-tandem and tandem with eyes open), gait speed, and the time to rise from a chair. The BOOMER is comprised of 4 measures: step test, Timed Up & Go test, Functional Reach Test, and Timed Static-Stance Feet-Together Eyes-Closed Test. The SPPB and the BOOMER will be measured at baseline and after three months by the research assistant in the participants' home and were chosen as they represent tests that would typically be done by a home care physiotherapist. Finally, participants and their caregivers will provide feedback on the platform and participation in the pilot study via one-on-one qualitative interviews completed during the last study visit.

We also employ user interaction design and proof of concept testing in clinic and at home settings to assess user's abilities to set up and use the ABLE platform independently. Via observation, field testing and family interviews, we will assess seniors' and family/caregivers' assessment of pleasure in the art-based experience, and value in the social engagement, as well as physical therapy impacts, and the potential that ABLE will encourage sustained use for varying individual of diverse ability and needs. Those results will enable our team to report on ABLE's success in its 4 key objectives: decreasing social isolation and increasing family interaction; experiencing pleasure and creative engagement via art making or game play; adhering to regular, effective exercise or physical therapy; and enhancing mood for this population. As well, our study will assess ABLE's impact in decreasing mood disorders and aggressive behavior in these populations, and to improve home and residential relations for participants. With those findings, we hope next to provide recommendations on how digital technologies such as ABLE can help to remedy the shortage of affordable and accessible health and rehabilitative care serves, and in turn, reduce the social and financial strain on families, residential institutions, and governmental health care systems created by fragility and dementia in our growing populations of seniors at home and in care.

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Entertainment Design of Elderly Community Oriented to Maker Space in University Libraries

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Abstract. Due to the intensified aging of Chinese population, the ratio of elderly people in China's total population has been increasingly in each year, Elderly community, which has developed into a relatively mature way of old-age care in developed nations such as European countries and the US, is still a relatively new topic in China. Therefore, How to build an entertainment space may be a problem.

The maker space in university library is a "destruction and rebuilding" of the original maker space, it reflects more of the auxiliary role in innovation process, while elderly community is the type of elderly living space integrating elderly care and living into one. The 3D printer and digital creation technology in maker space are a type of technology that quickly transforms thoughts into physical products. While enriching the entertainment activities of elderly community, it is necessary to build certain technological method to enable elderly people to, through simply operations, transform their thoughts into physical products. Such unique maker-space-oriented community space design, and its provided methods for elderly entertainment, or its comprehensive keynote of helping people to exercise their physics and mind, is similar to that of maker culture. The embedded-type maker service that is promoted in maker space of university library is to provide corresponding assistance and help by analyzing readers' innovative thoughts, by integrating such service model into some service models in entertainment space, it could help elderly people to complete their needed creation in the process of entertainment.

So, building the entertainment space in elderly community into an unique maker space model like that that in university libraries and strengthening the external world's physical and psychological stimulation to them could effectively help slowing down elderly people's intelligent degeneration and organ aging rate. This thesis implements detailed survey on elderly community, finds its existing problems and studies the related entertainment methods, meanwhile, detailed analysis is made on the related characteristics of the maker space of library, and such type of innovation method represented by maker space is integrated with the entertainment way of elderly community, and the entertainment space of elderly community is finally created to make arrangement and allocation of its different activities.

Keywords: Maker space · University libraries · Elder · Entertainment design

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1 Introduction

The maker space, also known as hacker space or innovation lab, is a platform for people to innovate. Technological production, scientific research and development, creative sharing are all makers' behaviors. Its entity originate from a novel experiment, initiated by that MIT bit and atom research cent in 2001, a micro-assembled laboratory, a micro-factory having almost any product [1]. However, it is advantageous to construct the maker space in the university library. It supports the concept of knowledge exploration and innovation practice, ability standard, eager to learn the staffing, perfect functions and rich resources and a guest space required for the perfect fit, and passenger space at the same time also to the innovation of the library service and the transition has brought new opportunities [2].

With the development of social economy and science and progress, the population "aging" has become a common phenomenon in today's world. For China's national conditions, the policy of "family planning" has been implemented. The proportion of the elderly population in the total population has been increasing year by year. This problem in the economic developed area than many impoverished region is serious, the developed countries are heavier than the developing ones, and the cities are heavier than the rural ones. The idea of an international community of old people has long been proposed. Today, the elderly community service in the United States, Japan, Singapore and other countries is relatively mature [3], the service process and the fixed project have formed a familiar system, in elderly community construction in the United States, for example the elderly residential facilities according to the old age, health status, and intend to roughly divided into Life care community, Nursing center, Nursing home (Personal care housing), Congregate housing, Independent residential (Independent housing). These facilities greatly facilitate the life of the elderly and provide comprehensive protection for the elderly in the home. In the United States, private companies have created two major categories of for-profit geriatric communities and nonprofit geriatric communities.

2 Maker Space in University Library

2.1 The Goal of Setting up the Maker Space of University Library Is Briefly Described

The maker space of university library is different from that of social and public library. Its advantage lies in talent resources, literature resources, innovative development and environmental space. Zhang [4] believes that the research library provides the problem of the maker space service, it is not a question of more space, more equipment and more activities, but the re-establishing the library service model. The university library should combine its own advantages. Explore new technologies, learn new skills, and cultivate the creativity and exploration spirit of people involved in high-fiber library maker space. While providing the relevant facilities, the user's imagination is applied to create the way of observing things.

2.2 Maker Space Equipment Configuration and Corresponding Activities

The university library maker space has a variety of equipment suitable for users' choice, and according to its own needs, it is equipped with excellent choice. The types of equipment that can be selected are: electronic, digital and computer tools, application software, digital manufacturing equipment, machine, tools, manual materials, etc. [5]. The technology of the maker space is changing rapidly, and many devices need to be supervised before the simple operation can be carried out [6]. Through unified assembly or face-to-face teaching mode, the user after mastering the use of the related facilities, through these convenient and complicated facilities equipment, realize their different ideas.

3 The Exploration and Conjecture of the Old Entertainment Mode Guided by Maker Space

Both physically and psychologically, older people are less receptive to new things than young people [7]. Through some forms of entertainment, it can help stimulate the brain thinking ability of the elderly, and can help the elderly to "exercise their muscles and bones" through physical action. A simple amount of activity has some corresponding effects in promoting the reduction of senile dementia. So for the guest space constantly exploring behavior analogy, simplify the design process of complex and changing to adapt to the elderly, convenient to accept and enjoy among them is the final design goal.

3.1 Study on the Behavior of the Elderly in the Fusion Maker Space

In the maker space, the makers create their products through self-creation. After the shape of the product is shaped, it will make some physical model construction through 3d printing, model creation and other manual methods. For the elderly, too complicated a process can be simplified, too much work can be neglected. So for the elderly, hands-on work can be simplified. Give a simple model of woodworking machining process for the ordinary people in some conditions, without having to for the wood processing, but gives an approximate shape work piece, The old people only need to do simple processing according to the arrangement, make the necessary form, and assemble these parts together to make the shape they want. At the same time, imitate the way of 3d printing, convenient to give the old some harmless printing raw material, make its manual knead or put forward some requirements, to explore its forming process, the process involved in the professional operation of building completed ahead of schedule.

In the maker space, communication and presentation are also important. After the old people complete their works, they help to complete their own exhibition space, so that the elderly can set up their own "little world". Integrate some of the things they have experienced and the rich experience of life, and guide them to accept some new space construction methods and new creative ways to inspire their passion for activities in their late years. The guide, is to improve the old people's subjective initiative, active activities, in their leisure time to help them do some simple movement rather than keep a posture and leading to loss of body physiology.

3.2 A Study on the Thinking Mode of the Old People with Innovative Thinking in the Fusion Maker Space

Brainstorming, this is an open thinking logic discussion. What is indispensable in the process of innovation is researching, discussing and thinking. For the elderly, their life experience is a kind of research result based on the accumulation of years, and many things cause and effect relationship and trend are not difficult for the elderly to control. Therefore, how to activate their thinking and help them to do daily thinking is a question worth discussing. Between the elderly can also through sharing, some demand in the form of interaction and build, the elderly daily entertainment activities, such as simple calculation of poker, etc., all is a reflection of the interaction. For the elderly, their thinking because of the age is relatively slow, in the process of brainstorming, the theme can be more interested in things around their life, such as knitting, a goal kick, etc., to give some thought to guide their discontent, encourages them to take their own stories, and let them take the initiative to think about the meaning of them.

Hearing is also one of the main sources of information received by humans. The be fond of according to the old organization some audio service measures also is a kind of feasible scheme, by reading, reading, and some in the form of music and sound transmission, digital music platform, through the design listening training, let old people make good use of some trivial time. At the same time, listening to music has some effects on some physiological functions of the elderly. Experiments show that some suitable music can help the elderly to relieve gastrointestinal diseases.

4 The Services of the Elderly Community

The embedded maker service advocated in the creative space of university library is to provide corresponding assistance and help by analyzing the readers' innovative ideas. Combining this service mode with some service modes in the entertainment space can assist the elderly to complete their own creations during the entertainment process [8]. Not only in the elderly community, sharing, learning, teaching and creation are the common features of the library and the maker space. Therefore, in order to arouse the old people's mentality of "live and learn", sufficient service is indispensable. By organizing activities to guide the elderly to describe the own experience and through the step-by-step teaching methods to help the elderly operating some equipment belong to their own small products, understand the old man in some similar knitting, unemployed, read newspapers, play chess activities such as China and Germany inconvenience, encouraging its's thinking of a solution, in the process of deepening process of hands and brain, no request in the results, but the creative results is to help protect the rights and interests.

While the maker realization and innovation process in maker space, meaning the demand stage, implementation stage, transformation stage and innovation result, could firstly apply to the action process of elderly entertainment space, in its designed entertainment space, the intension of active thinking of elderly people could be stimulated in fixed process. This thesis describes the components in related maker space and the innovative products that could be created by such components under the guidance of maker culture, and a horizontal comparison is made with the previously existing but less regarded entertainment items contained in the entertainment center of elderly centers, their similarities and differences are compared, by integrating the physical conditions and physiological needs of elderly people, the related auxiliary tools and entertainment ways that are suitable for them are determined. Meanwhile, those that would be eventually generated by maker could be basically concluded as commodity types. While for elderly people, evaluation could be made on their works through simulated sales inside community or other similar methods.

5 Conclusion

University library in the guest room is a new model of a library to change, it has from the traditional information service and knowledge management to digital support, will be in the traditional sense of the guest room to used to guide people to participate in and encourage the creation of knowledge. The elderly, after a long period of precipitation, will think about many things in nature. Thanks to a falling body function and the ability to think, the elderly daily life activity will gradually decline, this time need some targeted guide to help it maintain a state of relative motion. Introducing the concept of university library and the guest room elderly community, and introduces some of the product processing process, some of the action of analogy and guest at the same time, design the elderly can adapt, acceptable activities, to help its recreation at the same time can also help them preserve one's health. As the proportion of elderly people is increasing, the concern for this group should be deepened.

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A Research on User Experience of Older Social Software

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Abstract. Purpose: Taking the elderly as the research object, this paper puts an emphasis on the inner needs of the elderly in an important position, and prevents the designer from subjectively replacing the user's expectations with his or her own ideas. Method: This paper proposes two kinds of research methods: interactive experience design method and implicit knowledge explicit design method. It analyzes the user experience process of senior social software, and studies the user expectations and design elements of senior social software use. Conclusion: The deeper exploration and summary of the needs of the elderly will have a certain reference value for the development of social software for the elderly.

Keywords: User experience design · The elderly · Social software Explicit design method

1 Preface

Since China entered an aging society in 1999, the aging population has accelerated its development. The elderly population has a large base, growing rapidly and increasingly showing a trend of aging and empty nesting. The number of disabled and semi-disabled elderly people in need of care has increased dramatically. The sixth national census shows that the population aged 60 and above in China has reached 178 million, accounting for 13.26% of the total population [1]. Caring for the elderly becomes the responsibility of everyone. With the increasing number of elderly people, the psychological and physical needs of the elderly need our attention. It is easy for senior citizens to feel lonely after they retire from the original interpersonal circle. A large number of old people has retired syndrome, which means that the elderly cannot adapt to new social roles, living environment and lifestyle after retirement. The anxiety, sorrow, fear, and other negative emotions emerged from the change, and therefore they need people's attention. Good interpersonal relationships can solve the loneliness of the elderly, add life joys and create a good family atmosphere. In recent years, with the rapid development of science and technology, old age groups have begun to enter the era of smart phones, and become part of the world's network [2]. Therefore, the design of social software for older groups is worth considering.

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2 An Analysis of the Status Quo of the Elderly User Experience Research

The user experience is from the user's point of view, so that the product meets the needs of people and reflects the human will. The user experience includes all aspects of people's interaction with products, programs, and systems. Based on this, Peter Morville proposed the user experience element honeycomb model (see Fig. 1). As early as in the 1940s, the human-computer interaction field has emerged a user experience research based on "usability" and "user-centered design" [3] was concerned with people's psychology and attitude and occupies the modern design. The study of user experience is conducive to the realization of the "people-oriented" concept, which helps to develop and design products in the right direction.

Fig. 1. Hive diagram of user experience elements

With the increasing attention to aging, research on product design for the elderly has become more and more widespread. The study of the user experience of older people in the country is relatively systematic and mature. For instance, Seyago and Blat [4] used ethnographic methods to study the obstacles and problems encountered by 388 senior citizens in Spain who used the Internet to communicate with their loved ones, and summarized the psychological and physical barriers that seniors face when using modern technology. The research results and theories have laid a favorable foundation for the study of the psychological expectations and user experience of the elderly on the use of social software. Zheng [6] studied the product design based on the physiological decline of the elderly. They analyzed and summarized the performance of the three major physical declines of the elderly and their product design strategies, and proposed the design concept of barrier-free products for the elderly and encouraged design. The division adopted a variety of solutions to solve the operational problems in the daily life of the elderly.

In China, great progress has been made in the research and design of user experience for the elderly. For example, Siu et al. [5] from the Hong Kong Polytechnic University used the elderly as the research center in the study of visual concept design of the elderly, and used the expectations and needs of the elderly as the basis for visualizing images, encouraging future investigation and research to focus on end users. To be secondary users, based on the product's practicality and effectiveness indicators in the selection of research objects.

Nowadays social software on the market such as WeChat, qq, and Weibo are mostly designed for young people. The positioning of design also tends to young people. There is very few social software designed and developed specifically for the target group of senior citizens. Therefore, researchers and developers are in the early stages. The research should focus on the needs of the elderly so that social software that meets the user experience of the elderly can be designed.

3 Research Methods

Taking into account the physiological and psychological characteristics of the elderly, social software design should focus on a good user experience, including the ease of operation, the user interface of the pleasant and emotional care of elderly people's physical and mental health. For this reason, it is very important for the collection of user information data in the pre-study period. Designers only really understand the needs of the end user, and the designed product can be accepted by a wide range of users, allowing users to have a good user experience. The expectation can be designed to allow users to understand how the product works and receive corresponding feedback in a metaphorical way, avoiding the older people's feelings of rejection due to inconvenient use of the product.

3.1 Interactive Experience Design Method

According to Bernd H. Schmitt's five interactive experience systems (sensory, emotional, reflective, behavioral, and related) at Cornell University, the designer should develop the psychology of the elderly into the product. The communication between people and products is an interactive process, aiming at achieving the availability of products and excellent user experience [7]. It provides a systematic design method for products and enables products to communicate and interact with users.

Nowadays, older people are using smart phones more and more frequently, which facilitate their use of social software. Whether they are outside or not at home, they can open social software to chat with family members and friends. When seniors are retired at home and alone, the social software can meet their needs to make friends regularly. When the children are unable to stay with the elderly while they are at work, the elderly can video chat with children through social software.

3.2 The Explicit Design Method of Tacit Knowledge [8]

The explicit design of tacit knowledge is generally a study of users and requirements, and the design content is provided to the user in a certain visual form or other manner, and the user experience continuously improves the experience content and form. Since there are always differences in knowledge and cognition between users and designers, designers need to make users understand how products work and receive corresponding feedback information in a metaphorical way [9]. Therefore, designers need to From the perspective of user experience, the user's psychological and behavioral patterns [10] were studied, and an interface system that conforms to the user's use is developed. The explicit design model of tacit knowledge for user experience is shown in Fig. 2. The Principle of Humanization.

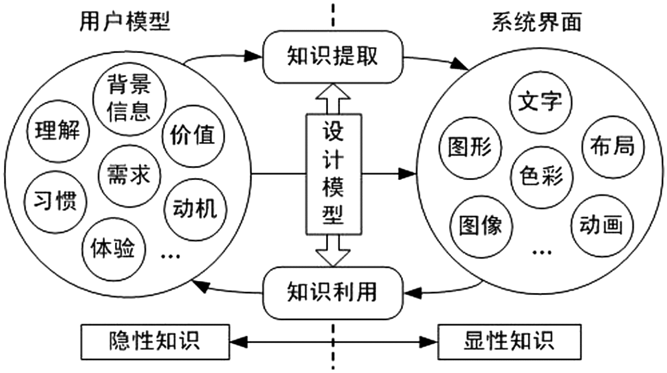

Fig. 2. Explicit knowledge design model of user experience

4 Analysis of Senior Social Software

With the development of information technology, smart phones have become more and more important in people's lives. They have become our most common electronic devices and tools with multiple functions, bringing great convenience to our lives while also changing our lifestyle. The unprecedented strength and portability of smartphones has attracted the attention and recognition of consumers and society, and this concern and recognition continues to grow. Since the popularity of smart phones among the elderly, the number of elderly people using social software has also gradually increased. When the elderly retires at home and the family members work outside, the elderly need to take care of their own lives. Since there is more time alone, coupled with the degradation of physical and psychological functions, the elderly are prone to loneliness. At this time, the elderly need to transfer their sense of loneliness through some things, thus improving their sense of well-being. Social software helps establish connections between old people and their friends and transfers social dynamics and news to the elderly. This not only reduces loneliness, but also ensures that the elderly do not derail from the outside world.

4.1 Analysis of Interaction Design Elements in Social Software

The core of designing social software for the elderly is to obtain a good product experience under the premise of barrier-free use. The achievement of this goal requires designers to fully consider the psychological needs and physiological characteristics of the elderly, in order to obtain a more perfect user experience. Paying attention to the elderly and "designing for users" is the performance of good communication between the designer and the end user in the interactive experience, and is also an important prerequisite for good software design.

When designing social software for the elderly, functional ease of use and interface simplicity are the main features of this group of users. "Laoyoubang (rd1860.com)" is a social welfare network platform established by the team of Professor Zuo Meiyun of Renmin University of China. It aims to provide a space for senior citizens to communicate and share, and promote the communication environment between young people and senior citizens. This platform has the following main features: It is a software platform developed specifically for the exchanges between the elderly, the elderly and the young people; there is a large font and the page is relatively simple, suitable for the elderly to read; there is time to remind the device, and after surfing the Internet for over 30 min, it will remind the elderly to rest their eyes and activities on the platform. Its philosophy is "the elderly cannot leave the internet, but they cannot be obsessed with the internet"; they have the function of "friends and relatives" to meet the needs of the elderly and work in the field. Private communication between children; "Forum" function to meet the needs of elderly community activities to share experiences and send

Fig. 3. rd1860.com social networking interface for the elderly

notifications; the most prominent is that "memoire" function is also available to satisfy users, this history can be chosen in the system to be left to oneself, left to the family or left to society. The interface of the old social networking platform rd1860.com is shown in Fig. 3.

4.2 User Expected Explicit Design Analysis in Social Software

Through the use of social software for the elderly, we can find that the main needs of the elderly for social software can be included in the following two use states, namely, input and output. The so-called input means that the old person accepts information when used, and the output means that the old person sends information to the other party when it is used. These two usage states require design to incorporate the physical and psychological characteristics of the elderly and consider the requirements of the elderly on the interface display. For example, because the eyes are not good, the fingers of the elderly are not flexible, so the application of fonts and pictures should meet the needs of the elderly to be large enough and as clear as possible; taking into account the academic limitations of older people, the presentation of the software should be intuitive and not have too much professional vocabulary. At the same time, we must consider the operational capabilities of the elderly. The intelligence of the elderly is constantly decreasing. Even if they have the ability to learn, it is extremely difficult for them to use complicated software [11]. Therefore, the software used by the elderly should be as simple as possible to make it operable. In this way, it is necessary to consider easy-to-understand operation methods, consider the display and expression methods that are easy to distinguish, reduce the complexity of software operation, and reduce the amount of information and the strength of information; try to minimize the memory burden of the elderly.

Regardless of whether the researcher or the designer is considering the social media software interaction interface design research for the elderly, both the user's habits and physiological characteristics (user model) should be taken into consideration, and the layout of the product interface should be optimized so that "products meet human needs". A good product interface can bring good experiences and memories to the elderly, and avoid negative emotions such as anxiety and fear caused by adapting products.

5 Conclusion

Since the coming of the information age, various software and networks have flocked to provide a good digital environment for the integration of the elderly into the family and society. At the same time, technology also brings inconvenience to the elderly. In order to reduce the burden on the elderly when using software, user needs should be integrated into the product. In particular, the information interface and operation feedback should be fully considered. The cognitive ability, behavioral characteristics and psychological expectation of the elderly, the use of products can be more in line with the people-oriented concept, thus promoting the stability and prosperity of a harmonious society.

At the same time, the development of the aging industry that comes into being with the increase in the living needs of the elderly will bring a new impact to the existing industries. How to design for the elderly is a topic worthy of exploration. This paper analyzes the user experience process of social software for the elderly, researches the user expectations and design elements for the use of social software for the elderly, and digs deeper into the needs of older users, providing a reference for the design of senior social software.

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How Do Aging Adults Adopt and Use a New Technology? New Approach to Understand Aging Service Technology Adoption

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Abstract. This study examines two traditional technology acceptance models and their applications in Aging Service Technology (AST). Technology Acceptance Model (TAM) and United Theory of Acceptance and Use of Technology (UTAUT) have been widely used in diverse technology adoption research. However, these models excessively depend on self-reported subjective measures, attitudes and perceptions of users, and their solutions lack practical contributions. In addition, both models lack unique contextual barriers needed for understanding the AST adoption process. To complement their limitations, a new approach that includes not only additional contextual constructs but also objective measures such as behavioral data or physiological measures is suggested. The new approach will contribute to the development of practical solutions to achieve Aging in Place.

Keywords: Aging Service Technology · Technology adoption · Aging adults Aging in place

1 Introduction

In the US, the number of the 65 and older population is 46 million in 2015 and will increase to 74 million in 2030 [1]. Most aging adults prefer to live independently for as long as they possibly can. However, physical and cognitive impairment, chronic diseases, and less social interactions challenge them to pursue independent living or aging in place. Aging Service Technologies (ASTs) such as sensor-based networks, fall and wandering detection technologies, and diverse electronic health applications, may relieve some of these challenges. These technologies mainly provide safety, security, independence and enjoyment in aging adults' living [2]. While their potential usefulness has been well-recognized, the adoption rates has not met the expectation [3]. Current AST does not fully consider important design and usability aspects such as motivation to use, demographic diversity, and specific technology contexts. Additionally, though aging adults cherish independence, privacy, and social interactions, current technology mostly focuses on safety and physical assistance.

The adoption of AST is crucial to achieve aging in place, which is defined as "the ability to live in one's own home and community safely, independently, and

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comfortably, regardless of age, income, or ability level" [4]. Early evidence indicates the advantages of an aging in place program, and people who lived in this program have improved cognition, lower rates of depression, and decreased activities of daily living (ADL) assistance [5]. As the number of aging adults who prefer to stay at their home increases, the technologies that help them remain in home are thus more needed. To maximize the benefits of aging in place, successful adoption of ASTs is critical. This requires the understanding of aging adults' patterns of technology usage in pre- and post-adoption to achieve better aging adults-technology interactions.

This study reviews existing approaches in technology adoption or acceptance research and discusses their applicability in aging adults' adoption of AST. Recently, a growing number of studies have been conducted in aging adults' technology adoption, but the methodologies used in the studies have not reflected enough aging adults' actual adoption behaviors and their usage patterns. In addition, the unique features of the technologies have not fully accommodated aging adults' attitudes and perception, and also the measures are not much differentiated from those of information technology adoption for general population. This study scrutinizes the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) which dominantly used in AST adoption research and addresses their limitations. As a conclusion, a new approach that may lighten the drawbacks of two approaches is suggested.

2 Existing Approaches in Aging Service Technology Adoption Research

2.1 Technology Acceptance Model (TAM)

The technology acceptance model (TAM) is the most cited information systems theory to explain and predict the process of users' system adoption attitudes. It is developed based on Theory of Reasoned Action (TRA) and Theory of Planned Behavior (TPB). Based on the investigation of the adoption process of basic information technology systems, TAM maintains that both perceived ease of use (PEOU) and perceived usefulness (PU) distinctively correspond to the adoption of self-reported system [6]. PU is defined as "the degree to which a person believes that using a particular system would enhance job performance" [6]. PEOU is described as "the degree to which a person believes that using a particular system would be free from effort" [6]. Due to its simplicity and applicability, TAM is the most prevailing theoretical framework that has been used to explain the information system adoption. The major constructs of TAM are shown in Fig. 1.

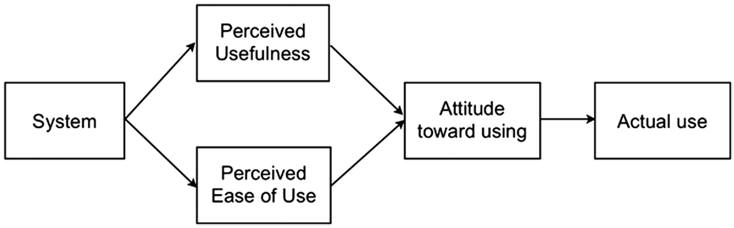

Fig. 1. Technology Acceptance Model [6]

2.2 Unified Theory of Acceptance and Use of Technology (UTAUT)

The United Theory of Acceptance and Use of Technology (UTAUT) was suggested to overcome the simplicity issue of TAM. UTAUT model is developed to explain the intention and use of new technology and to achieve a unified view of user acceptance by comprehensive examinations of various models including the Theory of Reasoned Action, the Innovation Diffusion Theory, Theory of Planned Behavior, Technology Acceptance Model, the model of PC Utilization, and Social Cognitive Theory [7]. It is empirically developed to understand user intentions to adopt information systems by four constructs: "effort expectancy, performance expectancy, facilitating conditions, and social influence [8]. These constructs identify dynamic relationships among organizational context, user experience, and demographic characteristics in the implementations of information systems [7]. In addition, UTAUT smoothly combines its constructs with two constructs of TAM by incorporating PU into "performance expectancy", and PEOU into "effort expectancy", "social norms", and "facilitating conditions" [9] (Fig. 2).

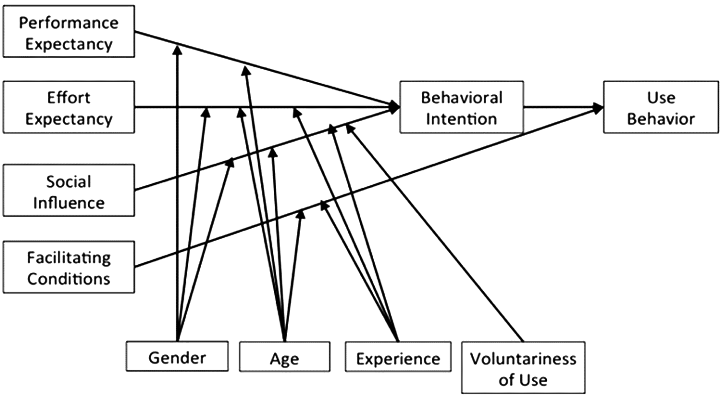

Fig. 2. United Theory of Acceptance and Use of Technology (UTAUT) [7]

3 Challenges and Opportunities in Aging Service Technology Adoption

3.1 Limitation of TAM and UTAUT in Aging Research

One of the limitations of TAM and UTAUT is that some constructs are not clearly defined, which results in the ambiguous relationship among them [10]. This issue makes it difficult to put the studies using TAM and UTAUT into practice. Instead of providing practical recommendations to improve the adoption, most studies just identify other factors that might influence adoption process [7]. In addition, most TAM-based studies adhere the same constructs without consideration of adoption environments or unique contexts. For an example, in healthcare system adoption, Van Schaik et al. [11] evaluated the effect of a portable system that assessed posture on clinicians. Since the study uses the same questionnaire as the TAM study, the results are simply repeated without any distinctive aspects of healthcare systems. UTAUT is also criticized by many aging researchers because its conceptual framework is based on unrealistic or oversimplified individual and contextual assumptions about how older persons decide to accept new technologically oriented products.

Though several studies about older adults' technology acceptance using TAM or UTAUT have been conducted [3, 12], few have investigated contextual usability issues and changes in acceptance patterns over extended periods of time. Originally, PU is indicated as the improvement or gains in task performance through the use of information system. However, task performance of AST is well beyond the simple use of the technology and includes various criteria such as physical functioning, attitude to life and satisfaction, gerontechnology self-efficacy, self-reported health conditions, cognitive ability, and social relationships [3]. Another issue is that, since PU depends more on individual performance, it is difficult to transfer PU to explain the collaboration among aging adults, family members, or care givers. Additionally, task performance improvement from process enhancement or workflow adjustment is difficult to be categorized as PU [13]. Similarly, the definitions of PEOU are vague and broad as well. Original TAM study simply defines PEOU as the lack of effort. This definition may fail to recognize the usability issues and user perspective problems of AST systems.

A better understanding of the barriers and facilitators that older adults face when using new AST could promote use and support to build successful deployment strategies. Examining attitudes and intentions about AST over time may be a useful method to elicit barriers and facilitators to acceptance because aging adults will have more time with the technology and may have the opportunity to use it in a variety of contexts.

3.2 Adoption Barriers of Aging Service Technology

AST is expected to improve the quality of living for aging adults and promote aging in place. However, such technology also brings forth new issues or concerns of aging adults, caregivers, and healthcare providers. There are multiple barriers to fully incorporate AST. These barriers include the technology complexity, lack of standards in data and design, privacy concerns, trust in technology, and risk of malfunctions. To overcome these barriers, performance incentives by payers and government, certification and standardization of data, removal of legal barriers, and security of medical data need to be considered [14]. A monitoring system may be a useful tool to assist aging adults maintaining independence in their living, but there are concerns such as social isolation, privacy, and information security [15].

4 New Approach in Aging Service Technology Adoption

Technology adoption of aging adults is different from those of other population. Aging adults' attitudes and perceptions on new technology are built and maintained by utilities, trustworthiness, powerfulness, and relevance with their past experience [16]. However, subjective measures, attitudes and perceptions, are not enough to analyze and envision the whole adoption process. Research based on self-reported measures may show different results with that employing direct objective measurement such as actual usage [17]. Though it cannot be excluded that self-reported subjective measurements of adoption or usage are biased [17], a new adoption model is needed to include more objective measures such as behavioral data or physiological measures. The patterns of behavioral data can educate and motivate individuals toward building better usage and better habits. The gap between collecting self-reported attitudes and perception and changing adoption behaviors or usages may be substantial, and just increasing in popularity of a new AST is not enough to bridge the gap. For example, health-related behaviors such as eating well and exercising regularly could lead to meaningful improvements in actual adoption of new health-related devices. New technologies need to create consistent new habits to use, to sustain external motivations or to turn them into internal motivations. This requirement of the pattern analysis of behavioral data and physiological measures will be an essential aspect to understand and enhance the AST adoption and usage.

5 Conclusion

This study provides a new approach that examines the predictors and influencing factors of aging adults' adoption of AST. Drawing from TAM and UTAUT, we examined limitations and challenges of the previous adoption research of AST and suggested a new approach including behavioral data and additional constructs such as perceived privacy risk and perceived benefit. Based on this new approach, we will collect the advantages and disadvantages of the activity tracker use in their daily activity and evaluate attitude and perception changes on new technology adoption. The outcomes of this study will be a foundation to further integrated interface design for aging adults' wearable device use.

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Research on Interactive Design of Vehicle Information Interface for Old People Based on Visual Characteristics

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Abstract. Based on the user-centered research method and the principle of human-computer interaction, and considering the characteristics change and influence factors of the visual mechanism of the elderly group, the information structure and visual perception elements of the vehicle information interface were designed and analyzed in this paper. The color, visual interface model, the icon and characters of the interface were tracked by eye, and then the dialog interface, graphical user interface and touch operation of the on-board information interface were analyzed to get the visual characteristics model and related design strategies of the elderly group. Based on the interactive design model and strategy of vehicle information interface from the research, this paper chose a representative vehicle information interface and carried out the depth research bu combining with the old user's actual use demand, and used the eye movement tracking technology and the GOMS model principle to evaluate. According to the design model and strategy, the design and practice were carried out from the perspective of the research. The old people can be provided for a more comfortable and friendly user interface and user experience to ease their oppression in operation, in this case, the old people are given more academic attention and humanistic care, which will provide theoretical guidance and technology support for the follow-up related research and practical work.

Keywords: Information interface design · Old age group · Visual characteristics Car information interface

1 Interaction Design of Car Interface

1.1 Human-Machine Interface Interaction Design

The traditional interface interaction design is mainly based on the subjective feelings of the designer, and more emphasis is paid on the beautification and function of the interface. The design of modern interfaces is more concerned with the user's interactive experience, and it gradually introduces scientific design concepts and methods. Since ACM established a special interest group for human-computer interaction in 1982, human-computer interaction has gone through over 30 years. After experiencing several decades of different development stages, it has been presented to users in more and more

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natural ways. However, with the rapid development of science and technology, the scale of computer user groups has gradually expanded, and the user's personality awareness and the continuous improvement of interaction requirements has been continuously improving, the information interface design faces enormous challenges.

Interaction is a mechanism for interaction between human and system interfaces. The basic framework for human interaction with the software system is the human-machine dialogue that is achieved through user input and system output. From this point of view, the interaction between humans and software systems can be considered as the mechanism of human-machine dialogue under certain circumstances. For example: In a car driving environment, the related ones are drivers, vehicle-mounted interactive interfaces, and car driving environments (see Fig. 1). Therefore, any human-machine interface interaction design under the carrier needs to build an interactive mechanism that conforms to the operator's physiological model and mental model.

Fig. 1. Vehicle driving and human-machine interaction environment.

The goal of interface interaction design is to enable the user to use the software system efficiently through human-computer system interaction, and to have a good emotional experience in interaction with the system; enable the user, the system, and the environment to be harmonized and unified. Among them, the user is the main body of human-computer interaction, and the system interface is the carrier of human-computer interaction. The environment is the influential body that runs through the entire human-machine interaction process. Only when these interaction factors are fully considered can the useful interactive interface be designed.

Interaction can be divided into prompt class interaction, push class interaction and unfolding class interaction according to its role. The difficulties of interaction design are mainly reflected in the following aspects: (1) The information system interface has a huge amount of information, and it needs users to find useful information in massive information, and make timely and correct reflections, complete the interaction process, and improve the intuitiveness of interaction. (2) The content structure of the information system is intricate and complex. In the process of human-computer interaction, complex contentization is needed to simplify the process, reduce the user's cognitive load, and improve the system's human-computer interaction efficiency. (3) The interactive interface of the information system is real-time. How to present the necessary real-time status to the user in a timely and effective way in the interface and solve the sudden events in the human-computer interaction process is also an interaction design consideration. (4) From the perspective of the environment, with the development of informatization, the scope of application of information exchange systems has become wider and wider. It is not only limited to industrial production, but is also increasingly used in military and aerospace businesses with totally different environments.

The basic interaction principle of the interface is mainly reflected in the following aspects: (1) The principle of ability level. The general principle based on the user's background is designed to meet the user's ability level. Namely: perception ability of the user group (vision, hearing); comprehension ability (knowledge and education level); operation ability (motion accuracy); work environment (low illumination, vibration, noise, etc.); task requirement (simple task, complex Tasks, important tasks, emergency tasks, etc. (2) Feedback principle. Timely feedback is an indispensable and important principle, which is expressed as an effective design of the status information, and the user knows the result of his operation and the current status of the system. The following points should be paid attention: Let users know their current location. The user has a good situational awareness and it is easy for him to make decisions on what to do next. Provide immediate feedback. Every time the user's operation has timely feedback, so that the user understands whether its instructions are valid. Reduce unnecessary latency. When the task is handed over to the system for processing or calculation, there will be a period of user waiting time, during which the user should be prompted to "it's now in working condition, how much time should the user be waiting for" and other similar prompt information, which is convenient for the user to make a decision waiting. (3) The user controls the interaction process principle. ① Meet the user's preferences physically and psychologically, in line with the natural needs of users. Design is based on people's habits to rather than let people to adapt to the machine. ② Users have the initiative. Give the user full freedom, and let the user operate according to their own wishes. At the same time, it provides users with a variety of operationally-executable channels and offers as many choices as possible for users at different levels. (4) The principle of effectiveness and security. ① Help design. Reducing the user's learning burden, providing auxiliary operating information and providing multiple executable methods for the same operation. ② Error-proof design. In the process of human-computer interaction, confirmation of prompt information, status reminder before cancellation, etc. should be included. ③ Privacy protection design. Consider the privacy of user information in many aspects and provide effective protection mechanisms, such as fingerprint recognition password mode.

1.2 Car Information Interface Human-Computer Interaction Design

With the advent of the automobile era, safe driving has become a top priority while improving operational efficiency, enriching material life, and enjoying modern and convenient transportation. Automated human-machine interaction has become an important research field. For the interactive design of the driving interface, the automobile needs to provide the most efficient and safe function interface according to different driving conditions, and optimize the function panel to achieve a full and convenient manipulation interface, to minimize the possibility of distracting driving attention and reduce old age Human driving load.

In addition to the design guidelines for human-machine interfaces, more theoretical knowledge should be sought to support our research. In the book the essence of interaction design, the general design principles of software interaction design for embedded systems are described. Based on the interactive design of automotive human-machine information interface, the following summary is made based on the author's understanding.

(1) Do not regard the product you are designing as a computer. Although the automotive human-computer information interface has a computer-like display, we can't just reduce the computer interface compression and place it on the small-screen vehicle-mounted human-machine information interface. We also need to consider the purpose of the human-computer information interface, but also consider how to use digital technology to enhance and improve the user experience.
(2) Integrate hardware design and software design. The design of the software and hardware elements of the system interface is critical, and based on goals, ergonomics, and aesthetic considerations, the interaction between hardware and software is also critical.
(3) Let usage scenarios drive the design. Another major difference between embedded systems and desktop applications is the usage of different contexts. Most of the software running on the desktop is used in a relatively quiet and private static environment. However, the information interface of automotive human-computer interaction is just the opposite. Its use is generally in a moving state. Therefore, the design of the embedded system must be closely matched with the use situation.
(4) The use of patterns should be wise. To design an embedded system, it is necessary to limit the number of modes, and the mode switching is preferably performed naturally when the situation is switched.
(5) Limited range. The on-vehicle embedded system is used according to the user's specific purpose during driving. Therefore, these systems must not be changed to universal computers.
(6) Balanced navigation and display density. Due to the limited interior space of automobiles, the automotive human-computer information interface is constrained to a limited number of displays. Designers must make full use of limited display technologies to satisfy users' information needs.
(7) Reduce and simplify input as much as possible. Almost all embedded system input systems are simpler than keyboard or desktop mouse devices. This means that car man-machine information and interface information input, especially text input, are difficult for users [3].

2 Cognitive Characteristics and Related Research of Elderly Population

2.1 Research on the Cognitive Characteristics of the Elderly

It is more difficult for older people to deal with new technology products than young people. For vehicle-mounted electronic products, they still have very clear requirements, such as communication needs, entertainment needs, and information needs. How to design an on-board information interface suitable for the elderly in light of the needs of the elderly, so as to eliminate the confusion of the elderly on vehicle-mounted human-machine interaction is the purpose of this article.

The cognitive psychology of the elderly includes perception, memory, thinking, creativity, intelligence, and learning (see Fig. 2).

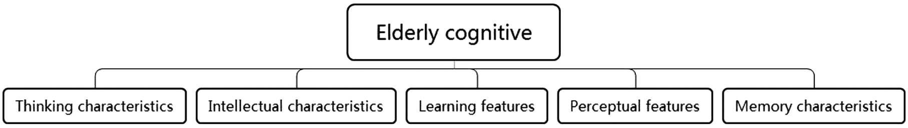

Fig. 2. Study of cognitive psychology among the elderly

The characteristics of the elderly perception. ① The visual characteristics of the elderly: Vision is the perception that people recognize the brightness and darkness of the outside world. As people grow older, their visual organs will gradually age. ② The auditory characteristics of the elderly: As with other organs of the human body, the auditory organs continue to age as they grow old, and their sensibility decreases.

The characteristics of memory in the elderly. ① Older people remember the past more clearly, but will quickly forget about what happened recently and what they learned. ② Older people's memory of things requires organizational processing and long-term storage of content. ③ Older people have better retention and re-cognitive activities, but their recall activities are declining quickly. ④ The mechanical memory effect of the elderly is not good. For example, they cannot remember names, place names, numbers, etc. well. Their decrease in mechanical memory also brings a lot of inconvenience in life.

The characteristics of the elderly thinking. Many older people often do not think well about problems as they did before, which shows that the thinking ability of the elderly is gradually declining. Although older people are not able to carry out such activities as conceptual learning, problem analysis, problem solving, and logical reasoning, there are certain individual differences between them. Some elderly people have a clear decline in their ability to reason and solve problems, but some older people still have better ability.

The characteristics of the elderly intelligence. The intelligence of older people is different from that of young people in the following aspects: ① Old people have a wealth of experience and knowledge, so the elderly can easily maintain nce and knowledge, following aspects: olderine in their ability to reason and solve problems, d intelligence is easy to decline. ② The elderly are more obtuse. ③ Older people have better performance on language intelligence tests that are influenced by experience and knowledge, but the performance intelligence test results are poor.

(5) The basic characteristics of the elderly learning. It will be very difficult for the elderly to learn new knowledge. This is because the elderly need to first understand the content of the study, and then grasp the learned knowledge through short-term memory and save it in long-term memory traces, but it is not entirely lacking in the ability to remember new knowledge.

2.2 The Study of Visual Characteristics of the Elderly

The elderly's visual system will be significantly degraded, causing the degradation of retinal imaging. As lens density and stiffness increase, pupil diameter decreases, lens opacity increases, and photoreceptor cells on the retina decrease, resulting in decreased optical information received by photoreceptors in the visual system and decreased vision. In addition, the maximum pupil dilation in the elderly is two-thirds of young people, so the pupil dilation of dim light has not reached an effective level. Therefore, what can be seen clearly for young people is difficult for the elderly to identify.

Older people's resolution of color declines with age. The thickening of yellow crystals in the eyes of older people may cause the eye's perception of color to decline. Generally, short-wave light will be filtered out. That is, blue light cannot enter the eyes. Therefore, older people are more difficult to distinguish between blue and green.

The sensitivity of visual comparisons for the elderly is declining. They want to accurately distinguish between targets and backgrounds, and must have clear boundaries and stronger contrast.

Older people are more prone to glare than younger people. The reason is that the opacity of the lens of the elderly causes light to be scattered in the eye, and it is difficult to see in sunlight or in strong lighting. In summary, the visual characteristics of the elderly are mainly the following:

(1) Decrease in photoreceptor cells and optical information received by photoreceptors
(2) Decrease in the ability to distinguish things under dim light
(3) Decrease in the ability to distinguish colors
(4) Decrease in visual contrast sensitivity
(5) Glare is more likely to occur
(6) The mobile phone interface for the elderly should be designed according to the visual characteristics of the elderly in order to improve the accuracy of the operation.

3 Vehicle Information Interface Design Method Suitable for the Elderly

3.1 Interaction Design of Vehicle Information Interface Based on Eye Tracking

The eye-tracking technique is used to test the layout of the interface. By measuring the total fixation time of the same task in the different layout of the elderly, the first fixation of the specific element time, the number of fixations, and the saccade path, the matching relationship between different types of information interface and page layout, and the influence of interface element location on the layout of the interface are sought. At the same time, the test data is analyzed, and the design of different interfaces is judged by quantitative indicators.

Experiments are carried out in three aspects. The first aspect: The independent variable of the experiment is sried out in three aspe, which is consisted of three levels: the layout of the single-level task interface, the layout of the double-level task interface, and the multi-level layout of the task layout of the interface is embodied by different levels of search tasks. The dependent variable of the experiment is “search efficiency”, which is measured by the total gaze time, the time of first looking at a particular element, the number of gaze points, and the saccade path. The data is acquired by eye tracker and analyzed by data analysis software.

In the second aspect, the independent variable of the experiment is quired by eye tracker and analyzed by data analysis softwants in Task B and Task C include three levels: the target items are in the upper right, lower left, and lower right positions of the interface respectively.

The dependent variable of the experiment is “search efficiency”, which is measured by the total fixation time and the number of fixation points. The data is acquired by the eye tracker. The time measurement is based on the principle of the GOMS model, and the time statistics and analysis are performed.

The GOMS model provides a time-cost assessment method that can be calculated and measured, with experimental operability and accuracy. The evaluator needs to carefully investigate the steps required for all users to complete the task so that the time required for the user to complete the task can be superimposed by the unit time of each step (see Fig. 3) [4].

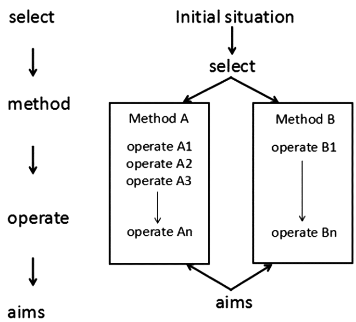

Fig. 3. Basic control evaluation method

3.2 Analysis of Experimental Results and Suggestions for Improvement

Through the analysis of the eye movement trajectory, it can be found that the oldest position of the elderly is the middle and upper area of inversion of the image’s analysis gaze point in the interest interval and can be used to evaluate the v which the importance of the icons and Use the frequency to determine the specific location. This principle is very important for the interface design of traffic-related in-vehicle information systems. Its design should enable users to quickly complete related tasks.

The number of icons displayed in the interface design should not be too much, especially the system interface with strict requirements on the completion time of the task. In the vehicle-mounted information system, more information feedback reminding modes are needed. Because the elderly have a short memory time, the information reminding during driving is emphasized.

Through experiments, it is found that in addition to looking at the icons, the elderly people also look at the text descriptions under the icons, but the reading ability of the elderly is decreasing, which is very unfavorable for the interface design of the onboard information system. Since the recognition of texts by humans requires more cognitive load and time than the icons, the design of the interface icons must be easy to be understood so as to minimize the user's attention to the text.

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A Study of Game Design Based on Sense of Loneliness of the Elderly

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Abstract. Objective: This article proceeds from "sense of loneliness of old people", and takes "Nanjing Happy Valley Gerocomium" as an example to verify the positive role played by the games in improving the sense of loneliness, thus providing future design of the game for the old with an effective theoretical support and design ideas. **Methods:** At first, the study sorts out the concepts of RPG games and classifies them by content through document research, then analyzes the current situation and development trends of RPG games, and introduces development and current situation of games for the elderly. Next, the study observes and records daily activities of elderly people in "Nanjing Happy Valley Gerocomium" through document research and selects typical respondents for one-on-one interview to identify the needs of the elderly for game design according to their physiological and psychological characteristics. **Conclusion:** With research methods including empirical analysis and in-depth interview, this article finds out the core reasons why the elderly have a sense of loneliness, proposes design principles of the games suitable for old people for the this problem, and explores the positive role played by game in improving sense of loneliness, thus providing future design of the game for the old with an effective theoretical support and design ideas.

Keywords: Elderly · Loneliness · Game design

1 Introduction

The number of the elderly above 60 years old in China has exceeded 210 million now, which is obviously higher than the traditional social standard for the aging society. It is predicted that during the 20 years from 2015 to 2035, the elderly population in China will double, and China will enter the stage of accelerated and severe aging [1]. As a result, many pension problems will emerge, among which mental illness caused by loneliness is particularly notable, which is also one of the major factors that endanger the physical and mental health of the elderly [2]. The loneliness of the elderly not only affects their own physical and mental health, but also leads to changes in their lifestyle and social relations, reducing their quality of life, and causing serious negative social effects. Therefore, how to make the elderly age in a healthy way is particularly important.

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State leaders also attach great importance to the aging problem. The “Internet +” that the Premier once proposed has pointed out a path for the development of the industry to care for the elderly. The rapid development of the era of Internet provides technical means for “Internet + pension” [3]. However, at present, there are no game products specifically designed for the elderly in the Chinese game market, and related research is only in the early stage. With the goal of helping the elderly age in a heathy way, this paper explores the positive effect of games on the loneliness of the elderly, and conducts field survey of the elderly to provide effective theoretical support and design ideas for future game designs targeting at these people.

2 The Loneliness of the Elderly and the Development of the Elderly Game Market

2.1 Analysis of the Loneliness of the Elderly

Direct studies of the loneliness of the elderly is not yet fully explored in the literature. Most papers focus on the interpersonal relationship and explore from the environmental and psychological aspects: on the one hand, the elderly might be living alone, resulting in their loneliness, i.e., interpersonal loneliness; on the other hand, the elderly might feel psychologically lonely due to various reasons, which is known as psychological solitude and existential isolation. These psychological problems can trigger physical ailments and mood disorders of the elderly.

According to the survey, 95% of the elderly have been troubled by loneliness. Over 90% of the elderly have the desire to get rid of their loneliness. The author also found through research that the elderly have deep feelings of nostalgia and they like memories, which provides strong evidence for designing games for these lonely elderly people.

2.2 The Elderly Game Market Status

At present, there are basically no games in China that are specifically designed for the elderly, whereas in many foreign countries, there are quite a few such games. For instance, Nintendo launched a touch-based video games targeting at the middle-aged and elderly people. Taking into account the special characteristics of the elderly, the game is designed on the touch screen and is easy to operate. This game was first introduced into the United States market, targeting at the 50 to 60-year-old group. Video games are quite popular in the European and American market. According to the Software Entertainment Association, nearly 20% of the older people above 50 years old in the United States play video games. Many universities abroad have provided courses on the study of games and their own culture. For example, Carnegie Mellon University has started courses on games and the psychology of the elderly, and review of the game culture. Stanford University also has courses on game design and medical care [4]. However, due to the constraints of research costs and technical conditions in China, there are very few domestic cases of research on the combination of health prevention and rehabilitation training for the elderly in the design of games.

2.3 Games Play an Active Role in Ameliorating the Loneliness of the Elderly

Games play a very important role in people's lives. They can inspire players to have goals and hope, help players relax, and effectively relieve and release their stress. To some extent, the elderly people are more in need of games. Compared with material needs, the elderly people generally pay more attention to the spiritual needs.

Studies abroad has shown that games are very effective in treating children with autism. Elderly people can also benefit from games. In Japan, many elderlies have played electronic or computer games, and more and more of them are involved in video games. Games will ameliorate their loneliness and help them age in a positive and healthy way.

3 Research and Analysis of Game Design Based on Loneliness of the Elderly

3.1 Game Design Based on Loneliness of the Elderly

This paper aims to investigate the psychological attitude and emotional needs of games of the elderly through in-depth field interviews, and to observe their psychological deficiencies from both the linguistic and non-linguistic aspects to trigger thinking and innovation in game design. The survey site is the Happy Valley nursing home in Nanjing, Jiangsu Province, which is facing serious aging problem. Considering the characteristics of the interviewees, traditional questionnaires can not be used. Alternatively, the author conducted a survey of random samples from 277 older people in the nursing home using methods of field observation and in-depth interview for empirical research (Table 1).

Table 1. List of statistics by repondents.

Items	Category	Number (person)	Percentage (%)
Gender	Male	120	43.3
	Female	157	56.7
Age	60–65	17	6.1
	65–70	75	27
	70–75	106	38.2
	>75	79	28.7
Health	Self-care	106	38.3
	Mild dependency	93	33.6
	Moderate dependency	52	18.8
	Cannot take care of themselves	26	9.3
Income (RMB)	<3000	95	34.3
	3000–5000	121	43.7
	>5000	61	22

The survey focuses on the following questions:

① Whether the elderly feel lonely, and how do they deal with these negative emotions;
② What are their usual entertainment options, and their attitude towards games for the elderly;
③ Design elements that the elderly like.

3.2 Investigation and Analysis of Game Design Based on Loneliness of the Elderly

Combined with the three core questions raised in Sect. 3.1, the analysis results are as follows:

Question ①: 90% of the elderly have different degrees of loneliness, usually showing loneliness, inferiority, sense of loss, depression, and even fear, accompanied by emotions such as sensitivity, suspiciousness, and stubbornness. In extreme cases, they may get emotional easily and their ability to adapt to the surrounding environment will also be reduced;

Question ②: The entertainment of the elderly is also confined to the nursing home. 85% of the surveyed elderly play chess, grow plants, or watch TV for entertainment. Among them, nearly 50% of the elderly grow plants. Therefore, we can combine this result with the pre-investigation game category design. Since the growth cycle of plant is relatively long, and requires relatively more effort, especially because different plants need different ways of growing, the elderly could spend plenty of time playing the plant-growth game in their free time, thereby reducing their sense of loneliness;

Question ③: The elderly's perception of games is quite outdated. 20% of them have a certain degree of resistance toward video games and think they cannot adapt to these games. 43% of them hold a neutral attitude towards video games, and the remaining 37% are curious about video games and want to try something new. The design of the game tends to be in nostalgia style and Chinese style, since the elderly usually have strong nostalgic feelings. Old things will evoke their memories of the past and are continuous, which will also bring the elderly the sense of security and comfort. Therefore, we can positively and correctly use the elderly's psychological attachment to vintage objects, and refer to objects in their era for scene design and color matching. Vintage objects such as basins with double happiness patterns, posters, porcelain mugs, antique records, old awards, or Chairman Mao's bust, etc., could remind the elderly of the past, thereby increasing their favorability toward the game, and reduce their sense of loneliness to a certain degree.

4 Game Design Elements Based on the Loneliness of the Elderly

Plot planning, character design, and scene design are the most basic elements during the specific game creation process, playing decisive roles in game design [5]. Combining with the analysis of previous interview of the elderly, we decide to use plant growing as the theme of our game. The plants are divided into different levels and different types. In order to obtain a higher level plant, players could accumulate credit of plant growth through watering, walking, and interacting with friends. The design of the game matches the nostalgia and emotional characteristics of the elderly, and combines the nostalgic style with the Chinese style. The scene design mainly features the style of 1950s and 1960s. The color design of the game uses orange scheme, which will stimulate players' communication and kind nature, making them feel better about life. Through our games, we strive to provide the elderly with opportunities and emotional support to communicate with the outside world so as to reduce their sense of loneliness.

4.1 Design of Game Characters

The design of game characters mainly considers three aspects. First, the character's appearance will have a direct impact on the senses of the elderly and evoke their emotions. Second, with their rich social experience, the elderly will associate characters' image with something else in their memory. Thirdly, the symbolic meaning of the character should be consistent with character design. Therefore, we design game characters that combine the cultural significance and the symbolic meaning based on the psychological characteristics and needs of the elderly. The author decides on four plant characters: prickly pear, chrysanthemum, narcissus, and ganoderma lucidum (also known as Lingzhi in Chinese). Each plant character has beginner, intermediate, advanced, and super levels. Once the player accumulates credits to certain threshold values, the plant will upgrade to the next level. In addition, each plant will (Fig. 1). The game characters are designed in accordance with plants' growth patterns, and the personification design also makes it easier to attract players. The refreshing color scheme along with the vivid and lovely overall effect matches the childlike psychological characteristics of the elderly.

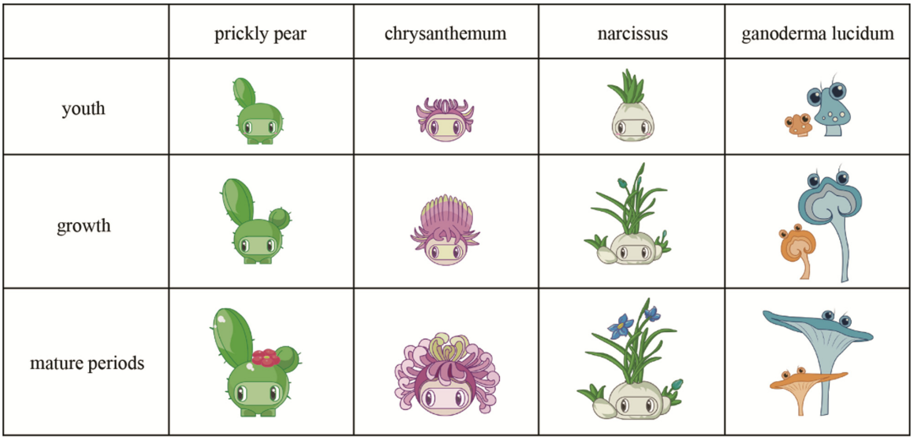

Fig. 1. Images of plant characters at different levels (painted by the author)

4.2 Scene Design

A good game attracts players with its beautiful scenes and exciting plots. Therefore, the task of scene design is to create a beautiful background. The game scene is the main component of game interaction. The quality of scene design not only affects visual effects, but also affects the appreciation and evaluation of the entire game. The scene of the plant growth game introduced in this paper is mainly based on the daily environment of the elderly, such as the living room, bedroom, study, and garden, etc. (Fig. 2). Considering the elderly's nostalgic feelings, I include the unique decorations of their era into scene design. All decorations of their era—indoor decorations such as vintage chandeliers, ceramic kettles and vintage radios, as well as outdoor decorations such as dark red brick walls in the garden, old-fashioned 28-in. bikes, and red satchels on the bike beams—create a visual effect exclusive to the elderly's old times and meet their feelings of nostalgia, thereby increasing their favorability of the game and reduce their sense of loneliness to a certain extent. In the use of color, it is necessary to consider the color requirements of the game itself, but also take into account the preferences and acceptability of the elderly. The elderly people generally prefer certain colors, such as the bright and clean colors. Thus, we should try to avoid over vivid or visually striking colors.

Fig. 2. Different scenes in game design (painted by the author) (Color figure online)

4.3 Interface Design

Unlike other products, the main purpose of game interface for the elderly is entertainment. Although the interfaces of most growth simulation games are also applicable, such as compatibility, validity, learning ability, and operability, some of the principles do not apply to games for the elderly. For instance, many games are designed based on the principle of efficiency, which requires minimizing the time it takes to run. However, the elderly people do not need to reduce the time spent playing the game. Quite to the contrary, they need to spend a lot of time on the game to alleviate loneliness, so they pay more attention to the learn ability, operability, fun, and interactivity of the interface. Additionally, due to the deterioration of eyesight in the elderly, the fonts and interface symbols should be enlarged as much as possible based on screen visibility. Colors of relatively strong contrast to the interface should be used for function buttons, but the contrast should not be too strong, otherwise it would be counterproductive.

The elderly people generally prefer simple interface styles over complicated high-tech styles. Due to the deterioration of cognitive abilities of the elderly, they might even fear or resist the latter type. Accounting for this specific characteristic of the elderly, I consider to use symbolic elements in the game interface and design "voice help" for the elderly. Since some old people might find the electronic screen dazzling due to deteriorated eyesight, the voice function can help the elderly understand the interface better, and might even serve as a reminder. The symbol design of the interface requires us to use a symbolic language that is easy to understand for both designers and players. Otherwise, the elderly might miss the suggestive symbols because they do not understand, which increases the difficulty of the game and stimulates their resistance to the game. Overall, the interface style should be simple and easy to let the elderly learn and master the game features and methods of operation, but also should not ignore the game's own entertainment principles.

5 Conclusion

Games for the elderly might smooth their moods and help them achieve the emotional balance. They can alleviate the loneliness of the elderly to a certain extent, and more importantly, they can encourage and stimulate their positive emotions, help them explore their potentials in the game, and obtain a sense of achievement and self-realization, bringing the elderly a rich emotional experience.

Design of games for the elderly should take into account their psychological needs and physical characteristics. Many old people like to listen to the traditional opera, so we can include elements of traditional opera into game sound effects, so that older people would be more familiar and less resistant to games. In the design of games, special attention should be paid to whether the game is easy to pass and easy to operate, and whether texts are in large fonts. Also, it is important to replace text with animation, include guide function in the game, and increase content richness. Considering the elderly's familiarity with video games, the overall degree of difficulty should be moderate and the game should be simple to play. To better meet players' requirements, the game should be interruptible at any time. Accounting for the elderly's color preferences, designers should not choose color schemes with excessively strong visual impact. Since many old people prefer nostalgic and Chinese style, vintage objects of their era in 1980s can be added into the scene design. These vintage elements will evoke their memories of the past and continuity, and make them feel comfortable and secured, thereby increasing their affection for the game and reduce their sense of loneliness to some extent.

However, due to the objective factors and the limits of author's ability, there are some limitations in this research, such as narrow research objectives and lack of universality of the results. Follow-up study will be continued.

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The Effect of an Integrated E-health Care Model on the Health and Life-Style of Chinese Elderly: Study Protocol

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Abstract. Background: Establishing a comprehensive community-based elderly care service system has become a major strategy to address aging issues in China. E-health applications such as a self-monitoring health device could potentially solve many of the challenges faced by elderly care. In this study, we adapted an evaluation framework to investigate the effect of an integrated care model.

Methods/Design: This study mainly evaluates the model's effect on the users' self-rated health, hypertension control and life-style change. We recruit 180 elderly participants (over 60 years old) from three communities in Beijing, Hefei and Lanzhou. A comprehensive questionnaire will be used in the baseline survey. A pair of participants with similar statues will be randomly assigned to intervention groups and control groups. The intervention group will receive a home-based self-monitoring device that records daily blood pressure data. Primary care physicians will contact them bi-weekly to give feedbacks on their blood pressure control and other care need. Additionally, participants' family members will be involved in the process to improve participants' adherence. After six months of intervention, we will conduct another questionnaire survey that elicits participants' responses on self-rated health, life-style, satisfaction and cost-effectiveness of the device. Feedbacks from the primary care physicians, family and study participants will be collected as well through face-to-face interviews.

Discussion: Our design attempts to capture the effectiveness of integrated E-health care model from different angles. If this model can improve elderly health management, it will in turn provide a feasible and effective solution for establishing the eHealth-based community collaborative elder care nationally wide.

Keywords: E-health application · Elderly · Assessment model

1 Introduction

Elderly care is a worldwide social and economic challenge for the public health system, and it requires the development of new management strategies [1]. China is heading for an elderly population crisis. Along with the epidemiologic transition, chronic conditions have become the predominant contributor to disability among Chinese elderly [2].

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Establishing a comprehensive community-based elderly care service system has become a major strategy to address aging issues in China. E-health applications such as self-monitoring health devices could potentially solve many of the challenges faced by elderly care, especially for those with chronic diseases. This device will help by transmitting elder-related data to share information among primary care physicians, family members and professional caregivers, thus creating an "elder-centric" collaborative care service system [1].

Despite the benefits and maturity of the technology, E-health applications are still not widespread in China. Small scale services, not integrated into local healthcare systems, dominate the scene [3]. Evaluation of integrated care service delivery processes will improve the current scientifically based data centered on barriers and facilitators toward integrated care delivery. Beyond this, scientific research in the field will generate outcomes from the perspectives of all involved with integrated care service delivery [3].

Although information evaluating the effectiveness of E-health application is mostly lacking [3], there were some studies developed models to assess health technologies. The European network for Health Technology Assessment (EUnetHTA) provided a practical tool for health technology assessment in Europe [4]. A framework for assessment of telemedicine technologies, named MAST, was established for decision makers to assist them in choosing the most efficient and cost-effective health technologies [3]. SmartCare trials evaluated the functions and impacts of the integrated health services from the point of view of the different principal roles [5].

In this study, we adapted an evaluation framework to investigate the effect of an integrated care model that combines a home-based self-monitoring health device, primary care physicians, and family members of the elderly over a six-month period in China.

2 Methods and Design

This study mainly evaluates the model's effect on the users' self-rated health, hypertension control and life-style changes. We recruit 180 elderly participants (over 60 years old) from three communities in Beijing, Hefei and Lanzhou. People with a hearing disorder or dementia will be excluded from the study. The starting point of the assessment would be when the elderly residents have been involved in the integrated-care program.

A comprehensive questionnaire that covers demographic information, life-style, self-rated health, disease history, health management, health service usage, social network, health literacy, and cognitive function will be used in the baseline survey. Social network measure is the abbreviated Lubben Social Network Scale [6]. Cognitive function is assessed by the Mini Mental State Examination (MMSE) [7]. A pair of participants with similar statues will be randomly assigned to an intervention group and to a control group. The intervention group will receive a home-based self-monitoring device that records daily blood pressure data. Primary care physicians will contact the participants bi-weekly to give feedback to help regulate their blood pressure and other care needs. Additionally, participants' family members will be involved in the process to improve participants' adherence, while, the control group will receive usual care. After six months of intervention, we will conduct another questionnaire survey that elicits participants' responses on self-rated health, life-style, satisfaction and cost-effectiveness of the device. Feedbacks from the primary care physicians, family and study participants will be collected as well through face-to-face interviews to understand the organizational changes and the effectiveness of integration of different care approaches.

All outcomes are adapted from SmartCare and MAST models [3, 5], and presented below in Table 1: Outcomes, timing and explanation for variables. Also, the table indicates the preferred collection methods for each variable, and the possible reasons for assessment. Multidisciplinary assessment involves evaluation of the outcomes of the specific E-health application compared with control groups, where the outcomes divide into five domains. The domain of Health Status Measures describes of the health concerns of the patients and also includes demographics and social related factors. The domain of Safety provides identification and assessment of hazards. The domain of the Elderly/Physicians/Family considers issues related to the perception of the elderly and families or physicians of the E-Health application including the participants and relatives acceptance of the technology. The domain of Economics evaluates the elderly's willingness to pay for the technology and the service efficiency benefits. Domain of Organizational impact measures is an assessment of what kind of resources have to be mobilized and organized when implementing a new technology, and what kind of changes or consequences the use can further produce in the organization.

Table 1. Outcomes, timing and explanation for variables [3, 5]

	Timing of measurement	Collection method	Notes
Health status measures			
Demographics	Baseline/after 6 months	Questionnaire	Indicator for health status, highly relevant for the usability of results after finishing pilots
Lifestyle	Baseline/after 6 months	Questionnaire	
Chronic disease management	Baseline/after 6 months	Questionnaire	Predictor of health outcome
Social networks	Baseline/after 6 months	Questionnaire	Might be affected by the intervention
Health literacy	Baseline/after 6 months	Questionnaire	Indicator for health status
Cognitive function	Baseline/after 6 months	Questionnaire	The MMSE is used to determine the levels of cognitive impairment
Safety			
Device failure	After 6 months	Backend data	Easy to establish. Reflects the reliability and safety
Subjects impairment	After 6 months	Interview	

(*continued*)

Table 1. (*continued*)

	Timing of measurement	Collection method	Notes
Elderly people/physicians/family			
Usage	After 6 months	Backend data	Reflects the usage and measures satisfaction
Satisfaction	After 6 months	Questionnaire	
Economic measures			
Willingness to pay	After 6 months	Questionnaire	Relevant if a service fee payable by end user/physician is considered to become part of the revenue model
Service efficiency benefits	During the follow-up	–	
Organizational impact measures			
Impacts on community staff	After 6 months	Interview	Key measures to understand the organizational changes caused by the new service, as well as to get a better understanding of what was actually achieved through the integration of different service silos
Impacts on physicians	After 6 months	Interview	
Service integration aspects	After 6 months	Interview	

Ethics approval was obtained from the Ethics Review Committee of the Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China (X170315009). All study participants will be provided written informed consent.

3 Discussion

Chronic disease prevention and management become important as a population ages [8]. E-health is emerging to address the limited capacity of the health care system to provide health behavior change and chronic disease management interventions [9].

The integrated E-health care model in this project involves multifaceted intervention. The overall aim of this study was to provide a protocol for assessing the effectiveness and contribution of an integrated E-health care model to elderly health, based on need the for further information by users.

Our design attempts to capture the effectiveness of the integrated E-health care model from different perspectives. If this integrated model can improve elderly health management, it will in turn provide a feasible and effective solution for establishing the eHealth-based community collaborative elder care nationally wide. However, due to time-constraints, this study only assesses the short-term effect of an integrated E-health care model on health and lifestyle, additional follow up should be conducted to determine the long-term effects and outcomes.

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Conflict of Interest. No conflict of interest.

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Analyzing Elderly Behavior in Social Media Through Language Use

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Abstract. Increasingly more elderly make use of social media in the Netherlands, being at the forefront compared to other European countries. We analyze the language use of Dutch (older) adults in Twitter in order to get insights in their behavior. Previous studies have identified several linguistic features that change as life progresses including pronouns. We don't find this change and we claim that this might be due to the fact that the users tend to adapt to the language of the platform. This is not the case for the topics addressed since we find differences in the use of hashtags, while the elderly use hashtags mainly in relation to leisure and politics, the younger users employ them mainly in relation to their working life.

Keywords: Elderly · Social media · Language use · Behavior

1 Introduction

Information and language technology can play an important role in assessing the changing behavior of individuals and can function as a means to transform cities into environments that support green and healthy lifestyles. In the context of the European project Grage (Gray and Green in Europe: elderly living in urban areas - www.grageproject.eu), we are carrying out a behavioral analysis of Dutch users based on social media data extracted from Twitter since increasingly more older adults make use of social media in the Netherlands, being at the forefront compared to other European countries.

Our goal is to achieve a better understanding of people's behavior on the basis of language use since previous literature has shown that there are several linguistic features that change as life progresses. In addition, we consider the use of hashtags that are a social media specific feature.

2 Previous Literature

In researching ageing behavior, it is important to define age, which is usually assumed to be the time someone has lived from one's birthdate up until the moment of inquiry (i.e. chronological age). The studies that consider language use often focus on chronological age [1–3]. However, individuals of the same age can use language in completely different ways, for example because they take different places in society.

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Therefore, the focus of various researchers has shifted to grouping subjects on life stages rather than on chronological age [4].

Previous studies have analyzed the linguistic features that change in combination with age. In particular, [1] found that aging is associated with a decline in negative emotion words and at the same time an increase in positive ones. Pronouns are quite revealing of social relationships and identity: subjects younger than 14 and older than 70 use first person plural most often, while individual in between these two age groups used it less. Another significant finding was that the use of self-references (meaning first-person singular pronouns) decreased dramatically with age, with an extreme decline for subjects older than 70.

On the other hand, [2] found that younger people's vocabulary contains a wide variety of slang words, such as swear words or non-derogatory slang. The domain of personal pronouns yielded as result that younger people use the pronouns 'I', 'my', 'myself', 'me', and 'you' significantly more than the older group. The older group showed a higher frequency for third-person singular and plural, as well as first person plural.

While these papers focused mainly on spoken and written resources for their analyses, there is a growing number of studies relying on a computational analysis of social media. They also focus on the use of pronouns as a variable and they suggest a tendency for younger people to use more self-references in the form of first-person pronouns in their language [3]. As people grow older, they tend to use more first person plural pronouns [3, 4].

As for social media specific features such as hashtags, [4] found that hashtags are used more often by older Twitter users: low usage in teens, a steep climb in the 20s, the highest and continuous use through the years up until the oldest participants category (over 60 years of age). Furthermore, [5] noticed that in Instagram the group of teens (13–19 years) posted fewer photos but added more hashtags to them than the adults (25–39 years) do. With respect to content the adult group displays a wider range of interests in topics and are very diverse: arts/photos/design, locations, mood/emotion, nature, social/people while the majority of the teens' hashtags concern mood/emotion and follow/like.

3 Social Media Use Among the Elderly

The Netherlands are at the forefront with respect to internet and social network use, this is the case also for the elderly [6]. Social networks use, at European level, in 2013 can be seen in Fig. 1, which shows that The Netherlands with 55% of users between 16 and 75 years old belong to the top positions. They are behind the Scandinavian countries (with Denmark scoring 63%) and England (less than 60%) and score above European average in use (43%).

If we consider the social media use (this includes online chatting, writing or reading weblogs, e-mailing and use of social and professional platforms) of the Dutch population in the last years (cf. Fig. 2), we notice a clear increase in all age groups. Almost 60% of those between 65 and 75 are active on social media while those above 75 years old are 20%.

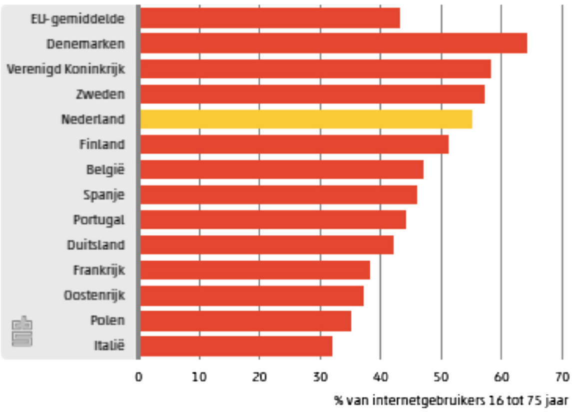

Fig. 1. Social media use in EU countries in 2013

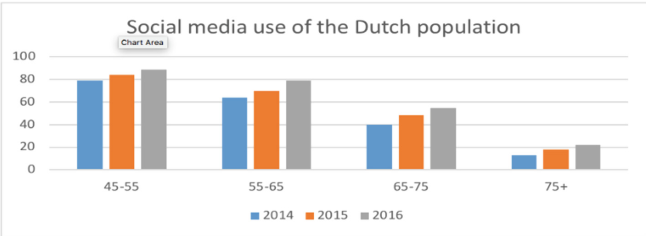

Fig. 2. Social media use 2014–2016

The development in the use of the various social networks for different ages in the years 2012 and 2016 is illustrated in Fig. 3. Where the two years are represented over each other and they partially overlap. It is possible to see that younger people use platforms such as Facebook and Twitter less, while the older population is using social networks more, this is especially the case for instant messaging. Furthermore, the use of professional social networks has increased in the age group 22–35 years old.

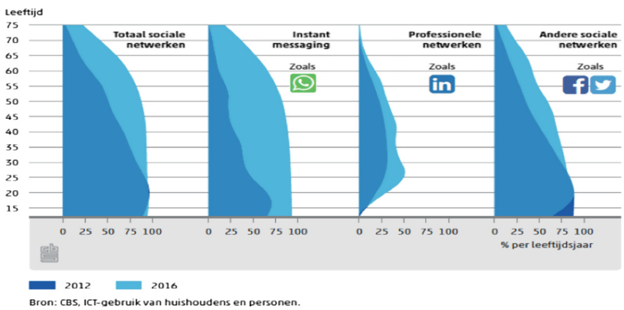

Fig. 3. Development of social network use

4 Language Analysis

Since social media are being used by an increasingly higher number of people, especially in The Netherlands, it seems relevant to employ social network data to analyze their behavior through language use. Users on a social media platform write spontaneously about their interests, providing information about their needs and their behavior.

In our work, we make use of chronological age of users, but we group them in three classes that reflect three life stages that are related to the active working life of the individuals (i.e. below 55), the pre-retirement stage (between 55 and 67) and post retirement (above 67). In this way, we overcome possible criticism in the use of chronological age [4, 7]. The users we selected from Twitter had to meet several requirements: their tweets should be publicly accessible and written in Dutch; they should have tweeted at least 400 tweets and they should show social activity, that is users with a number of followers higher than 300. The classification of users in age groups was carried out manually on the basis of their profile information and the picture posted, the same with respect to gender. Two people have verified the selection in order to retain only those users for which there was agreement in the classification.

We have carried out a preliminary analysis of the most frequent words in the tweets of the selected users and we have focused initially on two age groups. We have carried out a pilot based on 18 users below 55 and 10 users above 67 in order to increase the chances of identifying different behaviour in language use.

Fig. 4. Frequent words of under-55

Fig. 5. Frequent words of above-67

The word clouds (cf. Figs. 4 and 5) reveal that Dutch articles '*de*' ('the'), '*het*' ('the') and '*een*' ('a') are very common in the text in both age groups, as well as the use of prepositions: '*in*' ('in'), '*van*' ('of', 'from'), '*voor*' ('before', 'in front of'), '*op*' ('on') and to a lesser degree '*over*' ('over') and '*bij*' ('by') are all used frequently. However, to assess behaviour, the use of pronouns is the most interesting to analyse and we notice that in the case of the group under-55 the pronoun '*je*' ('you' sing.) is more frequent than '*ik*' ('I'). In the above-67 group, the presence of the pronoun '*ik*' ('I') is attested as well as that of the first-person plural '*wij*' ('we'). To assess whether one group uses a word more frequently than the other, a statistical metric suggested by [8] has been used:

$P_{ov67}(w)$ = relative frequency of word w in tweets of subjects over 67
$P_{un55}(w)$ = relative frequency of word w in tweets of subjects under 55

$$\text{variance} = \sqrt{(Pov67(w)/Nov67 + Pun55(w)/Nun55)}$$

$$\text{t} = (\text{P}_{\text{ov67}}(\text{w}) - \text{P}_{\text{un55}}(\text{w}))/\text{variance} \tag{1}$$

If the score t is positive, the word is used more often in the tweets written by people older than 67, if negative, the word is more frequent amongst the under 55 group.

Our analysis, revealed that the overall pronoun use increased with age and the pronoun category and the highest frequency in both groups was first-person singular. This usage might imply that the reason for people to use social media is to convey one's own interests and experiences, even as people become older. In addition, as can be seen in Fig. 6, the two age groups make a very similar use of the pronouns contrary to what assumed in previous literature.

		> 67		< 55		
Pronoun	Translation English	Times used	P(w)	Times used	P(w)	T-score
Ik	I	663	0,01271	1204	0,01168	0,00958
Je	You,your (sing.)	791	0,01517	1199	0,01163	0,03281
Jij	You (sing.)	68	0,00130	141	0,00137	-0,00172
We	We	110	0,00211	327	0,00317	-0,01887
Wij	We	214	0,00410	64	0,00062	0,13978
Jullie	You,your (plur.)	31	0,00059	118	0,00114	-0,01626

Fig. 6. Pronoun use in the two age groups

5 Hashtags Analysis

Our preliminary analysis of language use has showed that the two extreme age groups share a very similar behaviour in this respect, more specifically in the case of pronoun use. It is thus relevant to assess whether this is the case also with respect to the topics being addressed and an analysis of hashtags use might be revealing. They are a social media specific feature and a relevant source of information given that they are used to index keywords or topics in Twitter, they are indicative of the debate that is being carried out in the platform. We have conducted a preliminary analysis based on the two age groups, that allows for a manual investigation given the limited number of users. Out of the 103.097 words of the tweets belonging to the under-55 group, 5318 were hash-tags, that is 5.2%. For the over-67 years old users, it was about 1% (i.e. 532 hashtags out of a total of 52.150 words). One possible explanation for this higher usage of hashtags in the younger group could be that Dutch citizens over-67 are usually retired, whereas those in the younger group still have a working life. Many of their hashtags have some relation to professions or the labour market and they might use hashtags to target specific audiences while this might not be the goal of the older group. We have selected the top 100 most frequent hashtags in each group which we have divided into categories, loosely based on the categories illustrated by [5], as can be seen in Fig. 7.

There are clear differences in the topics being addressed by the two groups. The most popular ones amongst elderly users are politics, locations, entertainment and news. Together, these categories comprise 75% of the hashtags. The under-55 group focuses more on work- and world-related tweets, with news, occupational terms, entertainment and companies as the most popular topics. The most noticeable difference between the two groups in terms of topics is that in the over-67 group, none of the topics of the hashtags relate to occupations or companies, and the references to congresses or fairs were much lower than for the under-55 group. Users under 55 write more tweets related to their profession while this is obviously not the case any more for the old adults.

Differences are even more obvious when we look at the theme of *sustainability* where hashtags related to it are only present amongst the younger age group where users belonging to it tweet about this subject in a work-related context. Similar difference can be noticed with respect to the hashtags related to nature that are used by the younger group more than by the group of the older adults. The over-67 group shows an extensive use of location-tags, more than three times as much as the younger group, and entertainment. One might conclude that for those over-67, Twitter is a means to communicate about leisure activities and about their interests where nature and sustainability do not occupy an important place in their communication (cf. [9] for further details).

Table 1. Distribution of the 100 most frequent hashtags into content categories.

Category	Examples in English	% over-67	% under-55
Arts/photos/design	Photography	4.7	1.2
Companies	[names of companies]	0	11.6
Economics	Financing	0.9	3.1
Entertainment	top2000	18.2	12.3
Events/conferences	congresIC	0.6	4.1
Sustainability	40dayssustainable	0	1.3
Locations	Iceland	20.2	6.6
Mood/emotions	Proud	3.2	1
Nature	Bees	0.6	4.3
News	Brexit, [names of Dutch newspapers]	9.4	29.8
Occupationalterms	website, qualitofhealthcare	0	14
Politics	[Names of political parties and laws]	30.8	0.8
Research/univers	RadboudUMC	0.3	0.8
Social/people	AbeltAsman	2.6	0
Sports	NedMex, OS2012	2.9	2.3
Twitter-tags	dtv (*durftevragen*, daretoask)	0.3	4
Other	Wastepaper	5.3	1.2

Fig. 7. Hashtag categories

If we extend this preliminary analysis to the three age groups and additional users (i.e. 100 users), this behavior is confirmed, as can be seen in the word-clouds in Figs. 8 and 9.

Fig. 8. Hashtag use for the groups under-55 (left) and between 55-67 (right)

We notice that the two groups below-55 and in between 55 and 67 exhibit a similar behavior with respect to Twitter use in that their discussion evolves around work related and technology related themes, this is even more the case for the 55+. The hashtag use is different for the group above-67 that is especially interested in politics, which is to be expected since this is a group that was more confronted with politics in their youth, as can be seen in Fig. 9. Leisure activities and television programs are also mentioned.

Fig. 9. Hashtag use for the group above-67

6 Conclusions

Previous literature has identified several linguistic features that change as life progresses: the use of pronouns being one important discriminator. We do not find this difference among the two age groups analyzed and we claim that this might be due to the fact that since more elderly are active in social media, they might tend to uniform to the language that is used in the platform regardless of age [10]. In a subsequent analysis, it would be relevant to assess when users joined the platform to evaluate whether membership age plays indeed a role.

We have also considered the use of hashtags and we noticed that here are differences in the topics addressed by the groups analyzed, while the elderly use hashtags mainly in relation to leisure and politics, the younger ones use them mainly in relation to their working life. Another important difference is that while the younger group uses hashtags related to nature and sustainability, this is not the case for the elderly who, however, use location tags indicating an interest for the places they live in, but maybe less for the environment. We claim that social media could play an important role in changing this attitude and behavior. We have observed that these differences are attested also when the analysis is extended to additional users and to the three age groups.

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What Was my Search Goal Again? Supporting Web Exploration in Information Search for Older Users

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Abstract. This study investigated how supporting search goal refreshing in working memory could cope with older adults' lower fluid abilities and helped them search for information with a search engine. 18 older and 30 young adults searched for information to four complex search problems with a classic search interface or with a search interface that displayed at all time their ultimate query. Results showed that the support tool improved older adults search strategies when navigating (i.e. reduced the amount of content webpages visited multiple times and the exploitation of the queries produced) and when reformulating (i.e. reduced the time required to reformulate their query).

Keywords: Information search · Aging · Support tool

1 Introduction

Information search (IS) with a search engine is a complex activity that involves many processes to formulate queries, process the search engine results pages (SERPs) and navigate between content webpages [1]. Older adults are one of the largest growing population of internet users. However, elderly users can face challenges while navigating. They spend longer dwell times on SERPs, they have more difficulties selecting a content webpage to investigate and they tend to exploit the queries they produce instead of reformulating [2–4]. Older users can also have more difficulties navigating between SERPs and content webpages (*i.e.* websites): they tend to delay the decision to switch to a new webpage, they can feel more disoriented and they tend to have more difficulties remembering the webpages they have previously opened up [5].

Researches showed that the age-related decline of cognitive abilities such as flexibility or update in working memory could account for most of these difficulties [1, 5]. To search for information, users must elaborate a coherent mental representation of their search need and keep it active in working memory all along the activity. Search goal maintaining in working memory is performed while allocating cognitive resources to information processing (*i.e.* comprehension processes, relevance assessment). As IS particularly requires more resources for older users [1–3] their difficulties to recall the fruits of earlier mental operations in working memory can further increase their difficulties and cause unadapted decisions [5].

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IS support tools have raised strong research interests, especially reformulation tools [6]. Prior studies showed that supporting older adults' search behavior could support reformulation (*i.e.* production of semantically more specific keywords) [7]. However, these tools require extra resources to be processed and may increase cognitive overload for older adults. To cope with the age-related decline of fluid abilities and support older users' search behavior, the present study investigated how a support tool that displays the user's current query (*i.e.* representation of the user's current search goal) can help older adults refresh their search goal and relevant information in working memory and improve navigational search strategies.

We argue that most of the IS stages that can cause difficulties for older users particularly require to refresh the search goal (and relevant information) in working memory in parallel with allocating resources to new information processing (*i.e.* SERPs evaluation, website selection and navigation). Hence, a support tool that facilitates the refreshing of the search goal in working memory, by displaying users' ultimate query at all time, should help older users save up some cognitive resources and foster better search strategies on SERPs and exploration on content webpages.

2 Method

18 older (age 65.11 ± 5.30) and 30 young adults (age 21.93 ± 2.79) searched for the answer to 4 complex search problems (*i.e.* query reformulation and web navigation required). Both groups had similar college studies ($t(48) = 1.39$, $p = .17$) and declared feeling as confident in using a computer to use the internet ($t(48) = .55$, $p = .59$). Participants were randomly assigned to a classic web browser or to the experimental interface that displayed the user's ultimate query at the top of the screen.

2.1 Design

The experiment was conducted with an experimental web browser that retrieved log files. Eye movements were recorded using SMI RED250 mobile binocular and remote eye tracker (sampling rate set to 250 Hz, 0.4° spatial accuracy and 0.03° spatial resolution). We used a flat display screen DELL 22" with a refresh rate of 75 Hz and a resolution of 1920 × 1080 pixels. Participants first completed a questionnaire (demographic information and internet habits) and a task measuring update in working memory (*i.e. n-back)*. Then, participants performed 4 IS problems either with the support tool (*i.e.* with their ultimate query displayed at the top of the interface) or without it (see Fig. 1).

Fig. 1. Screen capture of the search interface elaborated (experimental group).

Information search support tool. The support tool consisted in a small module that displayed at the top-center of the search interface users' ultimate query (*i.e.* every time participants reformulated, the query displayed changed). The support tool had 2 functions: (i) support refresh in working memory at lower cognitive costs and (ii): support the exploration of content webpages at lower cognitive cost (*i.e.* the query displayed was clickable and allowed users to return to the SERP.

Search Problems designed. In line with prior works, complexity of the search problems was defined *a priori* [8] based on the amount of information to be processed, the level of precision of the navigational path to be elaborated and the cognitive processes required to produce queries (*i.e.* inferences). The 4 complex search problems we designed required users to (i) produce queries and reformulate them with more specific keywords and (ii) navigate on content webpages to gather relevant information and find the target answer [2–4]. The search problems tackled a variety of topics to interest both young and older adults (such as *TV*, music, literature). See Table 1 below for examples of search problems.

Table 1. Examples of search problems.

Which French writer, who is a master of suspense and fantastic, has written an historical and fantastic best seller and a series of young adults' novels whose female heroine has super powers.
Find out which French musical group of urban music, composed of 5 artists who are named after Egyptian gods come from Southern France.

2.2 Data Analysis

First, the use of the support tool was investigated with eye-tracking data (*i.e.* number of eye fixations, which corresponded to the number of times participants gazed at their query to refresh in working memory their search goal). Secondly, following Preacher and Hayes' method [9] moderation analyses were conducted to investigate whether the support tool could moderate the detrimental effects of age on IS. Hierarchical multiple regression analyses were conducted with age and support tool (dummy variable). Update in working memory (*i.e.* n-back z-standardized score) was entered as covariable. Interaction term between age and the support tool was entered in the second step of the model. Significant interaction term with a negative beta suggests that the moderation is buffering the relation between age and the dependent variable.

- Search performance: number of correct answers found
- Multiple consultations of content webpages: total number of content webpages divided by the number of content webpages revisited (*i.e.* higher ratio reflect more exploration and fewer multiple visits of previous content webpages).
- The number of webpages revisited per query (*i.e.* high number of content webpages visited multiple times per query reflects deeper exploitation [5]).

- Time querying: time taken to reformulate divided by the number of keywords per query (*i.e.* Higher time querying may reflect difficulties to reformulate).

3 Results

3.1 Age Differences in the Use of the Support Tool

Results showed that older adults tended to make more eye-fixations to the support tool than young ones ($t(19) = -1.98$, $p = .06$; M = 21.31 SD = 11.72 vs M = 12.42 SD = 8.72). Interestingly, older adults also made significantly more eye-fixations on the module displaying the query than young ones when they were processing content webpages only ($t(19) = -2.12$, $p < .05$; M = 12.33 SD = 8.64 vs M = 5.59 SD = 5.80).

3.2 Impact of Age, the Support Tool and Interaction Effects on Search Performance.

The model accounted for a significant proportion of the variance of search performance ($R^2 = .20$, $F(4,43) = 2.70$, $p = .04$). Effect of age was not significant (B = .14, $t(43) = .08$, p = .93). The support tool significantly improved the number of correct answers found (B = 3.49, $t(43) = 2.20$, $p = .03$). Effect of the covariable was significant (B = .53, $t(43) = 2.22$, $p = .03$). The interaction term did not reach significance (B = .53, $t(43) = -1.32$, $p = .19$). Table 2 below provides means and standard deviations for all variables.

Table 2. Means and standard deviations for all *DVs*

DVs	Without the support tool		With the support tool	
	Young adults	Older adults	Young adults	Older adults
Search performance (%)	57.14 (24.21)	47.62 (20.25)	48.96 (18.73)	50.00 (16.67)
Nb multiple consultations webpages	8.11 (5.19)	12.02 (12.96)	9.35 (5.48)	23.93 (22.47)
Nb of revisited webpages per query	2.05 (1.64)	6.79 (3.89)	1.88 (1.35)	2.21 (1.23)
Time querying	10.87 (3.35)	22.13 (13.86)	12.23 (6.67)	14.45 (3.51)

3.3 Impact of Age, the Support Tool and Interaction Effects on Search Behavior

Multiple consultations of content webpages. The model accounted for a significant proportion of the variance of multiple consultations of content webpages ($R^2 = .26$, $F(4,43) = 3.87$, $p < .01$). Effect of age was not significant (B = .28, $t(43) = .70$, $p = .48$). The support tool significantly reduced the amount of multiple webpages consultations (B = − 1.82, $t(43) = -3.04$, $p < .01$). Effect of the covariable was not significant (B = .26, $t(43) = .83$, $p = .41$). The interaction term reached significance (B = − 1.28,

$t(43) = -2.09$, $p = .04$). To investigate the significant interaction, we used the simple slopes technique and the Johnson-Neyman test to define the value of the moderator that had a significant impact. Results showed that for older adults, the support tool significantly reduced the amount of webpages revisits (p < .04, no effect appeared for young ones p = ns).

The number of webpages revisited per query. The model accounted for a significant proportion of the variance of the level of exploitation of queries ($R^2 = .46$, $F(4,43) = 9.10$, $p < .001$). Effect of age was not significant (B = .06, $t(43) = .15$, $p = .88$). The support tool significantly reduced the number of webpages revisited per query (B = − 1.57, $t(43) = -2.73$, $p < .01$). Impact of the covariable was not significant (B = −.46, $t(43) = -1.56$, $p = .13$). The interaction term reached significance (B = 2.11, $t(43) = -1.56$, $p < .001$). For older adults, the support tool significantly reduced the number of webpages consulted multiple times ($p < .001$, no affects appeared for young ones ($p = .47$).

Time querying. The model accounted for a significant proportion of the variance of the time spent querying ($R^2 = .34$, $F(4,43) = 5.63$, $p < .001$). Effect of age and support tool were not significant (B = .73, $t(43) = .28$, $p = .78$ and B = − 2.43, $t(43) = -1.01$, $p = .32$). The covariable significantly decreased the time spent querying (B = −2.57, $t(43) = -2.64$, $p = .01$). The interaction term reached significance (B = 10.19, $t(43) = 2.58$, $p = .01$). In line with prior pattern, for older adults, the support tool significantly reduced the time required to reformulate queries amount of webpages revisits ($p < .001$, no effect appeared for young ones p = ns).

Table 3 below presents a synthesized overview of the significant moderation effects of the support tool on the relation between age and search performance and behavior.

Table 3. Overview of the significant moderation results observed (* reflects significance)

DV	Model significance	Age*support tool (ST)
Search performance	*	ns
Multiple consultations of content webpages	*	* ST reduced older users' multiple consultations
Level of exploitation of queries	*	* ST reduced older users' exploitation of queries
Time querying	*	* ST reduced older users' time querying

4 Results

The present study investigated how a support tool that helps users refresh their search goal in working memory (by displaying the user's ultimate query) could improve older adults' search behavior and performance.

First, results showed that after controlling the ability of older adults to refresh information in working memory, effect of age alone was overall not significant on search performance and behavior. The ability to refresh information in working memory improved search performance, fostered more exploration (*i.e.* decreased query exploitation) and reduced the time spent reformulating. These findings tend to corroborate how the age-related decline of fluid abilities can account for the impact of age on IS [1].

Findings of the present study provided new empirical evidence for the benefits of supporting search goal refreshing in working memory for older adults. Results showed that the support tool reduced the number multiple visits of content webpages, the exploitation of queries and the time needed to reformulate for older adults. Indeed, when users could not rely on the support tool to refresh their search goal in working memory, older adults encountered more difficulties than young ones (more multiple webpages consultation, query exploitation and longer time querying which can reflect disorientation and perseveration strategies [5]). In contrast, when users had the support tool, no age-related effect appeared. These patterns highlight how helping older adults save up some cognitive resources that would have been allocated to search goal refreshing in working memory can buffer the negative impact of age on IS.

Interestingly, eye-tracking data also pointed out that older adults made more eye-fixations to the support tool when they were processing content webpages. This pattern may also reflect how supporting search goal refresh in working memory can help older users elaborate relevant processing strategies on websites (*i.e.* focus attention to relevant information in content webpages, improve relevance assessment and extraction of information). Supporting webpages content processing seemed to have, in terms, helped older adults reformulate queries more efficiently (*i.e.* reduced the time required to reformulate).

In a nutshell, findings showed that older user-friendly search interface should cope with the age-related decline of update in working memory. Support tools should reduce the cognitive processes users have to engage in order to search for information with a search engine. Displaying users' ultimate query at all time seems to represent an easy and efficient way to support older adults' activity and foster more flexible strategies. Further works should investigate this support tool for search tasks of various nature and with larger samples.

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Development of Cognitive Function Evaluation Contents for Mobile Based on MMSE-DS

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Abstract. Mild cognitive impairment (MCI) is considered as the intermediate stage between the cognitive changes of normal aging and dementia, which is marked by decline in memory but preserved ability to perform activities of daily living compared with that of healthy individuals of the same age. These patients need to delay the progression to dementia through early diagnosis and use the standardized Mini-Mental State Examination (MMSE) as an assessment tool.

This study realized the content into a convenient mobile application for assessment of cognitive abilities based on MMSE for Dementia Screening (MMSE-DS) modified as a Korean version, and verified the consistency of a modified version compared to MMSE-DS and user satisfaction. Most content items consist of multiple-choice questions with four answer choices to allow convenient assess to the content via mobile devices. Since it is challenging to identically express questionnaire items assessing patient's active performance as a content, items are represented as following: First, in an item on folding a given paper in half in response to examiner's command, a subject is asked to draw a line on a yellow rectangle at the location where paper can be folded in half. Second, in an item on exact copying of two intersecting pentagon figures, a subject is asked to find a pentagon figure same as the pentagon shape in the given example. As a result, the Intraclass Correlation Coefficient (ICC) was 0.938, showing a significantly high correlation.

Keywords: MCI · Dementia · MMSE-DS · Cognitive function
Mobile contents

1 Introduction

As South Korea rapidly becomes an aging society amid economic growth and medical technological development, mild cognitive impairment (MCI) that depresses cognitive function is increasing [1]. MCI is the problem of weakened memory compared with that of the same age group, referring to the status of impaired activities of daily living other than dementia. That is, MCI is a middle stage between normal aging and dementia and known to be a high-risk group possibly developing Alzheimer's disease according to preceding study results so far. Therefore, it is clinically important that MCI patients detect it in the earliest possible phase before progressing into Alzheimer's to maximize treatment effect.

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In order to identify MCI patients, cognitive function test must be implemented and it is also essential to provide appropriate cognitive rehabilitation programs for patients. Paper and pencil test based on paper questionnaires is known to be frequently utilized as a cognitive function test method so far. Such a method can hardly control the conditions taking place in the test process according to a patient's seriousness of disease; thus, it is prone to errors in grading and recording. Moreover, if an inexperienced inspector implements the test, the objectivity of measured data could have a problem. It is also true that test details and grading data are difficult to keep in any convenient manner [2].

In order to resolve such problems, computer-based cognitive function test methods have been developed since the late 1990s to help reduce the effect of test environment while ensuring objective test results. Such computer-based methods are easy to analyze data and keep their details and data efficiently. As their reproducibility and staff efficiency are high, many studies have suggested they would be useful [3, 4]. However, most of the studies using computerized methods stop at finding the usefulness of test in normal people, elderly people and diseases such as schizophrenia. There has been no computer-based cognitive function test method for universal use [5]. Recently, in Korea, cognitive function test applications for mobile use are increasingly developed, which are easily accessible anytime anywhere [6]. Google Play Store provides dementia test applications such as Mental Health Test, Smacare, Dementia Check, and White Paper for Dementia. Most are developed based on the K-MMSE (Korean-MMSE), MMSE-KC (MMSE-Korea Child), and MMSE-DS (MMSE for Dementia Screening) that reorganized MMSE (Mini-Mental State Examination) for Korean people [7–10]. But, since it is difficult to express the questionnaire details identically in application, many details are arbitrarily changed or removed. Furthermore, the reliability of clinical agreement cannot be confirmed.

Therefore, in this paper, a mobile application was developed for cognitive function test to have the maximum possible similarity with the MMSE-DS questionnaire items which are strong in assessing the reading/writing areas, in particular, according to test subjects' educational background while having no difference from K-MMSE in distinguishing MCI from dementia. Particularly, MMSE-DS could score differently the test subjects even with the same difference in items and implementation methods between the existing K-MMSe and MMSE-KC questionnaires [9]. It is made by the Korean Ministry of Health and Welfare after simplification to help improve reliability and accuracy [10].

This study sought to help test subjects easily utilize the developed application based on MMSE-DS test items and deliver stronger reliability than that of the existing applications. To test it, the agreement (intraclass correlation coefficient) of results between existing MMSE-DS questionnaire and contents was inspected and the subjects were surveyed to examine their satisfaction with the contents.

2 Implementation of Contents

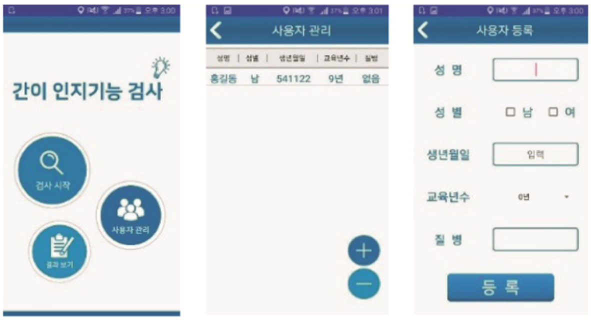
2.1 MMSE-DS Item Classification and Normative Score

MMSE-DS cognitive function test has items on time orientation (5 questions, 5 points), place orientation (5 questions, 5 points), memory registration (1 question, 3 points), attention (1 question, 4 points), memory recall (1 question, 3 points), naming (2 questions, 2 points), shadowing (1 questions, 1 point), order execution (1 question, 1 point), figure copying (1 question, 1 point), and judgment and common sense (2 questions, 2 points) to make the total of 19 question items with 30 points. The appropriate point of normative score is classified according to users' academic background, age and sex. In the case of scoring under the appropriate point, the user is decided to belong to the cognitive decline group; and in the case of exceeding it, normal group [11].

2.2 Application Composition

In the application of this paper, the questions of every item were placed in the upper part of the screen and the answers and choices, in the lower part. For the convenience of mobile device operation, 4-choice questions were employed rather than short-answer questions to get answers to multiple choice questions.

As in Fig. 1(a), the application main page consisted of test start, user management and view results. Before test start, users make user registration in Fig. 1(b) and (c). In user registration, name, gender, date of birth, number of education years, and disease details are filled in to create an appropriate normative point.



(a) (b) (c)

Fig. 1. (a) Main screen (b) User management DB (c) User registration

2.3 Application Contents

First, for the information on time orientation and place orientation items (time, location, etc.), the values provided from mobile device were employed. Questions in the application were organized identically to those in the questionnaire. Questions on memory registration, memory recall, and shadowing acoustically presented words and sentences for users to remember and select among the choices. The question on attention to subtract 7 from 100 consecutively and the question on naming to answer the right names of "time" and "pencil" were made as 4-choice questions.

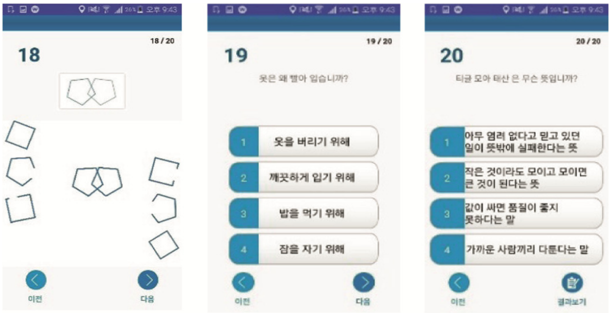
Questions on order execution and figure copying were difficult to apply to mobile devices in the form of question to evaluate test subjects' active execution. Thus, depending upon developers' arbitrary interpretation, question forms have changed arbitrarily. I order execution questions, test subjects are evaluated for their execution ability to, for instance, fold paper in half according to the order of an inspector. But, existing contents have changed question text differently such as 'put garbage in the garbage can', 'get the correct order of presented pictures'. In this present paper, however, instead of making users fold paper, they are instructed to draw a line on the yellow rectangle as in Fig. 2(a), to ensure the most similar execution to that under the questionnaire. The criterion for correct answer, as shown in Fig. 2(b), is to have a line within the shaded area in the program, which trisects the rectangular both horizontally and vertically as in Fig. 2(c).

(a) (b) (c)

Fig. 2. Interface for instruction execution

Figure copying question is to evaluate a test subject's mirror tracing of the two overlapped pentagons presented. Most of the existing contents either excluded the question or changed forms to "combine two triangles", etc. However, figure copying question is to assess if a test subject can draw figures correctly by looking at the presented figures and if the figures are correctly overlapped in their drawings with a view to assess their ability of organization. Previously-produced contents can affect the organization ability assessment.

For this reason, it was decided, in this present study, to place in the upper part of screen the same picture as the overlapped pentagons presented in the MMSE-DS questionnaire as in Fig. 3(a). Test subjects choose the figures identical to those presented in the lower left and right sides of screen they drag them to the empty place in the center. After they choose a pentagon, the correct answer is processed by operating the area coordinates of the two pentagons. Figure 3(b) and (c) are the questions on judgment and common sense, which are set up in 4-choice questions so that patients who are unaccustomed to operate mobile device can choose right answers conveniently. The question details were made identical to those in the MMSE-DS questionnaire.



(a) (b) (c)

Fig. 3. Interface for figure copying, judgment and common sense

3 Test Method and Results

3.1 Test Subject

The cognitive function test for mobile device was verified with the help of hospitals having a rehabilitation medicine department by testing 20 male and female brain disease patients (9 men, 11 women) aged 19 or older who had given consent to test participation among the outpatients or hospitalized patients receiving rehabilitation treatment. In the event that a test subject or his or her representative requests to cease the clinical research; or if visit schedule is not met or subjects do not cooperate; such subjects were replaced with new subjects to avoid possible disturbance in clinical study progress. The causes of disease of selected test subjects were cerebral infarction in 6 patients; cerebral hemorrhage in 8; brain tumor in 2; traumatic brain disease in 2; and brain damage in 2. Their total average age is 57.9 and the average period from disease occurrence to the present day of cognitive function test is 709 days.

3.2 Test and Survey

Each of the MMSE-DS questionnaire and cognitive function test application for mobile device developed in this study were implemented with at least 7-day interval in between. A total of 2 experienced inspectors participated, who had received sufficient education on consistent evaluation criteria. Then, to understand the convenience of the contents and satisfaction, the inspectors surveyed the 20 patients participating in the treatment with 5-choice questions on accessibility, convenience in use, satisfaction with UI, satisfaction with use, usefulness, etc.

3.3 Agreement Evaluation

To quantify the measurement error in the Inter Class Correlation Coefficient (ICC), an index commonly utilized in evaluating repeatability and reproducibility, or Reliability Coefficient; this paper employed the Standard Error Measurement (SEM) and Smallest Real Difference (SRD). Generally, if the reliability coefficient of ICC = 0.80, agreement level is viewed high [12]. Moreover, to see if each of the patients' test score change is determined at the confidence level o 95%, the SRD was utilized [13, 14]. The SEM has small measurement errors in the case of less than 20% of the highest score among the measurement values; thus, it seems reliable [15].

3.4 Test Results

Table 1 shows the results of comparing agreement between the MMSE-DS questionnaire and the contents produced in this paper. The ICC of test results is 0.938, exceeding the reliability index of 0.8. SRD = 2.664 within 10% of the max value; and SEM = 0.961 within 10% of the average value. Based on the results, the mobile-device cognitive function test application of this study seems to have sufficiently consistent results with those of the questionnaire.

Table 1. The degree of agreement between MMSE-DS and the application

		Inter-rater					
Evaluation	n	Mean (SD)	ICC	95% CI	SEM	SRD	Max
MMSE	20	22.15 (6.08)	0.938	0.952–0.975	0.961	2.664	30

Figure 4 shows the results of survey on convenience and satisfaction. Responses of at least "Yes" were 80% in Question 1; 55% in Question 2; 80% in Question 3; 80% in Question 4; and 70% in Question 5. On average, "Yes" or better responses were frequent in the results. Such survey results indicate that the application developed in the study is appropriate in terms of convenience and satisfaction.

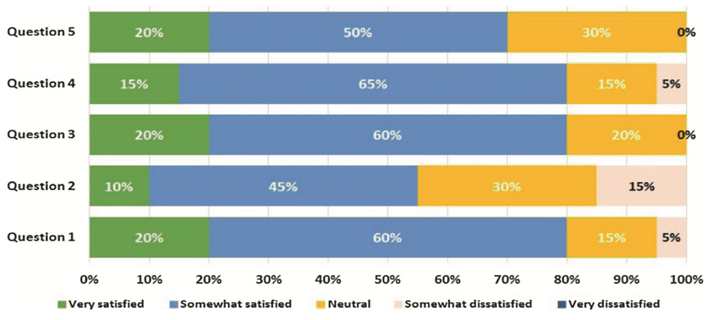


Fig. 4. Result of questionnaire about convenience and satisfaction

4 Conclusions

With the surging number of patients with dementia in South Korea, research has been going on to detect MCI cases in the early stage to delay its progress into dementia. Accordingly, computerized contents for cognitive function test and training are actively developed and many relevant mobile applications are presented. Most of the existing commercialized applications were developed based on K-MMSE and MMSE-KC but their question items are less similar to those in the original questionnaire.

Such a weakness is shown in order execution, figure copying, reading and writing, and judgment, by excluding some of the existing questionnaire questions or causing arbitrary interpretation. In consideration of the accuracy and reliability of questionnaire questions, this present study employed MMSE-DS questionnaire combining M-MMSE and MMSE-KC and worked to ensure the highest possible similarity to the questionnaire questions.

First, the order execution question to make subjects fold a given sheet of paper in half following the order of an inspector was converted to make subjects draw a line of folding in half on a yellow rectangle.

Second, the figure copy question was to let subjects draw identically to the two presented overlapped pentagons. In this study application, it was changed to let subjects find and arrange appropriate pentagons among those given in the choices.

Third, the judgment question was set up identically to the MMSE-DS questionnaire question. Subjects choose the right answer among the four given choices.

The developed application was tested to compare with the conventional MMSE-DS questionnaire. As a result, the inter-class correlation coefficient ICC = 0.938, higher than the reliability coefficient ICC = 0.8, indicating sufficient degree of agreement. Based on such results, it is expected to use the mobile application to solve the problems of conventional questionnaire such as error in grading and recording, objectivity in measured data, and convenience in test details and grading data storage. Moreover, in the survey on convenience and satisfaction, at least 70% of the subjects gave a positive answer, implying that, regardless of age, most are accustomed to using mobile devices. This finding seems because most of the results pages were visualized for their easy understanding. Therefore, with this convenient and easily accessible mobile application, anyone does not have to be bothered by other people's awareness on cognitive functional weakening while responding to changes on their own or with the help of their family through continued test taking.

The evaluation of the mobile application developed in this study bases on the results from some of the test subjects. It is necessary to include more subjects to verify in the future.

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Evaluation of Touch-Based Interface Design for the Elderly Based on Cultural Differences

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Abstract. A study was conducted to evaluate the cross-cultural differences of the elderly preferences on touch-based interface design. Hofstede's theory of cultural dimensions [3] was used as the theoretical framework to guide this study. In this study, different age groups of Korean and Indonesian elderly were recruited to do the usability testing of a touch-based interface design. A prototype was designed with the culture-related features to compare their preferences. Value Survey Module (VSM) 2013 was used to collect their cultural dimensions scores. Usability rating questionnaires were used to measure their satisfaction scores toward the prototype. The interface features rating questionnaire was distributed to collect their preferences toward the touch-based interface design. The objectives of this study were: 1. To identify the differences in cultural dimensions scores, 2. To identify the differences in usability testing scores based on Nielsen's evaluation criteria, 3. To identify the differences in touch-based interface design preferences of the elderly based on different cultures. Significant differences are found in the cultural dimensions scores, as well as the touch-based interface features ratings. Significant differences are also found in the usability testing which included four criteria: efficiency, learnability, errors, and satisfaction. The results of this study can be used to improve the design of the touch-based interface for the elderly based on their cultural differences.

Keywords: Cross-cultural study · Usability · Touch-based interface Elderly

1 Introduction

A smartphone is a popular communication device that typically has a touchscreen interface. Although it is widely used, the elderly consistently have lower rates of this technology adoption than the general public [1]. Designing for the elderly involves more than designing to accommodate the physical and psychological changes due to the aging effect. Their preferences on the interface also can be different according to their cultural characteristics. Therefore, the cultural differences should be considered in designing the appropriate interfaces for the elderly.

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There have been many studies that explored the interface design for the elderly, including one by Boustani [2]. On the other side, there has been a cross-cultural study that evaluated the user preferences on the cell phone based on cultural differences [5]. The purpose of this study is to evaluate the culture effects on touch-based user interface design preferences of the elderly based on nationality and age groups.

2 Literature Review

2.1 The Elderly Population

The definitions of an elderly person range from 50 to 80 years old and above [10]. There has been a research about the touchscreen mobile user interface for seniors that was aimed at people older than 50 years old [11]. ALTEC-Project study how elderly people deal with technologies that are used in everyday life. From 1400 subjects, 200 subjects were older than 60 years old [8].

2.2 Culture Dimensions

There are many aspects of culture that impacts the interface preferences, such as user's nationality, language, religion, the education level, and the form of education [9]. Hofstede's theory of cultural dimensions is the best known and most applied theory of intercultural communication [3]. Cultural dimensions were measured using Value Survey Module (VSM) 2013. In this questionnaire, there is a new dimension named Indulgence. Since there are only a few adaptations about this dimension, it will not be considered further in the study.

Power distance (PDI) is defined as the extent to which the less powerful people in society accept and expect that power is unequally distributed [3]. Individualism (IDV) represents a preference for a loosely-knit social framework where people are expected to look out for their own interests take care of themselves, whereas collectivism indicates an inclination toward a tightly-knit social framework where people expect their companions to look out for their welfare and where personal goals are subordinated to those of the group [3]. Masculinity (MAS) measures the degree to which a culture separates gender roles. Masculine cultures focus on the traditional assignment of assertiveness, competition, and toughness, and feminine roles focus on the orientation to home and children, people, and tenderness [3]. Uncertainty avoidance (UAI) is defined as the extent to which the members of a culture feel threatened by uncertainty and the unknown situations, along with the eagerness to avoid these situations [3]. Long-term orientation (LTO) indicates that the country fosters virtues oriented towards future rewards, in particular, perseverance and thrift [3].

2.3 Touch-Based Interface Features and Correlated Cultural Dimensions

Table 1 shows the interface features that have been summarized from the previous studies of touch-based interface design for the elderly [2] and cell phone interface design based on cultural differences [5]. Each attribute has been mapped with its

Table 1. Proposed interface features and correlated cultural dimensions

Interface features	PDI	IDV	MAS	UAI	LTO
Large amount of contents				Low	
Secondary information about contents				High	
Meaningful classification of contents	High				
Friendly and informative error messages			Low		
Icon or image-based style		Low			
Colorful interface		Low			
Large and clear font style				High	
Aesthetical interface			Low		
Clear menu labeling	High				
Minimal steps	High				
Large and clearly distinguished targets	High				
Single touch-based interaction					High

relationship according to the cultural dimension, based on the cross-cultural study of websites interface design [9].

3 Methodologies

3.1 Research Questions and Hypotheses

This study has been designed to answer the following questions:

- What are the differences in cultural dimensions scores between the older adults and elderly groups across Korea and Indonesia?
- What are the differences in the usability testing scores between the older adults and elderly groups across Korea and Indonesia?
- What are the differences in touch-based interface ratings between the older adults and elderly groups across Korea and Indonesia?

The hypotheses corresponding to the research questions are listed as follows:

- There will be a difference in cultural dimensions scores between the elderly in Korea and Indonesia and between the older adults and elderly groups.
- Users with higher uncertainty avoidance and higher long-term orientation will have higher scores on efficiency, learnability, fewer errors, and higher rating on the task with the cultural related feature.
  - Users with higher uncertainty avoidance will have higher scores on all the tasks.
  - Users with higher long-term orientation will have the higher score on the task zooming a photo.
- There will be a difference in touch-based interface design preferences between Korean and Indonesian elderly, and between the older adults and elderly groups.

3.2 Usability Testing

The prototype has been designed with the features of high uncertainty avoidance and high long-term orientation cultures to compare the preferences of the Korean and Indonesian elderly. Its features include a strict amount of contents, secondary information about contents, large and clear font style, and single-touch interaction.

According to Nielsen [7], there are four evaluation criteria for the usability that need to be considered. Table 2 shows the parameter of each criterion.

Table 2. Nielsen's evaluation criteria

Criteria	Description	Parameter
Efficiency	Assessment of time needed for carrying out a task	Time
Learnability	Easiness to learn the system	Time
Minimal errors	Errors made by users when using the system	Number of error taps
Satisfaction	User preferences on the system	Questionnaire

Two experiments were conducted separately in Korea and Indonesia. First, participants were asked to complete the demographic questionnaire and VSM 2013 questionnaire to collect their demographic and cultural dimensions scores. Then, they were asked to carry out the tasks assigned to the touch-based interface: call a number, add a new contact, send a message, and zoom a photo. The last task reflects the long-term orientation as it utilizes a single-touch interaction. The execution time and the number of mistakes of each task were measured. The usability rating questionnaires were distributed after each task to measure their satisfaction scores toward the interface design. Finally, the interface features rating questionnaires were distributed to collect the data about their preferences toward the interface design.

4 Analysis and Results

4.1 Participant Demographics

A total of 40 participants were recruited in this study, 20 in Korea and 20 in Indonesia. The participants belong to two groups, the 50–59 years old group which is referred to as the older adults group and 60 years and older group which is referred to as the elderly group. Table 3 shows the demographics of participants.

4.2 Hypotheses

Cultural dimensions mean scores were calculated using the formulas in VSM 2013 manual. Table 4 indicates that all of the cultural dimensions are significantly different between Korean and Indonesian elderly.

Table 3. Participant Demographics

	Frequency	%
Nationality		
Korean	20	50
Indonesian	20	50
Age		
50–59 years old	17	42.5
60 years and older	23	57.5
Gender		
Male	13	32.5
Female	27	67.5
Education level		
High school/Diploma	28	70
Bachelor's degree	7	17.5
Master's degree	4	10
Doctoral degree	1	2.5
Occupation		
Private company employee	20	50
Entrepreneur	7	17.5
Unemployed	13	32.5
Smartphone usage	*Years*	
Korean	4.8	
Indonesian	3.95	

Table 4. Cultural dimensions scores (Two-way ANOVA)

Cultural dimension	Korean	Indonesian	Sig. (2-tailed)
Power distance	−5	39.56	0.021[a]
Individualism	−5.25	60.192	0.000[a]
Masculinity	28	−31.154	0.000[a]
Uncertainty avoidance	6	−49.698	0.03[a]
Long-term orientation	31.75	137.225	0.000[a]
Cultural dimension	50–59 years	60 years and older	Sig. (2-tailed)
Power distance	25.214	13.846	0.498
Individualism	40	14.942	0.104
Masculinity	−4.5	1.346	0.665
Uncertainty avoidance	5.5	−62.857	0.439
Long-term orientation	90.821	78.154	0.449

[a]Significant at 0.05 level.

Table 5 shows that there are significant differences between the older adults and elderly groups in completing all tasks and task zooming a photo.

Table 5. Time measurement for efficiency and learnability (Two-way ANOVA)

Evaluation criteria	Korean	Indonesian	Sig. (2-tailed)
All tasks	33.325	33.091	0.913
Task zooming a photo	34.85	32.434	0.416
Evaluation criteria	50–59 years	60 years and older	Sig. (2-tailed)
All tasks	29.884	36.532	0.003[a]
Task zooming a photo	28.607	38.677	0.002[a]

[a]Significant at 0.05 level.

Table 6 shows that there is a significant difference between the age groups on the task zooming a photo.

Table 6. Number of Errors (Two-way ANOVA)

Evaluation criteria	Korean	Indonesian	Sig. (2-tailed)
All tasks	0.313	0.360	0.487
Task zooming a photo	0.55	0.473	0.620
Evaluation criteria	50–59 years	60 years and older	Sig. (2-tailed)
All tasks	0.384	0.288	0.166
Task zooming a photo	0.707	0.315	0.016[a]

[a]Significant at 0.05 level.

Table 7 shows that there is no significant difference found between Korean and Indonesian elderly as well as the age groups.

Table 7. Satisfaction scores (Two-way ANOVA)

Evaluation criteria	Korean	Indonesian	Sig. (2-tailed)
All tasks	4.54	4.572	0.875
Task zooming a photo	4.638	4.913	0.2
Evaluation criteria	50–59 years	60 years and older	Sig. (2-tailed)
All tasks	4.708	4.403	0.14
Task zooming a photo	4.9	4.651	0.246

Table 8 shows that there is a significant difference between Korean and Indonesian elderly in the single-touch interaction feature.

Table 8. Interface features ratings (Two-way ANOVA)

Interface feature	Korean	Indonesian	Sig. (2-tailed)
Large amount of contents	3.95	4.181	0.417
Secondary information about contents	4	3.923	0.770
Meaningful classification of contents	3.85	4.363	0.089
Friendly and informative error messages	4.1	4.220	0.646
Icon or image-based style	3.3	3.181	0.761
Colorful interface	3.45	3.368	0.830
Large and clear font style	4.45	4.368	0.780
Aesthetical interface	3.5	2.918	0.092
Clear menu labeling	4.2	4.258	0.780
Minimal steps	4.1	4.368	0.373
Large and clearly distinguished targets	4.25	4.231	0.945
Single touch-based interaction	3.8	4.555	0.032[a]
Interface feature	50–59 years	60 years and older	Sig. (2-tailed)
Large amount of contents	4.143	3.988	0.587
Secondary information about contents	4.050	3.873	0.503
Meaningful classification of contents	4.386	3.827	0.065
Friendly and informative error messages	4.193	4.127	0.8
Icon or image-based style	3.093	3.388	0.45
Colorful interface	3.464	3.354	0.773
Large and clear font style	4.364	4.454	0.760
Aesthetical interface	3.171	3.246	0.825
Clear menu labeling	4.293	4.165	0.542
Minimal steps	4.264	4.204	0.84
Large and clearly distinguished targets	4.2	4.281	0.773
Single touch-based interaction	4.286	4.069	0.527

[a]Significant at 0.05 level.

5 Discussion and Conclusion

The results show that there are significant differences in all cultural dimensions scores between Korean and Indonesian elderly. The differences in cultural dimensions scores are influenced by nationality culture.

Regarding the efficiency and learnability test results, it was found that the older adults group completed all tasks significantly faster than the elderly group. Based on the errors test results, it was found that the elderly group had significantly fewer errors on the task zooming a photo than the older adults group. There is no significant difference found in the satisfaction test results. It can be concluded that the differences in time and errors measurement are driven by the age groups culture.

Furthermore, there is a significant difference in the interface features ratings between Korean and Indonesian elderly. It was found that Indonesian elderly had a higher preference for single touch-based interaction feature than Korean elderly. The difference in this feature preference is influenced by nationality culture.

This study compared the elderly's preferences on touch-based interface design based on nationality and age groups cultures. The results found significant differences in the cultural dimensions scores and interface features ratings between Korean and Indonesian elderly, as well as usability testing criteria between the older adults and elderly groups. The interface design embedded with culturally preferred design elements reflecting users' culture can be more effective in the communication for the users [4]. This finding also can help designers in designing and developing the touch-based interface design that is culturally appropriate for the elderly.

There was a possibility of selection bias due to convenient sampling. Therefore, if a completely random sampling method were used, the significance level of the results would be increased. Furthermore, background variables such as the education level and occupation could not be matched perfectly which therefore may affect the results.

For the future work related to the cross-cultural studies, it is suggested to consider the influence of the cultural dimensions on the responses of rating questionnaire, if applicable, as Johnson [6] has found that the cultural dimensions are associated with the response style of the respondents. By adopting certain methods to reduce the effects of response bias, the results of the research can truly reflect the cultural differences and lead to a higher reliability and validity.

Compliance with Ethical Standards. This research was supported by the KIST Institutional Program (2E27200). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institution at which the studies were conducted. Informed consent was obtained from all individual participants included in the study.

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Virtual and Augmented Reality

Use of the Augmented REality Sandtable (ARES) to Enhance Army CBRN Training

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Abstract. This paper presents the results of an evaluation of the Augmented REality Sandtable (ARES) as a training tool during the Chemical, Biological, Radiological, and Nuclear (CBRN) Captain's Career Course (C3) Table Top Exercise (TTX). Two teams, one that used ARES and one that did not, were compared across a series of course assessments, knowledge acquisition tests, and self-reported questionnaires. The ARES team used the system to develop various map overlays, evaluate their proposed strategies while integrating feedback from the CBRN plume-transport and dispersion simulations, and brief their results to the course instructor for evaluation. Results reveal an overall positive perception of ARES in terms of supporting the development of course outputs. Recommendations for future iterations of the system were gathered from the ARES team following the TTX.

Keywords: Augmented reality · Military battlespace visualization
Military decision making process · Plume dispersion modeling

1 Introduction

The United States Army makes use of a wide array of data that may be visualized geospatially. Soldiers and Army leadership may subsequently use these data in a variety of ways, including for training and mission planning. In the context of the study presented here, geospatial data are used within a structured decision making process (called the Military Decision Making Process, MDMP) to understand a situation, develop a course of action, and produce an operation plan. Specifically, the study investigated two groups of students (all officers in the U.S. Army or U.S. Marine Corps) that made use of two different sets of tools to complete a course exercise. The conditions were: (1) a set of traditional tools used in the course, including computerized maps, worksheets, and other resources presented via Microsoft PowerPoint; and (2) a new suite of tools provided as part of the Augmented REality Sandtable (ARES), a research and development testbed under development by the U.S. Army Research Laboratory (ARL). The purposes of the study were two-fold: (1) collect subjective and quantitative measures

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of student performance using the two sets of tools, and (2) evaluate use of a new computer simulation modeling Chemical, Biological, Radiological, and Nuclear (CBRN) effects on ARES. This section introduces the ARES platform, the course, and the CBRN simulation, respectively. Subsequent sections present study methodology, results, and a brief discussion of findings.

1.1 ARES, the Augmented REality Sandtable

The Augmented REality Sandtable (ARES) is a research and development testbed with the aim to improve tools for visualizing and interacting with battlespace information, providing a user-defined common operating picture at the point of need [1]. The ARES platform supports visualization through several modalities, including but not limited to a traditional sand table (7' × 4') with projected, visual representations of an area of operations and related terrain and tactical data. The data are fed from a computer through a commercial projector above the sand table. However, ARES is device agnostic and does not necessarily require the physical sand table. The platform provides various interaction modalities that adapt to the use case (e.g., a mobile software application for tactical planning and mixed-reality headsets like the Microsoft HoloLens and HTC Vive). Figure 1 shows the sand table implementation of ARES in use during the study.

Fig. 1. CBRNC3 students utilizing ARES during the TTX.

1.2 Chemical, Biological, Radiological, and Nuclear Captain's Career Course (CBRNC3)

The CBRNC3 is an extensive course that "provides company grade CBRN Officers the technical skills and knowledge to perform the duties and responsibilities required of company commanders and brigade level battle staff CBRN Officers [2]." A Table Top Exercise (TTX) is held at the end of the course which emphasizes the implementation of the military decision making process (MDMP) and rapid decision-making and synchronization process (RDSP) during various CBRN defensive and offensive scenarios. The MDMP is a seven-step "iterative planning methodology to understand the situation and mission, develop a course of action, and produce an operation plan or order [3]." The goal is to provide commanders with information to support their understanding and visualization of the tactical environment [4]. RDSP is a five-step process that "lets leaders avoid the time-consuming requirements of developing decision criteria and comparing courses of action (COAs) [5]." While the MDMP is done in the planning phase which usually takes a few days and results in the optimal solution, the RDSP is conducted during the execution phase and requires timely and effective solutions [5]. The CBRNC3 TTXs are designed to evaluate the students' ability to apply both processes to operational scenarios. Students are expected to generate multiple map overlays and hazard prediction plots and brief them to the instructor (taking on the role of a commander) in accordance with MDMP/RDSP doctrine. In the past, this course lasted 22 weeks with multiple TTXs conducted throughout the course. Modifications are being made to enhance the effectiveness of the course, therefore the multiple TTXs that were conducted throughout the course are being replaced with a single week-long TTX that incorporates various CBRN scenarios. The evaluation of ARES was conducted during this single week-long TTX.

1.3 CBRN Simulation

The ARES-integrated simulations for CBRNC3 utilize a version of the Weather Research and Forecasting (WRF) model [6, 7] that has been augmented for plume transport and dispersion modeling. The WRF model was adjusted to target a domain size of 50 to 200 km on a side, translating to a simulation capability of 1200 km^2 to 20,000 km^2. The mesoscale simulation domain size chosen will automatically determine a horizontal resolution between 0.5 km and 2 km. This size of domain can produce 6 simulation hours with the first frame arriving roughly after a minute. This first minute is part of the automated simulation initialization, boundary, and plume release conditions.

This model is not part of the Joint Effects Model (JEM)/Joint Warning and Reporting Network (JWARN) system. The WRF-based CBRN simulation is fully integrated within ARES such that topography of a mapped area (as measured by ARES camera using the user-shaped sand as a proxy to map terrain) is ingested into the WRF-based simulations, directly affecting simulated plume transport and dispersion.

2 Methodology

2.1 Participants

Twenty-eight Soldiers from Fort Leonard Wood's CBRNC3, 21 males and 7 females ($M_{age} = 29$ y.o., $SD = 3$) participated in the evaluation. Participation was voluntary and no compensation was awarded. Participants were mostly from the U.S. Army, but two were Marines. The number of years in the services ranged from 4 to 16.5 years ($M = 6.9$, $SD = 4$). The number of CBRN related training courses they have taken prior to the current one ranged from 1 to 13 ($M = 2.6$, $SD = 2.9$). Additionally, only six reported being deployed to a CBRN unit ($M = 8.7$ months, $SD = 8.6$).

Information reported on the demographics questionnaire also stated that no one, except for a single participant, had previous experience with an augmented reality sand table. Further, the majority (21 participants) have had experience interacting or using a tablet in general ($M = 4.6$ years, $SD = 3.3$), but only a small portion reported using a tablet to edit images (7 participants).

2.2 Questionnaires

Table 1 lists and describes the five subjective and objective questionnaires employed in the study to elicit subjective feedback from participants. Additionally, a grading rubric for the briefs (CGSC Form 1009s) was used to elicit a measure of team performance from the course instructor. This grade provided an assessment of the quality of the students' presentations when using ARES compared to the traditional method. The instructor focused on grading teams on two main factors: accuracy and support. Grades are provided using 5-point Likert items (1 = Unsatisfactory; 5 = Exceptional).

Table 1. Questionnaires eliciting subjective and objective feedback from participants

Questionnaire	Description
Demographics	Captured general information about participants, learning preference, and any military, technology, and/or CBRN experience.
Knowledge Assessment	Multiple choice and short-answer items regarding MDMP doctrine to test if students gained a better understanding of the CBRN MDMP/RDSP after using ARES. This was implemented as a pre- and post-assessment before and after the TTX. The assessments were validated by the course instructor.
Team Diagnostic Survey (TDS)	Assessed the structure, skills, and communication within a team [8]. Some items of the questionnaire were removed that were deemed irrelevant to the study. Ratings were indicated using 5-point Likert items (1 = Highly accurate; 5 = Highly inaccurate).
Self-efficacy	Assessed how students perceived their ability to perform the CBRN MDMP & RDSP following the TTX. The questionnaire was broken up into two main sections: (1) perceived confidence in their battle staff team to complete each item related to MDMP & RDSP and (2) perceived self-confidence in contributing to future development of items related to MDMP & RDSP. Ratings were indicated using open-ended responses.
Technology Acceptance Measure (TAM)	A self-report that captured the user's ratings on eight subscales: perceived ease of use and usefulness of the system, heightened enjoyment, focused immersion, anxiety with use, output quality, behavioral intention, and personal interest in new technology in relation to system characteristics and probability of system use [9]. Ratings were indicated using 7-point Likert items (1 = Strongly disagree; 7 = Strongly agree).

2.3 Experiment Design

A between-subjects design was used to compare the effects of utilizing ARES on CBRNC3 TTX course deliverables, knowledge acquisition, team collaboration, self-efficacy, and technology acceptance. The class was split into two teams (14 in ARES and 14 in Traditional) for the TTX. The instructor assigned battle staff roles to each person on the teams. Each team was also comprised of sub-teams and coordination among these sub-teams was required to generate the appropriate MDMP/RDSP outputs. One team used ARES to conduct the TTX and the other conducted it as they traditionally would in the course (Fig. 2). ARES was in a separate location from the traditional team, so the teams were not aware of each other's outputs or briefs. The traditional approach involved sub-teams developing MDMP/RDSP outputs using Microsoft Word and PowerPoint on either desktop or laptop computers. This group would use PowerPoint only to brief the instructor on each output. The ARES team had the same resources available to them as the traditional group, but they also had ARES to create and brief their outputs. Plume model simulations were available to both teams if they wanted to utilize them, but the traditional team had to use an additional system (Joint Effects Model (JEM)/Joint Warning and Reporting Network (JWARN)) located in another room while the ARES team had the benefit of the plume simulation integrated within ARES. Prior to beginning work on the exercise, a researcher led a face-to-face training provided to the entire ARES team at the same time.

Fig. 2. ARES team (left) and traditional team (right) developing MDMP outputs.

3 Results

Two-sample *t*-tests were used to assess the effects of utilizing ARES on CBRN MDMP/RDSP outputs, knowledge acquisition, team collaboration, and self-efficacy compared to a traditional approach. Bonferroni corrections were made to determine significant differences between the two groups ($\alpha = .0125$). Sample size for each analysis varied as some participants were not present on the first and last day of data collection, but the minimum was $n = 27$.

3.1 CBRNC3 Briefs Grading Rubric

Two-sample *t*-test found no significant difference between the traditional ($M = 4.33$, $SD = 0.68$) and ARES ($M = 4.50$, $SD = 0.75$) teams on accuracy scores, $t(60) = -0.094$, $p = .17$. Similarly, two-sample *t*-test found no significant difference between the traditional ($M = 4.57$, $SD = 0.69$) and ARES ($M = 4.63$, $SD = 0.77$) teams on support scores, $t(62) = -0.300$, $p = 0.17$.

3.2 Knowledge Assessment

Percent difference scores for pre- and post- knowledge assessments were calculated for each team and then a two-sample *t*-test was run. No significant differences were found between the traditional ($M = 21.6$, $SD = 6.62$) and ARES ($M = 20.6$, $SD = 8.71$) on percent difference knowledge scores, $t(23) = 0.407$, $p = 0.34$.

3.3 Team Diagnostic Survey (TDS)

Two-sample *t*-tests were run for all 13 subscales of the TDS. A significant difference was found between the traditional ($M = 2.52$, $SD = 0.65$) and ARES ($M = 1.88$, $SD = 0.66$) teams on ratings for Knowledge and Skill Related Process Criteria, $t(26) = 2.59$, $p = 0.008$. No other significant differences were found for all other subscales ($p > 0.0125$).

3.4 Self-efficacy Questionnaire

Two-sample *t*-tests were run on all items of the self-efficacy questionnaire. A significant difference was found between the traditional ($M = 86.8$, $SD = 7.8$) and ARES ($M = 94.3$, $SD = 8.5$) teams on ratings for how confident they felt their team could develop a course of action output, $t(26) = -2.43$, $p = 0.011$.

3.5 Technology Acceptance Measure (TAM)

This measure provides descriptive data and was focused specifically on ARES technology so only the ARES team completed this measure. The lowest rating was for elicited anxiety while using ARES ($M = 3.4$, $SD = 0.7$) and ranged to the highest rating which was for perceived enjoyment while interacting with ARES ($M = 4.9$, $SD = 1.1$).

4 Discussion of Results

The goal for this evaluation was to explore the effects of utilizing ARES on CBRNC3 outputs, CBRN MDMP & RDSP knowledge acquisition, team collaboration, enhancing a sense of CBRN MDMP & RDSP skill competency, and perception of accepting ARES technology as a training and application tool. Findings are briefly discussed in this section.

An interesting significant finding is that the ARES team rated themselves as more confident in developing an MDMP output as a team, specifically the COA deliverable. The COA is an output that is comprised of many parts and requires extensive team communication and collaboration which results in multiple map overlays that contain information from all sub-teams. The results indicate that after interacting with ARES, they felt they had a better sense as a team that they could generate a COA in the future compared to the traditional group.

The ARES team and Traditional team performed similarly in terms of instructor assessments of CBRNC3 MDMP & RDSP outputs generated and briefed during the TTX and there were not statistically significant performance differences. Two limitations due to logistical and time constraints lead to difficulty in accurately assessing group performance. The first is that the grading scale (i.e., 1 to 5) used on the CGSC form 1009s may not be sensitive enough to capture true differences that exist between groups. The second is that the instructor of the course was the same instructor that evaluated both teams. Generally, student assessments in a research experiment should be performed by an independent team of evaluators to avoid the potential for bias. Future evaluations may want to consider using multiple instructors not involved in training the students to grade the course outputs.

Based on feedback gathered during a debriefing session, the ARES team much preferred using ARES over the traditional tools (PowerPoint) to create the MDMP & RDSP outputs. They said they could create these outputs quickly and could make less tangible products but still provide the same, if not better, level of detail during their briefs compared to how they created them previously.

5 Conclusion

This evaluation provided the opportunity to investigate ARES as a training tool for the CBRNC3 TTX. The initial findings of this evaluation hold great promise for future applications of ARES. A key recommendation is that future work conduct detailed user-needs analysis of the potential end-users and focus on developing the functionality to meet their needs while ensuring continuous usability evaluations are conducted to support intuitive and efficient interaction with the system.

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Developing an Synthetic Binaural Interactive Soundscape Based on User 3D Space Displacement Using OpenCV and Pure Data

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Abstract. This poster describes a transdisciplinary research concerning the development of an interactive binaural soundscape that responds to user 3D displacement. Soundscapes can be described, according to R. Murray Schaffer (1977) in his book "The Tuning of The World" as an immersive environment which is defined by the combination of all acoustic resources, natural and artificial within a given area as modified by environment. These soundscapes might be generated through the recording of an "natural" specific environment using ambient microphones or it might be completely synthesized using pre-recorded acoustic resources in order to simulate an specific soundscape. The development of artificial soundscapes opens up a whole new range of possibilities such as the development of virtual environments that are able to create an immersive context that allows the user to feel inside the virtual environment. When we create a soundscape that is able to respond to user displacement in a 3D environment like a room, for example, can navigate in a virtual 3D sound environment. Trough the use of a system of cameras we are able to track the user position in a 3D environment and adjust accordingly the previous created soundscape using binaural synthesis. The present project uses OpenCV and Pure Data in order to develop this interactive environment that might be used to develop games for the deaf and to create soundscapes to Virtual Reality environments.

Keywords: Binaural · Soundscapes · Interactive · OpenCV
Pure data · Virtual reality

1 Introduction

Acoustic environments have several types of sound sources. As sound comes from vibrations, anything that is not completely static emits sound, at different intensities, tones and timbres. With so many sound sources generating so much information, we can't pay attention to almost everything we hear because we start to consider it as noise. We can take as an example a person who lives

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near an airport and is disturbed by the noise of neighbors upstairs while not even noticing the noise coming from the planes that take off and land near their residence. The more we are exposed to sounds the more we become used to the point of not noticing them anymore.

According to the ISO 12913-1 [1] soundscapes are constructed from a relation between physical and perceptive phenomena, and can be seen as the human perception of the acoustic environment. The soundscape can be analyzed differently by each person and in different contexts. This research aims to propose an interactive binaural soundscape in order to better understand the relationship between individual, place and context that influences the experience of different people in a particular acoustic environment.

We must use reproduction techniques, from a technological perspective, focusing on the perception of the soundscape. The physical characteristics of the sound that allow the location of the sound source in space and the perception of all interaction of this source with the environment are interpreted when there is a difference of information between the two ears. Binaural reproduction allows us to perceive this difference of information so that we can simulate the soundscape with fidelity.

2 Theoretical Background

2.1 Soundscapes

We can call soundscapes the sound or combinations of sounds that form an immersive environment. Characteristic bells, noises, musical compositions, the specific sonority of each environment, all together creates a soundscape. The soundscape can be defined by three elements: figure, background and field [2]. The figure is where the focus of interest of the listener is concentrated, the background are other elements that make up the scenario where the figure is and the field is the place where everything occurs and that creates this figure-background relationship.

Focusing on sound perception also means focusing on geographic studies that emphasize the importance of a place within a process of meaning-making composed of elements such as geographic coordinates, technological means, social arrangements that develop and many other information. In historical research, hearing has a major disadvantage because the lack of records does not make it possible to have some information about the loudness and intensity of certain objects and environments. Unlike the visual, all the historical contribution we have about the sound landscape is through auditory testimony.

The great problem of auditory testimony is precisely how the relation of sound sources between figure and background is determined. As in Schafer's own example, anyone looking into the clear water of a lake can perceive the reflection itself or the lake bottom, but not both at the same time [2]. From the moment that attention is focused on one sound source, the other becomes an unperceived background and this information is lost in the testimony.

No matter how much the physical dimension contributes, the consideration of sound as a figure or background is intrinsically linked to the habits trained through social and cultural construction and the individual's interest and state of mind. Sound is classified by its physical characteristics, the way it is perceived, its function and the emotional and affective states that it stimulates. All these subjective and objective parameters cannot be analyzed separately when it comes to sound landscape, it is necessary an interdisciplinarity that creates a correlation between the hi-fidelity records and the listener's perception of that sound source.

We relate to the sound imagining visual representations of its reproduction, we perceive its positioning between the speakers, whether they are loudspeakers or headphones [3]. When we imagine or perceive a sound as if it is in the center between two speakers it is not there in fact. What happens is that it is coming out with the same intensity and at the same time of all the speaker and giving us that feeling of symmetry. If we make a panning of this recording, we can move its image left or right, inside the limits defined by the position of the speakers. In addition, we also create a notion of spatiality through effects like delay and reverb, that adds to the sound record a sense of depth. But even so, it is necessary to use extra tools and methods to create a high-fidelity auditory immersion.

2.2 Binaural Sound Representation

Let's separate two audio playback modes between spatialization and auralization. The first one searches for surrounding sound fields, with ambience, through signal processing based on psychoacoustics that give a sense of spatiality. On the other hand, auralization aims to simulate legitimate sound fields with the highest fidelity possible based on wavefront propagation, generating a perception of a sound field that integrates the listener, the primary source (figure) and the secondary sources (background) that composes the sound field [4]. Auralization can be achieved by multichannel through a speaker-matrix or binaural, using a two-channel playback based on the auditory spatial cues of psychoacoustics. The latter is much more relevant to this research and therefore will engage our discussions.

Binaural reproduction is based on how our brain processes the acoustic information that reaches our ears. It is necessary to use a headphone for this technique, because this way ears will receive a direct sound wave, without influence of the external field after the reproduction of the speakers. Our auditory system can distinguish directivity and distance from sound sources from Head Transfer Functions (HRTF). The main HRTF indicators are the Interaural Time Difference (ITD) and the Interaural Level Difference (ILD), which analyze, respectively, the time and intensity difference that the same sound is perceived between one ear and the other [5].

In high-frequency sounds, that have a small wavelength, an acoustic shadow forms in the farthest ear from the sound source, which leads to a decrease in intensity in comparison to the closest ear and makes the ILD quite noticeable. At low frequencies, which have longer wavelengths, it does not generate an acoustic shadow but a delay occurs in the wavefront, which makes it possible to perceive the direction through the ITD.

ILD and ITD are auditory locator indicators for the horizontal plane. For the vertical plane, the indicators are monaural, which generates a spectral alteration in the sound due to reflections of the chest, head and external ear. These changes occur due to the interference of the reflected waves mentioned above and by direct waves, with a lag that increases some frequencies and degrades others.

Finally, the distance can be perceived mainly by the variation of intensity. In open environments, the sound pressure level (SPL) decreases by six dB when the distance between the listener and the source is doubled, when the distance is decreased by half the inverse happens. While in a closed field this variation of SPL happens due to the relation between direct field and the field of reverberation (where there is predominance of the direct field) the law of attenuation for open environments is still valid. From the point where the reverberant field predominates we evaluate the time difference between the direct sound, which travels a minor path and therefore arrives first, and the reverberant sound, which comes later by traveling a greater path and giving us the impression of origin of the walls.

Throughout life we have memorized this great variety of transfer functions corresponding to the directions and distances of the sound sources and with this we weigh all these functions and distinguish the exact location of the sound. Even though the HRTF of each person has variations due to existing physical differences, the result is still satisfactory and effective, allowing to create emulations with optimum fidelity.

3 Binaural Interactive Soundscape

When we hear someone testify about a sound landscape when we are already familiar with it, we easily recognize and visualize what is being said, because we already have that landscape formed in our mind. When the sound landscape is unknown, the person creates an image quite different from the one the witness wanted to pass on to it, as in most of the information that carries a subjectivity. Taking Salvador as an example, which is a tourist city and with a strong sound peculiarity, it is remarkable the lack of understanding of the people of other cities when someone tries to comment on the sound of the city.

The proposition of the binaural interactive sound landscape is to get the listener to have a first-person experience in the field of sound rather than an external presentation. This will make it possible for him to walk through characteristic places with a faithful sound record and make his own analysis of the sound of the place, feeling inserted in it. In addition, this experience also allows you to recognize sound sources and map their position. As described in Fig. 1, this research is based on computer vision system that will recognize user displacement and through TUIO protocol will send real-time information to a sound synthesis patch written in Pure Data.

The sounds used will be sounds that refer to specific places, precisely so that we can insert people who are not accustomed to that place in a sound field

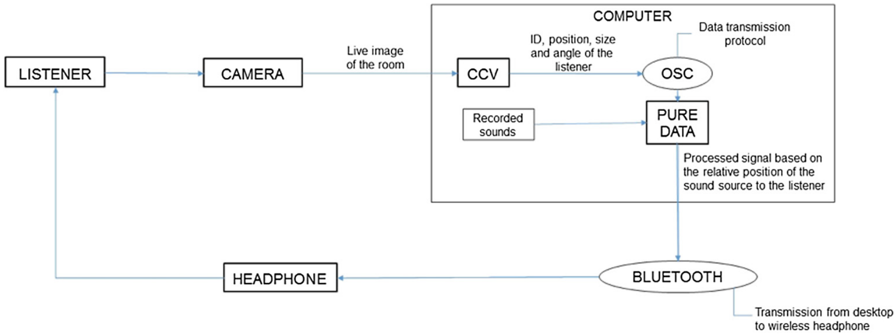

Fig. 1. High level diagram describing the system software and hardware involved

with elements other than what they usually hear, and thus have with them the experience of having to contemplate the and create their own relationship of figure-background in that sound field. We intend, initially, to use the sounds of the historic center and/or the fairs of Salvador, due to identity and also logistics, since it is the city where the University and the laboratory are located. But the intention is to create sound landscapes from other cities as well, to have a larger catalog and allow a better evaluation of reaction and interactivity with unfamiliar soundscapes.

The sound objects will be samples of recordings with an acceptable resolution and made at strategic points to facilitate the mapping and the creation of the dynamics of movement in relation to the listener.

The positioning and displacement mapping of the user will be done by an infrared camera, which makes the color difference not a problem and allows the mapping even in the dark environment, and thus incite a more intense hearing immersion. The camera will be used as an image source for Community Core Vision (CCV). CCV reads a video stream, identifies the object contained in the video, and decrypts data from the object (e.g. coordinates, size, rotation angle).

Since we will have only one person at a time participating in the experiment, Session ID, which is what identifies the video object, will only import to be used as a transfer of the other data sent. Other parameters that are also not relevant are the speed and rotation speed, after all, it is sent after the movement of the object and if the audio synthesizer is to process and execute the speed after the listener is already in the next position there will be a latency large and that will increase with the chain reaction. Because the change of direction and intensity of sound is not procedural between one position and another, it is necessary that this change occur in the shortest time possible, because in addition to making the differences are in small levels, our brain understands small time differences only as distance variation processing. Thinking about this, the ideal is to use a camera with 60 frames per second, so that it would work with 16.6 ms between the samplings, entering the concept in the Hass effect [6].

The data will be sent to the audio synthesizer, which in this case will be Pure Data, via Open Sound Control (OSC)/TUIO described in [7]. After the Pure Data patch receives the angle and user position in x and y coordinates, we calculate the azimuth with the difference between the angle of the position of the sound source in relation to the user position. After this information is calculated we can update the parameters of the synthesized audio samples.

4 Expected Results

Since we are going to do the experiments in a flat room, and at the beginning the parameter of the sound source elevation in Pure Data was not very efficient, the location will be much more noticeable in the 2D plane. But even so we expect a much greater efficiency than the stereo system with only panning and volume as parameters of 2D position, because, as said before, in stereo we have a sound image in 3rd person, while the use of azimuth with Earplug allows us to create an immersive sound field.

We will try to experiment with people who already know the soundscapes that will be reproduced so that they can speak about the similarities and differences of the natural sound fields for the synthesized recordings for binaural. We hope to see how the latency of all processing will work, and even if it occurs with considerable value, how much it will influence the perception being that the hearing will be the only reference in a dark room.

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Enriching Mixed Reality Systems with Mobile Applications

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Abstract. Mixed reality systems immerse users into environments where reality is bridged with virtual worlds. The proliferation of augmented reality compatible devices constitutes a useful means to overcome application limitations. The research presented in this paper focuses on the enhancement of mixed reality environments using mobile applications by altering the virtual parts of mixed reality environments, enriching application functionality, promoting social interaction and facilitating user-generated storytelling authoring and narration. The presented ongoing work builds upon a green screen mixed reality application which can be used in combination with one or more augmented reality application instances, showcasing the benefits of employing mobile augmented reality applications to complement MR systems.

Keywords: Mixed reality · Augmented reality · Mixed reality enrichment Mobile applications · Storytelling

1 Introduction

Mixed reality (MR), sometimes referred to as Hybrid reality (encompassing both augmented reality and augmented virtuality) refers to the merging of real and virtual worlds to produce new environments and visualizations, where physical and digital objects co-exist and interact in real time. The reality-virtuality continuum presented by Millgram et al. [13] allows the classification of applications in terms of the users' feeling of presence and illustrates systems' distribution in accordance to their fundamental characteristics, ranging from completely virtual environments to reality-based systems. In between these distinct categories there are systems in which the physical and the virtual world are combined [2], blending reality with computer-generated imagery and encompassing augmented reality and augmented virtuality. Mixed Reality is applied in various contexts, including games, and in particular tabletop games [16] in order to preserve the physical artifacts of the game. In the domain of cultural heritage, Grammenos et al. [11] use pieces of paper that host additional information upon placement over areas of interest. Another interesting approach is presented by Ridel et al. [15], who employ pointing to reveal virtual cultural heritage exhibits in a metaphor similar to the flashlight.

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Mixed reality encompasses immersion, which is based on covering physically a person's stimuli, namely vision, spatialized sound and haptic feedback [4], so as to engage users and bridge reality with a virtual environment generated by interactive systems. Immersion is strongly related to the interaction process: in addition to perceiving a Mixed Reality (MR) application with human senses, the interaction modality employed constitutes a decisive factor in feeling of immersion and the overall user experience.

Augmented Reality (AR) is defined by Carmigniani and Furht [7] as a real-time direct or indirect view of a physical real-world environment that has been enhanced/augmented by adding computer generated information to it. According to [10] AR refers to computer displays that add virtual information to a user's sensory perceptions, enhancing the user's perception of and interaction with the real world by superimposing virtual objects and cues upon the real world in real time. Digital storytelling is accomplished using AR technologies, thus providing an immersive means of narrative presentation across a variety of domains ranging from scientific information [3] to cultural heritage information [1].

Mobile devices are widely employed for creating and deploying AR systems [14]. The improved sensing and processing capabilities of modern mobile devices facilitate the creation of a variety of applications, including AR applications, which can communicate and interoperate with existing systems. The proliferation of handheld devices such as smart phones provides a pool of potential interactive system control devices with which the users are familiar. These control devices can be straightforwardly connected to interactive installations through a typical mobile application.

2 Design Decisions and Rationale

Installations in public spaces typically turn into multiple-user applications, even if they are designed as for single user. It is common that passers-by are inquisitive regarding interactive installations and approach them. This procedure is defined by Brignull and Rogers as the "honey pot effect" [5], as the more people approach a display, the more passers-by are attracted to view the exhibit. This paper presents ongoing work regarding the use of mobile applications (e.g. AR applications) to enrich interactive mixed reality systems.

Applications deployed on mobile devices have the potential to provide various perspectives of the reality viewed by users during interaction in virtual environments. Thus, spectators are able to examine additional aspects of either the user or the computer generated imagery, allowing the exploration of different stories. An indicative example can be the capitalization of interactive systems deployed in Ambient Intelligence environments, which contain fruitful information on users' aims and the context of use.

Mobile applications can act as second screen displays, allowing systems connected with the framework to be augmented with additional information, which they are not displaying for the sake of improved user experience in MR environments. Moreover, certain applications are natively incapable of presenting certain content types: a 2D application presenting photographs can be enhanced by 3D models or 360 degrees panoramic videos.

Narratives are another aspect which can be unfolded using applications deployed on mobile devices through the presentation of visual storytelling through state-of-the-art computer generated imagery (CGI). Stories and narratives can be described, in a broad sense, as “unique sequences of events, mental states, or happenings involving human beings as characters or actors” [6]. This process adds up value to story presentation and differentiates simple event sequences from stories, as stories include the implicit and explicit bindings between the individual events, especially when the story is presented in an interactive manner [8]. Story narrations can be either loosely defined, such as a multimedia selection chosen by an end user, or well-defined, such as an event sequence unveiling a historical period. Moreover, real-time assistance, application key features or even thorough tutorials can be presented using the mechanisms of storytelling in a manner which users are familiar with.

In addition to enhancing individual interactive systems, the work presented in this paper aims to facilitate social interaction and encourage user-to-user communication. Social interaction is carried out both through face-to-face verbal communication and through messages sent via the AR applications. Furthermore, the users are able to affect the MR installation itself. In the case of a MR application similar to a green screen, AR users are able to alter the displayed backgrounds, initiating social interaction through the MR application and adding up to overall playfulness of the experience.

3 Implementation

In order to elaborate on the application of AR to MR systems an individual component has been designed and implemented so as to facilitate the in-between communication. The developed component, i.e. Mixed Reality Server (MRS) in Fig. 1, retrieves data from the MR system describing users’ location in a coordinate space defined by the MR system’s position. MRS exposes two types of information: user locational data and MR application context.

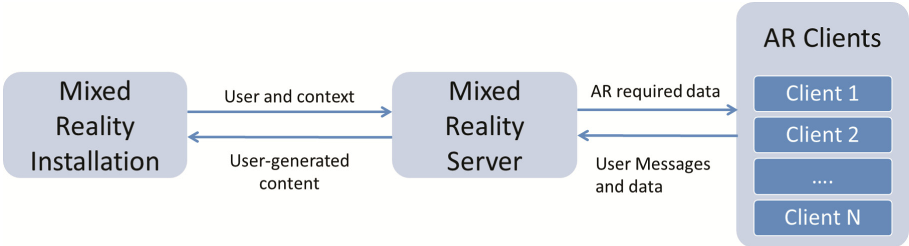

Fig. 1. Component architecture

User locational data regard each user’s unique id and skeletal 3d transformations which describe necessary positions and rotations of skeletal joints. The communication exchange regarding positional data between MRS and AR client applications is accomplished via web sockets in order to support real-time bidirectional information flow.

MR Application context includes exposed data regarding the application's state in real-time, allowing interested client applications to be aware of the displayed content in an agreed coordinate system. The provided information is not limited to the rendered multimedia, but also includes semantic information, content metadata and points of interest within the elements.

Two individual prototypes were designed and implemented to illustrate the potential of AR for adding value to interactive mixed reality systems. Both prototypes were implemented to support full body skeletal tracking, using the Kinect One depth sensor [12]. Skeletal joints transformation (position and rotation) are transformed from the sensor's space to the application's display space. At a later stage, MRS provides each skeletal joint transformation in real world coordinates both as the points in which people are physically located and in which they are rendered in the MR display; thus, each AR application is able to superimpose information either in front of the users or on top of the application.

3.1 BeThereThen

The first prototype, *BeThereThen*, is an extension of BeThereNow [9], a mixed reality application that immerses users in landscapes in a manner similar to green screens. The prototype aims to assist social interaction in the cultural heritage domain, facilitating storytelling and user-generated content.

The developed prototype offers the ability to exhibit historical aspects of the displayed landscapes through suggested photographs or videos. Users are capable of choosing specific elements from a multimedia collection related to the currently shown landscape using an AR mobile application. The users are able to interactively unveil in their own private display aspects of the CGI shown in the public MR display. The background landscapes where the application users are virtually standing in can be filled in with user-generated content, such as views of the same landscapes at different time periods through historical photographs or graphic representations. This is accomplished either by completely replacing the background or by brushing the preferred areas of the MR environment via touching the AR display. Upon completion, the users are able to instantly take a real-time photograph of the users in front of the MR display immersed in their personal background. An indicative view of the MR display is shown in Fig. 2, where a user is standing in front of the Venetian fortress of Castello a Mare (Koules) in Heraklion. A large section of the fortress is fused with a photograph of the early 20th century, creating a unique mixture of the initial background with a historical representation.

Fig. 2. The result of using the AR prototype application for blending landscapes with historical photographs

Furthermore, the resulting background can then be saved into a collection of altered landscape backgrounds. As a further step, the users are able to define sequences of sceneries, creating their own personal stories, which can be made public and shown in the main MR display on demand.

3.2 HelloThereNow

The second prototype extending BeThereNow [9], *HelloThereNow*, was created aiming at allowing users to superimpose information on the MR display. The overlaid information can be either placed over sections of the background or follow a specific user, if visible on the display.

Firstly, information laid over background artefacts can annotate aspects of the illustrated elements. For instance, in the scenery of a market with traditional items, users can annotate the products sold with a message sharing their personal opinion. Such an example is shown in Fig. 3, where a woman has shared her personal experience of the traditional showcased products.

Additionally, users are able to create personalized messages and share them with other users. These messages can be sent to other users of the mobile AR application or be shared with the public MR display: users are able to choose people visible in the MR display and make comments, create annotations or even add thought clouds with messages (Fig. 3). This communication can be either named or anonymous: the named comments can be persistent, i.e. be shown for a prolonged period and facilitate discussion with other users, whereas anonymous comments are only displayed for a short duration of five seconds and are meant to create a mini-game with other users around the public display in order to find out the author of the message.

Gamification constitutes another aspect towards which AR can contribute to. Apart from messages, the prototype is able to assign elements to the users interacting with the MR system. These elements are suggested in accordance to the background currently

Fig. 3. Screenshot from the MR display with a named annotation holding a user's personal opinion about elements being sold in the showcased traditional market (left) and an anonymous message following the user of the MR system (right).

visible and include everyday objects such as accessories or clothing that can be mapped to a specified body area. The user of the AR application drags the objects on the user's body and the application automatically selects the nearest skeleton joint and assigns the element to the corresponding joint, allowing users to make objects follow either a user's torso or a specific part, such as the user's hands or feet (Fig. 4).

Fig. 4. View of the AR application on a mobile device as a user assigns an element to follow user's movement in the MR display

4 Conclusions and Future Directions

This paper reported on ongoing work regarding the potential of employing augmented reality technology via mobile devices to enhance mixed reality systems. The presented approach aims to enrich the functionalities and improve the user experience of mixed reality systems located in public spaces through AR mobile applications. Two prototypes were created to enhance an application similar to green screen, facilitating social interaction, user-generated content and storytelling, while also acting as second screen displays. The next steps involve evaluating the prototype, firstly in-vitro using informal methods and secondly qualitatively in-vivo, so as to measure the proposed system's likeability and receive users' comments, suggestions and recommendations. Future work includes extending the system to be integrated in Ambient Intelligence environments, exploiting the potential of functionalities such as user (re-)identification, context of use knowledge and user profile information. Profile information includes data regarding user interests, preferences, semantic knowledge and interaction metadata.

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How Users Distinguish Trees Within a Virtual Environment

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Abstract. The gaming industry always faces the continual challenges of striking balance between real-time computing performance and graphics presentation quality. This is particularly apparent for a game with vast wildlands scenes which demands for a large number of tree models. From the visual perception perspective, this paper investigated whether people can distinguish trees with uniqueness of various features (relative orientation, density of branches, leaf color) using the same tree model in a virtual environment. During the controlled experiment, quantitative research methods were used, which measured the statistics of tree variations. The results suggested that our methods successfully contributed a strategy in saving graphic resources without user consciousness and maintaining high graphics performance.

Keywords: Visual perception · Procedural modeling · Real-time rendering
Tree variation · Virtual environment

1 Introduction

In real life, no two trees look alike. But in a virtual environment, it would be nice if we can replicate the richness of natural environment of the real world. Many adventure games often feature vivid and complex forest landscapes for the purpose of players' immersion. Thousands of trees have to be rendered in real time (with less than 8 ms) for an immersive environment, which requires a significant amount of resources in the development and digital stages of production. Figure 1 gives an example of huge density of tree models rendering in a virtual environment. Currently, many games mostly employed techniques such as planar texture maps, simple tree structures, or Level of detail (LOD) for forest, which unavoidably create an unrealistic experience.

Human perception has a limited capacity to process visual stimuli. For example, research has found that for a crowd of people in a 3D animation, which only needs three variations of human figures so that users will consider the crowds are realistic [3]. In this research, we investigated human perception of trees within a virtual environment. Our goal was to find a balance between the number of tree variations and human perception. Our objective was to identify the limits of human perception so that developers can spend less effort and minimum resources on tree construction while still producing realistic effects.

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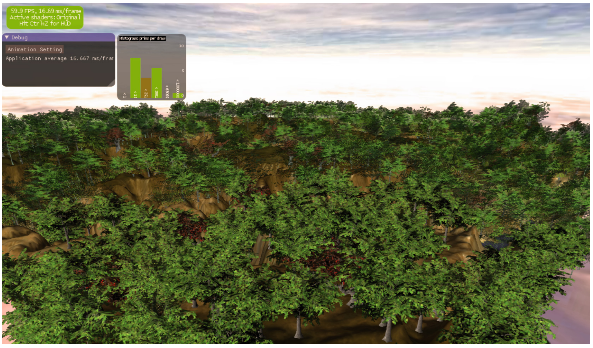

Fig. 1. A real-time rendered forest using only two tree models.

The remainder of this paper is structured as follows. In Sect. 2, we briefly review the related work on human perception and tree modeling. In Sect. 3, we describe our experiment in detail. In Sect. 4, we present our results and perform the analysis. In Sect. 5, we make our conclusions and summarize the contribution. In Sect. 6, we discuss the experiment limitations and suggestions for future work.

The assumptions of this study were: Participants responded accurately and honestly during comparing paired renderings, followed by answering the percentage of similarity based on whether they can distinguish trees according to their perception. Participants had basic knowledge of trees and spatial ability in virtual environment to accomplish the whole experiment. The number of participants was enough for the study to gain results. Global illumination, hardware, and rendering method remained the same in each scene shown to participants. The study methods were appropriate to gain results answering the research question.

The limitations of the study were: The trees models rendered within virtual environments were limited to available hardware. The study was limited to cooperation of subjects to take experiment and their availability.

The delimitations of the study were: The study focused on intuitive interactions between human and virtual environments. One months allotted to engage the participants.

2 Related Work

Investigating human perception of virtual environments, especially of computer games, or integrating the procedural modeling of trees into a virtual environment, either of two is not a new idea. However, the previous literature lacked a consolidated approach to cover both aspects simultaneously.

From human perception perspective, Boot et al. [1] designed tasks to discover the perceptual and cognitive impacts of playing entertainment games. Hoyet et al. [2] provided statistical methods for the comparison of variations. Sakaguchi and Ohya [4] proposed a modeling and animation methods for botanical trees in an interactive virtual environment, which gave “a new top-down approach in which a tree’s form is defined by volume data that is made from a captured real image set, and the branch structure is realized by simple branching rules" (p. 272). Smelik et al. [5] developed a survey on procedural modeling (PM) in virtual environments using PM tools.

The related work provided valuable reference and inspired our idea described in the paper.

3 How People Distinguish Trees in a Virtual Environment

Our approach emphasized human perception by showing participants groups of trees with uniqueness of different factors in order to measure whether they could recognize two trees using the same model under some conditions. Our experiment used quantitative methods for experiment design and data analysis. In the experiment, three parts were used separately. For the first part, we tested whether user could distinguish trees with the uniqueness of relative orientation changed. For the second part, we tested whether user could distinguish trees with the uniqueness of density of branches changed. For the third part, we tested whether user could distinguish trees with the uniqueness of leaf color changed.

We used multiple variations but let them be tested separately one by one and randomly ordered the variations for subjects to construct our control and experiment groups. The variations included relative orientation (the clockwise angle from the initiating orientation to the experimental orientation), branch density (the number of branches on a specific length of trunk), and leaf color. The experiment required one-sample t-test statistical analysis for each variation. Figure 2 provides examples of tree variations.

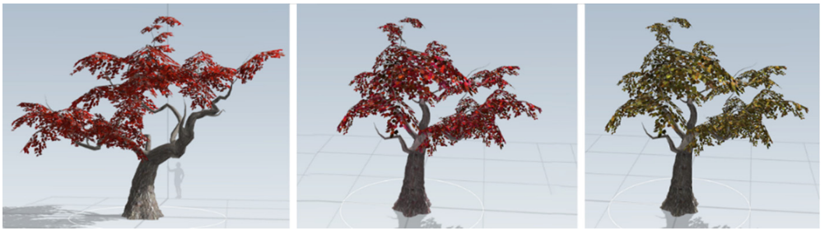

Fig. 2. Left: the original tree model; Center: the tree model with relative orientation changed; Right: the tree model with both relative orientation and leaf color changed. (Color figure online)

The experiment environment was as follows: a Windows 10 home 64-bit (10.0, Build 14393) operating system, Inter(R) Core(TM) i7-6700HQ CPU @ 2.60 GHz (8 CPUs) processor, GeForce GTX 1080 graphics card, 16384 MB RAM memory, and using DirectX 12 APIs.

The paper was intended to make statistical inference about the population of all the users on Amazon Mechanical Turk. Voluntary sampling was used in experiment. Subjects were recruited on Amazon Mechanical Turk randomly and they got reward for participating the experiment.

The survey questions were posted on Amazon Mechanical Turk. Before the start of survey, subjects were given an application narrative form. If they agreed to all, then jumped into the survey questions page. If not, ended the survey. After subjects have answered the survey questions, the survey ended. The response from the subjects on all three survey questions were collected.

3.1 Effects on User Perception of Uniqueness of Relative Orientation

As in Fig. 3, a rendering of two trees was shown to subjects at the same time. Both trees used the same geometry models with only the orientation of the right one was changed by 90° compared to the left one. Subjects were given a slider to choose a percentage on how much similarity they considered between the left tree and the right tree. The scale of the slider was between 0 and 100.

Fig. 3. Tree models with only relative orientation changed.

The null hypothesis was people could not distinguish trees using the same model with relative orientation increased by 90° ($\mu_1 = 0$). The alternative hypothesis was people could distinguish trees using the same model with relative orientation increased by 90° ($\mu_1 \neq 0$).

The test statistics is calculated as follows:

$$t = \frac{\bar{x} - \mu_i}{s/\sqrt{n}},\ i = 1, 2, 3$$

where $\bar{x}$ is the sample mean, s is the sample standard deviation of the sample, n is the sample size.

Set significant level α as 0.01. If the p-value of the t test was smaller than this statistical significance, then the null hypothesis was rejected. If not, we could not reject the null hypothesis.

3.2 Effects on User Perception of Uniqueness of Density of Branches

In terms of density of branches, as Fig. 4 shown, a rendering of two trees was shown to subjects at the same time Both models used the same models with only the branches of the right one was procedurally decreased by 4 compared to the left one. Subjects were given a slider to choose a percentage on how much similarity they considered between the left tree and the right tree. The scale of the slider was between 0 and 100.

Fig. 4. Tree models with only density of branches changed.

The null hypothesis was people could not distinguish trees using the same model with branches procedurally decreased by 4 randomly ($\mu_2 = 0$). The alternative hypothesis was people could distinguish trees using the same model with branches procedurally decreased by 4 randomly ($\mu_2 \neq 0$).

The test statistics was shown in Sect. 3.1. Set significant level α as 0.01. If the p-value was smaller than statistical significance, then the null hypothesis was rejected. If not, we could not reject the null hypothesis.

3.3 Effects on User Perception of Uniqueness of Leaf Color

For the leaf color, Fig. 5 shows rendering of two trees was shown to the subjects at the same time. Both models used the same models with only the leaf color of the right one was changed to brown while the left one was green. Subjects were given a slider to choose a percentage on how much similarity they considered between the left tree and the right tree. The scale of the slider was between 0 and 100.

Fig. 5. Tree models with only leaf color changed.

The null hypothesis was people cannot distinguish trees using the same model with leaf color changed from green to brown ($\mu_3 = 0$). The alternative hypothesis was people can distinguish trees using the same model with leaf color changed from green to brown ($\mu_3 \neq 0$).

The test statistics was shown in Sect. 3.1. Set significant level α as 0.01. If the p-value was smaller than statistical significance, then the null hypothesis was rejected. If not, we could not reject the null hypothesis.

4 Results and Analysis

Results. The data from three parts of the experiment was collected separately. We recruited 25, 26, and 23 subjects for part 1, 2, and 3 respectively. We had the one-sample t-test results for part 1, 2, and 3 using SAS (Tables 1, 2 and 3).

Table 1. T-test results for variation in relative orientation.

n	mean	Std Dev	Variance	Minimum	Maximum
25	42.80	16.96	276.16	20.00	70.00
99% CL Mean			99% CL Std Dev		Std Err
(34.3462, +∞)			(12.3102, 26.4262)		3.3921
DF			t Value		Pr > t
24			12.62		<.0001

Table 2. T-test results for variation in density of branches.

n	mean	Std Dev	Variance	Minimum	Maximum
26	46.54	23.48	530.33	0.00	90.00
99% CL Mean			99% CL Std Dev		Std Err
(35.0927, +∞)			(23.4849, 17.1412)		4.6058
DF			t Value		Pr > t
25			10.10		<.0001

Table 3. T-test results for variation in leaf color.

n	mean	Std Dev	Variance	Minimum	Maximum
23	66.96	25.10	629.87	0.00	100.00
99% CL Mean			99% CL Std Dev		Std Err
(53.5351, +∞)			(25,6612, 18. 3988)		5.3507
DF			t Value		Pr > t
22			12.51		<.0001

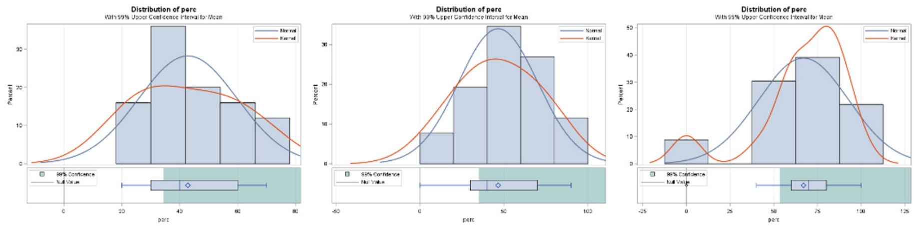

Fig. 6. From left to right: The statistics distribution graphs from the response of similarity of paired tree renderings in all three factors: relative orientation, density of branches, and leaf color.

Analysis. From the tables and graphs, we obtained some findings from the data:

- The three factors showed significant effects on user perception. The subjects could not distinguish tree models when we altered a single unique factor, be it relative orientation, density of branches, or leaf color, changed in some extents, while we were using essentially the same tree model.
- For each factor, the distribution graphs depicted that the data was in accordance with normality, which means the statistical inference we made was valid and reliable. Thus, the results we gained from the sample data are generalizable and can be used for future applications.
- The factor, relative orientation changed by 90°, is the most effective factor among the three factors. Changing relative orientation could be an easy and effective approach for the industry to adopt when they are to build art resources asset libraries and to gain good game experience for players.
- The ranking of the effects on the three factors:

$$\text{Relative orientation} > \text{Density of branches} > \text{Leaf color}$$

- The leaf color was the most controversial factor among the three factors for the experimenting subjects. A number of subjects thought the two trees using nearly totally different model while some subjects recognized them using the same model. It might not be the first choice for industry to change leaf color when they intended to reduce art resources and seek for great performance (Fig. 6).

5 Conclusions

Our research contributed a new strategy for the gaming industry to save art and computing resources from a user experience perspective. Changed relative orientation by 90°, density of branches procedurally decreasing by 4, and change leaf color from green to brown are all effective methods to increase vegetation variety within a virtual environment using limited geometry models. Because only a few tree models are required to be loaded into the scene, game designers can allocate more resources on other development tasks and create a faster iterative design feedback loop. Our strategy on reducing GPU and CPU usage also implies that gamers will have smoother user interactions and experience as well.

6 Future Work

In this study, we recruited subjects from Amazon Mechanical Turk, which did not include the people under 18 years old according to the AMT's term. In future works, we will investigate users including teens and kids to find out whether these factors still have significant effects on people group of younger ages.

We only investigate one factor at one level at a time for each part of experiment for the moment. In future works, multiple levels can be tested to obtain a quantitative relation on how much extent can people distinguish tree models. Moreover, more factors can be introduced in the experiment to test the effects on user perception.

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Picture Book-Based Augmented Reality Content Authoring System

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Abstract. Various augmented reality systems have been developed and used in diverse areas recently. However, it is still difficult a user to create augmented reality contents since most authoring systems require 3D objects to create contents. Most users are not familiar with the tools that are used to create 3D objects. As a result, most users only create augmented reality contents with provided 3D objects and it limits the diversity of the contents. In this paper we proposed a picture book-based augmented reality authoring system. A user could create diverse augmented reality contents with 2D objects extracted from captured or provided images instead of 3D objects with the proposed system.

Keywords: Augmented Reality · Authoring · Augmented reality picture book

1 Introduction

Augmented Reality (AR) provides information by augmenting the real world with virtual information. As smart mobile devices are widely used and AR enabling technologies are stabilized, AR applications have been applied in diverse areas such as entertainment, manufacturing, and education.

AR books have been developed for assisting children's education [1–3]. AR books can help users to understand contents of the book or provide users additional information by augmenting virtual information on the book. AR books have the advantage of boosting user interest and improving user immersion, but they are not yet been used much. Most AR books simply support the experiences of providing AR contents. Few AR books provide ways to author AR contents, but users can only create AR contents with providing 3D models with these authoring systems. Even though the authoring system allow users to import their own 3D models to the system, only few users can create 3D models because it requires knowledge about 3D modeling tools such as 3DS Max and Maya. To overcome this problem, we proposed the picture book-based AR content authoring system that could create AR contents based on 2D objects instead of 3D objects in mobile environment. A user can create AR contents using every objects in the real world by capturing the image of the objects. This is the main advantage of the proposed system comparing with existing AR authoring systems.

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2 Proposed Method

2.1 System Overview

The proposed system can be divided into authoring and visualization. The authoring part contains page selection, object creation, and object setting procedures (see Fig. 1). A user selects a page of a book on which created objects will be augmented. Next a user captures an image of a target object and draws an outline containing the target. The system extracts the target and creates a 2D object in the object creation procedure. A user can provide dialogue to the 2D object by adding a speech bubbles. After finishing the scene creation, a user can view the AR content using his/her mobile device.

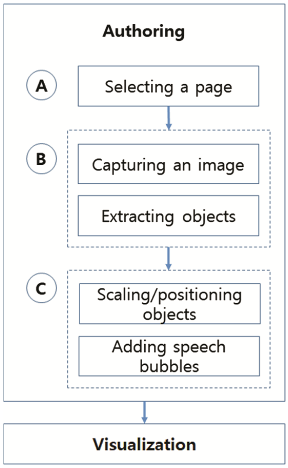

Fig. 1. System overview

2.2 Page Selection

The first procedure of the authoring part is the page selection. A user selects one of the pages of a book in the page selection procedure. This page is used as the basis for a new AR content. A user can augment virtual objects created in object creation procedure, which is described in the following section. This page can be selected in two ways. A user can capture an image of the selected page of the book or select one from a database containing images of the book.

2.3 Object Creation

The object creation procedure contains image selection and object extraction. A user can capture a real environment or select an image that contains target objects. Target objects can be extracted from the images by drawing outlines of them. The outlines are drawn by touch interaction on the mobile devices (see Fig. 2). The staring and the ending points are automatically connected to ease of creating a closed region with touch interaction. Each closed region represents one 2D object that will be augmented on the image selected on the page selection procedure.

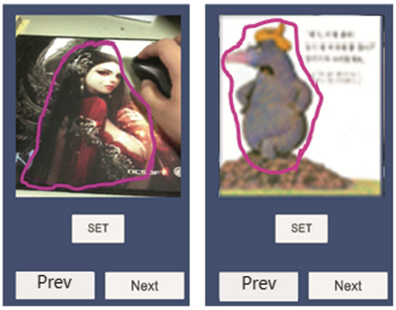

Fig. 2. Drawing an outline to select an object

2.4 Object Setting

In the object setting procedure, the extracted 2D objects are augmented at the desired positions with right sizes and speech bubbles are added to 2D objects to create a new content.

A transformation widget shown in Fig. 2 is used to position an object in the augmented world. A user can select one of x, y and z axes and translate the object along that axis using a single touch interaction. The object is scaled using pinch and spread motion of two fingers. A user can also select the cube located at the end of axis and move it to scale the object along the selected axis more accurately (Fig. 3).

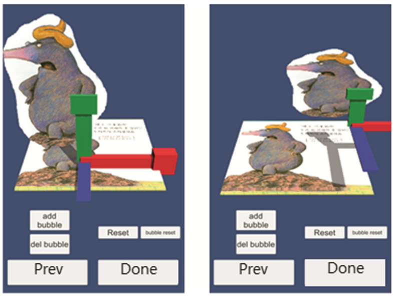

Fig. 3. Translating the object with the transformation widget

A speech bubble template is appeared on the screen when a user clicks the 'add bubble' button. A user can input text on the speech bubble. The bubble is bound by selecting the target object and is located at the default position. A user can move the speech bubble with a 2D position widget along the x and y axes to modify the position of the speech bubble (see Fig. 4).

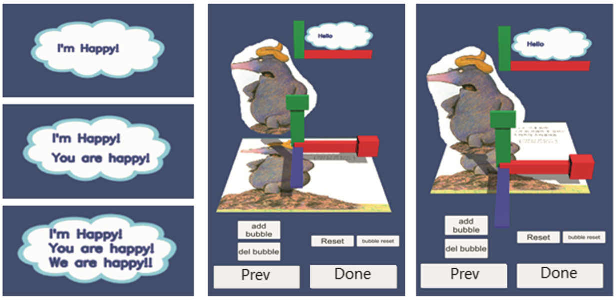

Fig. 4. Adding a speech bubble

2.5 Visualization

The visualization procedure allows a user to view the AR content created with the authoring procedure. A user can view the augmented objects and speech bubbles by directing the camera attached on the mobile device to the selected page of the book (see Fig. 5). A user can move around the selected page to view various side of the content.

Fig. 5. Viewing example

3 Conclusion

Most existing AR authoring systems support users to create AR contents with 3D models. Users can create AR contents with provided 3D models and their own 3D models. 3D models may provide users more immersive experience but it is difficult to create them. Most users are not familiar with the tools that are used to create 3D models. As a result most users only create AR contents with provided 3D models and it limits the diversity of the AR contents.

This study introduces an AR authoring system that can easily generate various AR contents with reduced immersion feeling. A user can create AR contents with 2D objects extracted from captured or provided images instead of using 3D objects. We conducted a user study with small group of university students and found that users can create diverse contents with the proposed system. As a future work, we will conduct a user study with larger group of people centered on the easiness of creating various AR contents and the comparison between 2D based and 3D based AR contents.

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Multi-user Collaboration on Complex Data in Virtual and Augmented Reality

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Abstract. With increasing task and system complexity, it becomes necessary to support workers, e.g. performing repair tasks, from a remote location. Current approaches utilize images or a video stream combined with annotations and speech to allow collaboration with remote users. We propose a technique that gives the remote supporter the ability to see a high fidelity point cloud of a real world object in Virtual Reality (VR). The VR user can indicate points of interest via a laser pointer. The local worker sees these indications on top of the real object with an Augmented Reality (AR) headset. A preliminary user study shows that the proposed method is faster and less error-prone regarding the comprehension of the object and the communication between the users. In addition to that, the system has a higher usability. This work shows that even non-virtual, collaborative tasks can be supported by new forms of user interaction using different technologies like VR and AR.

Keywords: Virtual Reality · Augmented Reality · Collaboration Remote assistance

1 Introduction

There are several tasks where collaboration can be assisted by Virtual Reality. Complex machines, software and data make it hard to be understood by a single user. Many tasks, like setup, service or repair of real machines need to be performed by a specialist or expert. Urgent or distant tasks can be performed by a remote expert with the help of annotated images or videos and speech communication. However, it is quite cumbersome for the expert to explain how the local worker should move and what he needs to do. This collaboration task can be improved by Virtual and also Augmented Reality. The collaborative Virtual Environment (VE) [4] allows multiple users to analyze and discuss information as well as interact with the VE and each other [1,3,7,12,13]. VR allows the expert to see the object of interest from a view point, independent from the worker. AR makes it possible to show indications and annotations directly inside the real world instead of an image. Furthermore, VR and AR technologies are very mobile and cheap.

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2 Related Work

Remotely supported collaboration can be achieved using different forms of technology. Kuzuoka [9] used a video stream to convey the intentions of the expert. The video is captured by the local user and then send to the remote expert who can annotate the viewed content. The annotated video is then displayed to the local worker. Bauer et al. [2] extended this approach and showed a mouse cursor that is controlled by the expert in an AR Head Mounted Display (HMD) which is worn by the local worker. However, the mouse location is only 2D and it's position is volatile if the HMD moves. Chastine et al. [6] used a 3D cursor to show the expert's intention. Still, the 3D cursor movement is difficult and slow. The system by Botteccia et al. [5] allows to place 3D animations in the field of view of the local worker. The goal is to demonstrate to a user, how a task should be solved. However, the predefined animations are not very flexible. Tachia et al. [14] used static depth sensors to capture the dynamic environment of the users. The 3D scene of the local user and the hands of the remote expert were combined and presented to both users. This system allows the expert to utilize hand gestures for his assistance. Kurata et al. [8] placed a camera and a laser pointer on the shoulder of the local worker. The remote expert saw the video stream and could control the laser to highlight a point of interest in the real world. Lanir et al. [10] expanded this idea and let a movable robotic arm carry a camera and a projector. The robotic arm could be controlled by the expert and the expert's annotations in the 2D video were projected on top of the real world. Oda et al. [11] tracked predefined local objects and represented these as virtual proxies to the remote expert. The expert could create copies of these objects and move them to the correct positions. The local worker saw the virtual copies in an AR environment.

3 Virtual and Augmented Reality Collaboration

VR allows users to interact with complex virtual data collaboratively. In addition to that, it is possible to extend the collaboration to the real world using AR. We propose a VR/AR collaboration system to aid complex tasks through remote collaboration. In order to supply the remote expert with the problem area, a virtual representation is needed. As a first step, a local worker captures a point cloud of the object/region of interest and sends it to a remote expert. The point cloud consists of several filtered Kinect v2 point clouds with color information. The extrinsic camera transform is calculated using the Lighthouse Tracking System of the HTC Vive. The recorded point cloud is displayed in VR for the expert using a HTC Vive (see Fig. 1). The expert can freely inspect the object from any angle and indicate locations using a laser pointer on a tracked controller. The local worker sees the laser pointing on the real object in AR with the Microsoft HoloLens (see Fig. 2). Furthermore, the remote expert and the local worker can engage through a speech communication system. The VR and AR world are calibrated using an anchor point, a HTC Vive Tracker, that is in a fixed location relative to the object. In AR, a coordinate system is placed on top of the anchor point to calibrate the different coordinate systems (see Fig. 3).

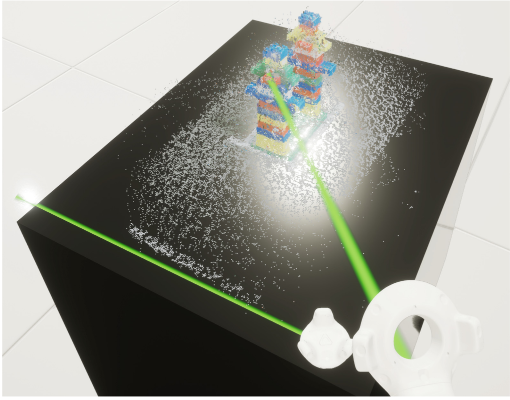

Fig. 1. The VR view from the remote expert with a HTC Vive. The expert highlights a red block using a laser pointer attached to a tracked controller. (Color figure online)

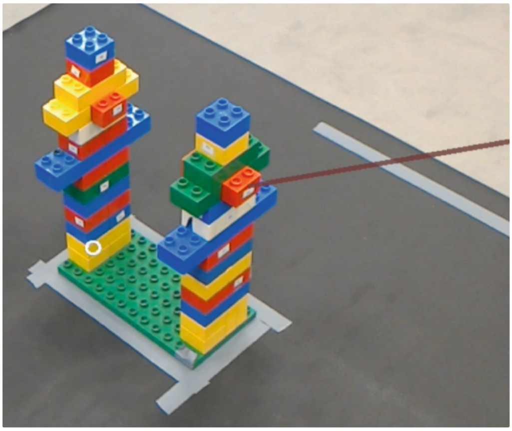

Fig. 2. The AR view from the local worker with a Microsoft HoloLens. The laser pointer highlights a red block. (Color figure online)

4 Evaluation

To evaluate the proposed concept a preliminary user study was performed. In this user study the system was compared to a system that contained pre-recorded images and a live video stream, as well as speech communication. The pre-recorded images serve for the preparation of the remote expert and the additional live video aids during the support of the local worker. The task for the expert

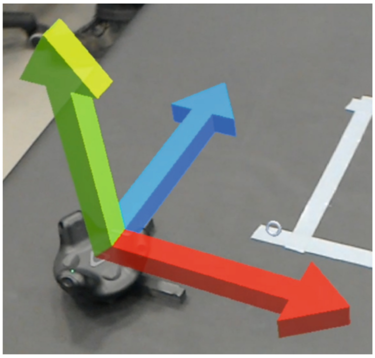

Fig. 3. The calibration of the AR coordinate system relative to the VR world (Color figure online).

in both setups was to locate a specific block in a set of two towers (see Fig. 2). To convey knowledge to the expert, he or she was given a list of four colors with a place holder for the target at the start or end of that list (e.g. red, green, blue, red, XXX). The varying lists represent sequential tower blocks from top to bottom. All sequences are unique. In a first step, the expert should locate the desired block. Secondly, the expert activates the communication with the local worker and indicates the block. When activated, the live stream is shown to the expert or the laser pointer is shown to the local worker depending on the current setup. Speech communication content is not limited, except for the unique color sequence. To finish one round the local worker confirms the block by reading a text label printed on it. For each setup, a pair of participants performed five training and ten timed rounds. The participants performed both setups. To minimize learning and fatigue effects in the results, the order of the two setups was mixed, the user switched roles on setup change and two different sets of towers were used. 26 people in pairs of two participated in the user study. Two teams were excluded from the evaluation because of tracking issues with the VR/AR setup. The participants had a medium experience with VR and a low experience with AR. Two subjects declared they suffer from a red green color deficiency. However, both reported that the block colors were strong enough to distinguish between them.

When locating the block, users were about 1.12 s faster with VR (Ø 9.90 $\pm$ 5.58 s) than with the images (Ø 11.02 $\pm$ 7.67 s). The difference in time for the second part of the task is only 0.73 s with Ø 12.24 $\pm$ 5.36 s for the VR/AR setup and Ø 12.97 $\pm$ 5.23 s for image/video. Both differences are not significant. When asked how easy it was to locate the block the VR expert rated the task significantly harder than the expert with images (see Fig. 4). On a scale from -3 (very hard) to 3 (very easy) users rated the location task with a median of 1 with VR and 3 with the images. It was easier for the participants to locate blocks in the images. The VR experts reported it was difficult to see the point cloud, because it was pixelated and imprecise.

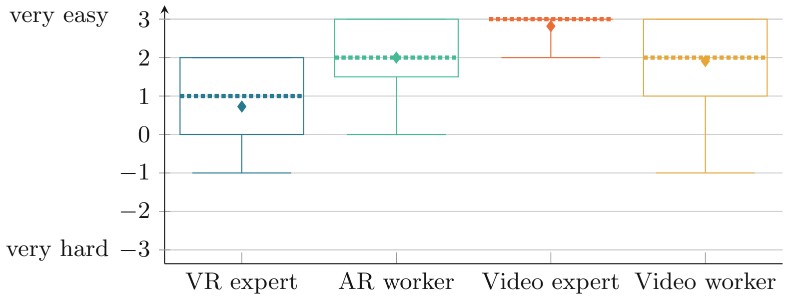

Fig. 4. Question: How easy/hard was it to locate the block?

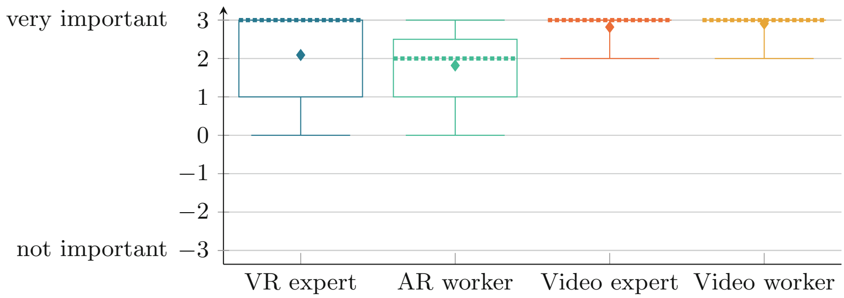

Fig. 5. Question: How important/unimportant was the use of speech communication?

The second phase of the task contained the collaboration between the two roles. Experts perceived the video stream mostly as confusing, since they could not control the perspective of the camera and the video was shaking, when the worker moved. This lead to the users often ignoring the video and focusing on the images. They coordinated themselves using unique color features of the two towers or their left and right location. Subjects that made use of the video used it to confirm locations by pointing with the finger on the blocks. When asked how important the speech communication for the task execution was, a significant difference between the local AR and video user occured (see Fig. 5). The participants made almost no errors with both setups. 8 out of 11 teams were error-free with VR/AR and 6 teams did not make a mistake with image/video. The other teams made up to 1 error with VR/AR and up to 3 errors with image/video.

The questionnaires NASA Raw-TLX and UEQ (see Fig. 6) show that there are the following significant differences between the two setups. The physical demand is lower for the image/video expert compared to the VR/AR expert ($p = 0.025$). The performance of the AR worker is higher than the VR expert ($p = 0.039$) and his or her frustration is lower ($p = 0.020$). The UEQ ratings show significant differences for both setups when comparing the two roles. Attractiveness ($p \leq 0.012$), stimulation ($p \leq 0.017$) and novelty ($p \leq 0.001$) are ranked higher for the VR/AR setup compared to the image/video setup.

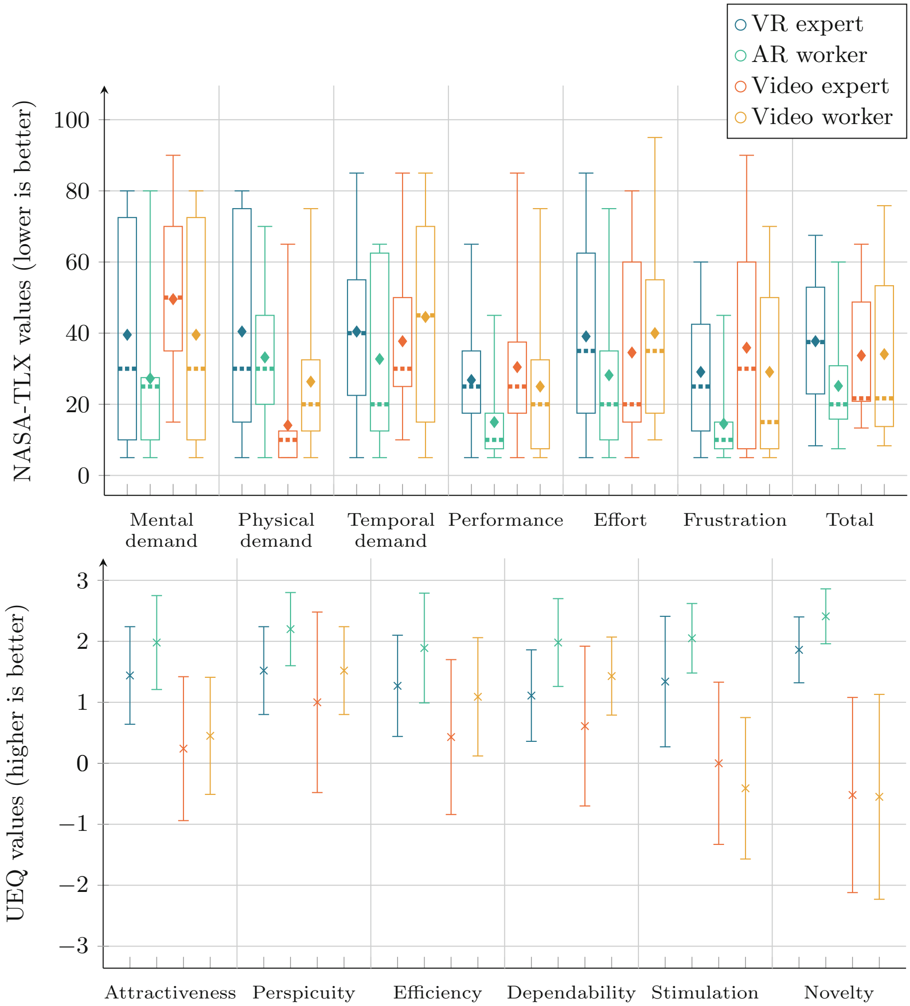

Fig. 6. NASA Raw-TLX ratings with box-and-whisker plots (diamond indicates average) and UEQ ratings with average and standard deviation.

In addition to that, participants were asked if the independent perspective had any (dis-)advantages. On a 7 point Likert scale from −3 (disadvantageous) to 3 (advantageous), users rated the system with a median of 2 (1. quartile = 1 and 3. quartile = 3).

5 Discussion

The evaluation of the proposed system shows that it is beneficial to use VR and AR technologies for the support of a local worker with a remote expert.

Locating a block is reportedly harder with VR, but faster. With further hardware improvements and adjusted data visualization the issues with the visibility of the point cloud should be solved. A problem that impairs the performance of the VR/AR setup is the calibration between the two systems. The manual calibration is error-prone and both tracking systems do seem to have slightly different distance measurements. This leads to a changing offset in the location of the laser pointer beam and therefore a shift of the indicated block. Furthermore there was no collision test from the laser with the object. Because of that, the indicated end location is ambiguous. If these issues are fixed the benefit of the VR/AR system might be not only a tendency, but a significant difference.

6 Conclusion

Our work for connecting two users shows that collaboration can be enhanced using VR/AR technology. Although there were some issues that resulted in an inaccurate laser beam, the system showed improved performance and user experience. For future work, we want to engage more than two users with full-body avatars in VR and AR. In addition to that, it would be interesting to determine how a collaboration of more than two users can be enhanced with new interaction techniques in VR.

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qVRty: Virtual Keyboard with a Haptic, Real-World Representation

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Abstract. Virtual Reality systems offer great possibilities to analyze and interact with data. However, they still lack a commonly accepted, efficient text input technique that allows users to record their findings. To provide users with an efficient technique for text input, a real keyboard and the user's hands are transferred into the virtual world. This allows real haptic feedback of the device and, as a user study shows, results in fast and accurate text writing. The proposed approach shows that a real-world ability can be transmitted directly into the virtual world without much loss.

Keywords: Virtual Reality · Keyboard · Haptics · Text input

1 Introduction

Virtual Reality (VR) allows users to interact with complex virtual worlds using buttons, gestures or gaze. This allows them to analyze data or explore virtual worlds. However, it is also necessary to input text, add annotations or log results. To implement a efficient text input technique that is fast, little error-prone and easy to learn, the well established QWERTY keyboard is suitable as a basis. Yet, to supply users with the full control over the keyboard, visual and haptic feedback is needed. Ideally, users can switch from the desktop pc into the virtual world without experiencing any performance loss, taking their writing skill with them.

2 Related Work

Current work can be grouped into device-based, gesture-based or multimodal input techniques [17]. Device-based techniques use a game controller [6,11,14,24,27,32,33], phone [7,13], keyboard [3,7,12,18,19,31], pen and tablet [3,7,25] or touch [4,8,16]. Gesture-based methods use hand [1–3,5,7,9,23,26] and head gestures [34]. Multimodal techniques often use speech [3,10,22].

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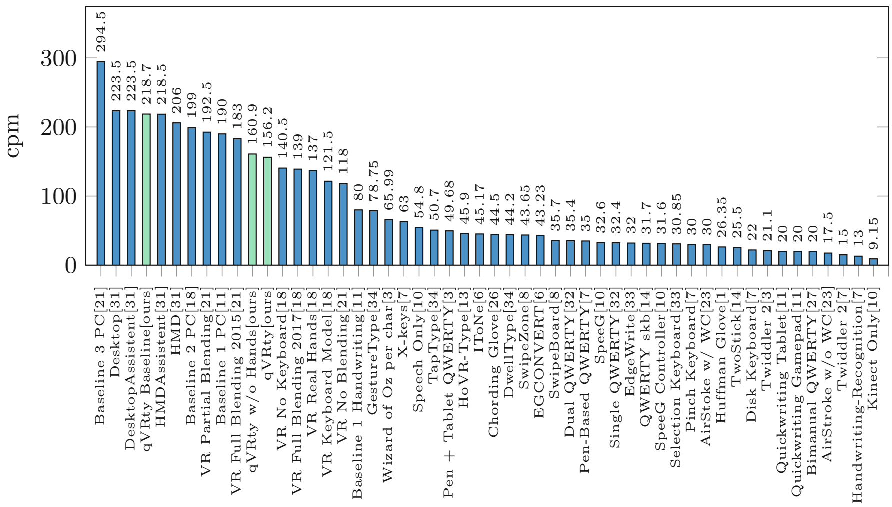

Fig. 1. Input speed of different techniques in characters per minute (cpm).

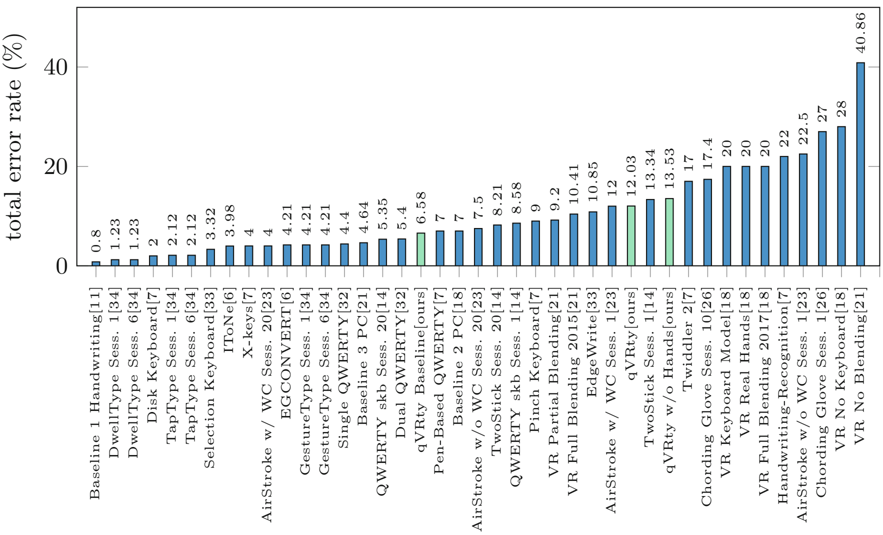

Fig. 2. Total error rate [28,29] of different techniques in percent. If the total error rate is not available the corrected error rate is used, since it is an estimation downward.

3 Text Input with a Haptic, Real-World Keyboard

Although there are plenty of methods that achieve text input in Virtual Reality, no technique has established itself as the defining standard. An analysis shows that the fastest techniques use a QWERTY keyboard (see Fig. 1). Error rates are lower when users type slower and concentrate on inputting single characters or when word correction is used (see Fig. 2). Haptic feedback improves input performance and usability [15,20,30].

We therefore present *qVRty*: a virtual keyboard with a haptic, real-world representation (see Fig. 3). Furthermore the hands of the user are tracked using a Leap Motion and then displayed in VR. The real keyboard is tracked using the Vive Lighthouse system and its virtual counterpart is placed at the exact same location in the VR world. The location of the Leap Motion device is tracked the same way. Since the keyboard is wireless it can be carried around the room and set up everywhere. However, the hand tracking solution is still cable bound and does not allow this. Adjustments to the virtual keyboard contain a larger font size and a red highlight on button press. The tracked hands of the user are represented as a skinny skeleton that allows to see more of the keyboard.

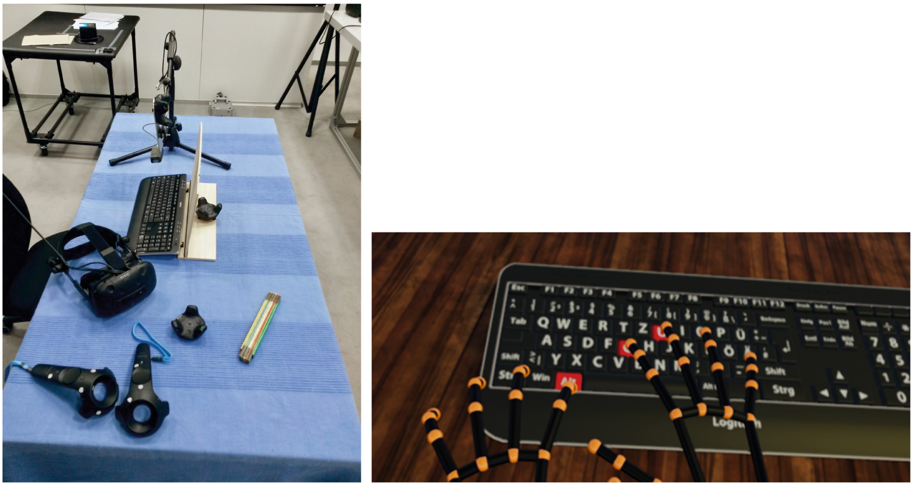

Fig. 3. View on the real keyboard (left) and its virtual counterpart (right).

4 Evaluation

A user study with 13 participants (9 male, 4 female) was performed to evaluate the performance of the approach. Participants were Ø 31.77 ± 12.74 years old. On a scale from 0 (low) to 5 (high) users experience with VR was Ø 1.77 ± 0.93. On the same scale, subjects assessed their typing speed with Ø 3.31 ± 0.63. Users were asked to type three different texts with the three techniques, typing with a keyboard in real-life as a baseline, qVRty and qVRty without the displayed hands. The order was randomized to compensate training and fatigue effects in the combined results. Before the first round, users were given 3 min to accustom themselves with the keyboard. The 1400-characters-long texts contained letters, numbers, german special characters and punctuation marks and were typed sentence by sentence.

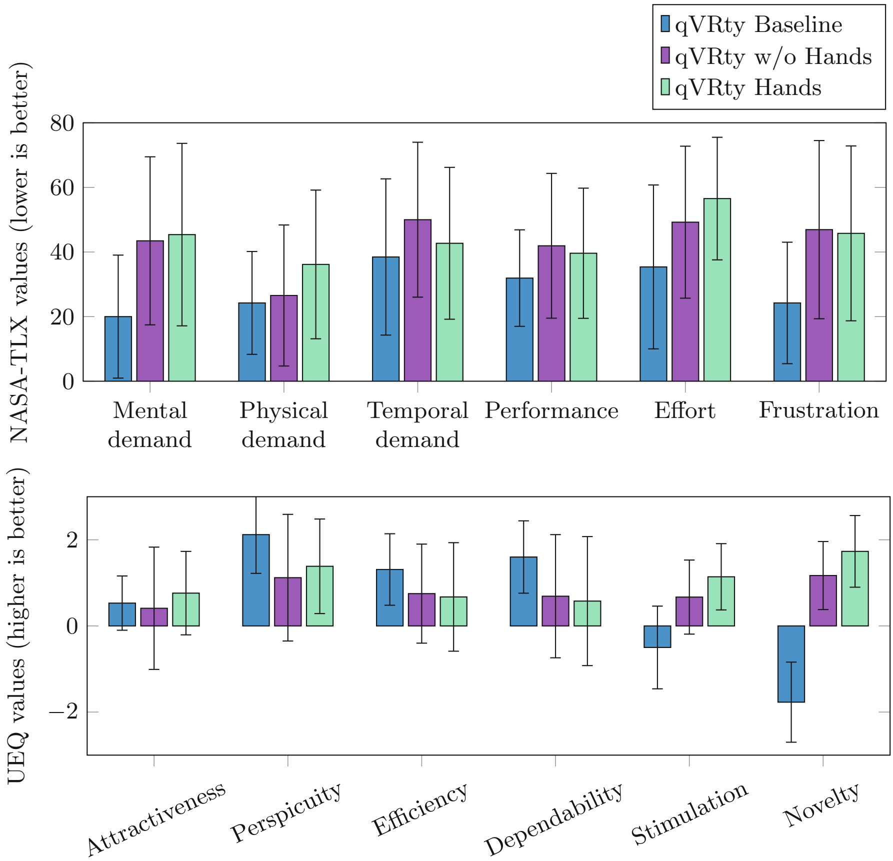

Fig. 4. NASA-TLX and User Experience Questionnaire (UEQ) results of the user study.

The results in Fig. 1 show, our technique is fast in comparison to the related work. The participants achieved Ø 218.7 ± 39.6 cpm with the qVRty baseline, Ø 156.2 ± 71.6 cpm with qVRty and Ø 169.9 ± 65.7 cpm with qVRty w/o hands. The difference between baseline to qVRty, and baseline to qVRty w/o hands is significant ($p \leq 0.000$). qVRty achieves 71% of the baseline speed without any training. Although users only performed one session with each technique, the error rates are average for a keyboard based approach (see Fig. 2). Users achieved error rates of Ø 6.58 ± 3.48 % with the qVRty baseline, Ø 13.43 ± 6.52 % with qVRty and Ø 12.03 ± 5.07 % with qVRty w/o hands.

According to NASA-TLX and UEQ (see Fig. 4), qVRty typing is appealing. The participants rank the mental demand significantly lower in the baseline case compared to qVRty w/o hands ($p = 0.048$). All other differences in the NASA-TLX are not significant. The differences between the results of the UEQ in the categories attractiveness, perspicuity and efficiency are not significant. Subjects rated the dependability between the baseline and qVRty significantly different ($p = 0.026$). The results of stimulation and novelty are significantly different for all pairs with $p \leq 0{,}016$ and $p \leq 0{,}040$ respectively.

Because of some tracking issues, the hands of the users were not displayed the whole time in the qVRty case. On average the hands were displayed Ø 70.34 ± 35.04 % of the time. The minimum and maximum display ratio was 58.88% and 99.82%. However, due to hand tracking issues the efficiency might have suffered.

5 Discussion

The results of the user study show that qVRty with and without hands performs equally well. This shows that the displayed hands were not as helpful as intended. There are two explanations for this. First, the participants are quite experienced keyboard writers as the high baseline shows. Fast 10-finger touch typers do not need to look at the keyboard for most of the time and therefore do not benefit from the displayed hands as much. Second, due to tracking issues the finger location could differ up to 2 cm from the real world which leads to inaccurate hands. However, qVRty is quite fast and reaches 71% of the baseline speed. The faster VR Partial Blending [21] reaches only 65% of the associated baseline.

Besides the fast speed, the error rate of qVRty is very low in comparison to other keyboard-based techniques. Only two of the techniques with more than 100 cpm register a lower total error rate as qVRty with and without hands (VR full and partial blending [21]). All other techniques with a lower error rate are slower.

Although the efficiency loss is significant in the quantitative metrics, the feeling of efficiency as indicated by the UEQ values does not differ significantly from the baseline. The questionnaires show that the mental demand of VR is higher than with the non-VR technique. However, both qVRty with and without hands offer a greater amount of stimulation and novelty. This shows that users still need to adapt to the new medium, but if they do, it can offer additional value.

6 Conclusion

In this paper, a text input method for VR is explored that is based on the well established technique from the desktop pc - the keyboard. A real keyboard and the users hands are tracked and transferred into VR. This allows users to immediately perform fast and accurate text input. The user study shows that VR technology can benefit from using familiar devices, but can also add novel features. It is possible to adjust the virtual keyboard to not only highlight the currently pressed button, but to change the text on any button according to the current application status. Another feature that can increase user performance with the proposed method is an error correction functionality. Like with smart phones, users could select a word correction by performing a small gesture towards text suggestions that float over the keyboard. For future work we would like to employ a more precise tracking to increase the value of the virtual hands.

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Capability for Collision Avoidance of Different User Avatars in Virtual Reality

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Abstract. Virtual Reality applications transfer users into immersive virtual environments, which can be shared with other remote or local users. Yet, multiple local users may collide, since the HMD obscures the view on the other party. To overcome this issue, a user avatar allows to estimate the location of others and to avoid collisions. However, different avatar representations can be used. We compare four avatars in a 28 participant user study. The comparison shows that the different avatars affect the number of collisions and the overall feeling of safety. As a result, local VR collaboration applications should represent the body of the user or highlight his or her location to increase user safety.

Keywords: Virtual reality · Collision avoidance · Avatar

1 Introduction

Virtual Reality (VR) applications allow user collaboration in a remote or locally shared physical space. A multi-user environment lets users engage in collaborative work to achieve better results [5,7]. Local collaboration has several advantages that a remote system cannot offer. Two local users in the same physical space can touch each other or exchange real objects, e.g. a controller or a hammer. Furthermore, only one area needs to be freed and equipped with a VR tracking system, which saves money. Also, local users can talk to each other and do not need to use a voice communication tool. A disadvantage of the local approach is the possibility of user contact, which can damage the hardware or even hurt the involved parties. To overcome this issue we present users with different avatar representations of the surrounding users. The various avatars are then compared regarding their ability to signal the other user's location and therefore provide collision avoidance guidance and a feeling of safety.

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2 Related Work

Several systems use local user collaboration to solve tasks in VR [1,9]. Salzmann et al. [6] developed an assembly training system using prop-based and virtual manipulation techniques. Two users, each wearing a Head Mounted Display (HMD), insert a windscreen into a virtual car. The users stood on a fixed location with sufficient distance, therefore user collision was impossible. The prop-based interaction improves task performance and collaboration, as well as achieves higher subjective ratings. In addition to that the prop provides passive haptic feedback and gives a direct connection between both participants. Beck et al. [3] use a CAVE-based system approach for group-to-group communication. Several local users perceive the virtual world from their own viewpoint using shutter glasses. All of them are projected into the virtual world via a 3D camera. This setup allows collision avoidance, because the local users do not wear a HMD and see each other. However, all users of a local group move as a unit through the VR world and individual user locomotion is not possible. Azmandian et al. [2] solve the collision problem of local users by altering their paths of movement. In a theoretical experiment they test different strategies for redirected walking to keep users apart. The disadvantage of this approach is that it does not aid collision avoidance when users are standing close to each other.

3 User Avatars for Collision Avoidance

A user avatar allows to estimate the location of others and therefore to avoid collisions. However, different avatar representations can be used. Several VR applications use a very basic user representation and only show the HMD and the two controllers that the user holds. We call this the basic avatar (BA) (see Fig. 1). This representation is very easy, since the location of the hardware is known and no additional effort is needed to use the BA. However, the floating HMD and controllers are very subtle. To increase the visibility of this avatar,

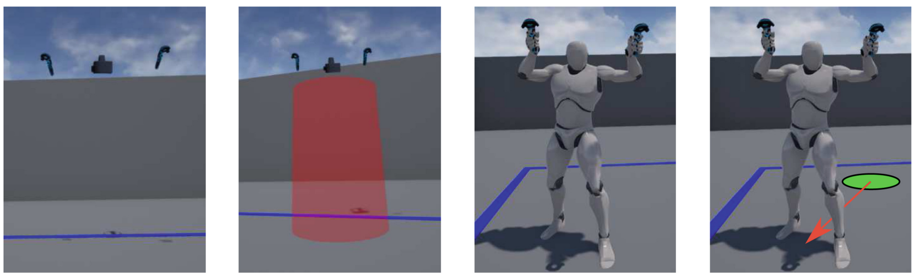

Fig. 1. The four different avatars that are compared regarding their capability to avoid collisions. The green circle of the shifted avatar represents the real position of the user and the avatar is shifted towards the location of the current user. (Color figure online)

we fitted it with a static bounding cylinder that can be seen by other users. Due to its strong indication, the cylinder avatar (CA) highlights the current location of the user and aids the users perception. With the use of pose tracking, a full-body avatar (FA) can be displayed. The FA brings all the movements of the user into VR. If external pose tracking is not available or unwanted it is furthermore possible to use inverse kinematic to estimate the location of the joints from the pose of the HMD and controllers, which is given through the VR system. Since we aimed to minimize effort and hardware cost to integrate the avatars in any application, we chose the second option. Because only the information about the head and hands was available, the legs of the FA did not move. If additional tracking is added to the feet this issue can be resolved. Because of network or application lag, it is possible that during a quick motion a user avatar is not updated as quickly as it needs to. The result might be that another user appears further away than he really is. With the shifted avatar (SA) a user appears to be closer in VR than he is in the real world, thereby introducing a buffer to further decrease the risk of collision.

4 Evaluation

We compared the four presented avatars in a 28 participant user study. To evaluate the capabilities of the different avatars a scenario was designed that would provoke collisions. In a competitive task, two users were asked to reach a target object as fast as possible without colliding with the other participant. The objects were placed at two different distances (evenly distributed) and so that the path of the users crossed (see Fig. 2). For each avatar a set of eight rounds,

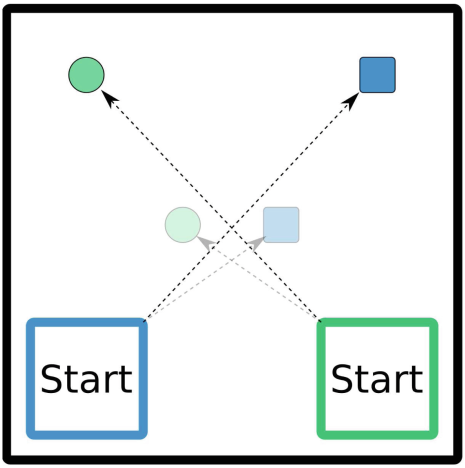

Fig. 2. The setup of the competitive user study. Both participants need to access an object, but their path's cross. The objects were placed at different distances with an even distribution.

three training rounds and five timed rounds, was performed. One round begins with a countdown and both users standing in their respective start zone. The round ends when a user grabs the object assigned to him/her. At the end of a set, users were presented with a questionnaire containing six questions rated on a five point Likert-scale.

Two participants completed one set of rounds, both using the same avatar. Each pair used all four avatars and performed four sets in total. The order of the used avatars was randomized to compensate for training and fatigue effects. At the very end a final questionnaire was given to the participants.

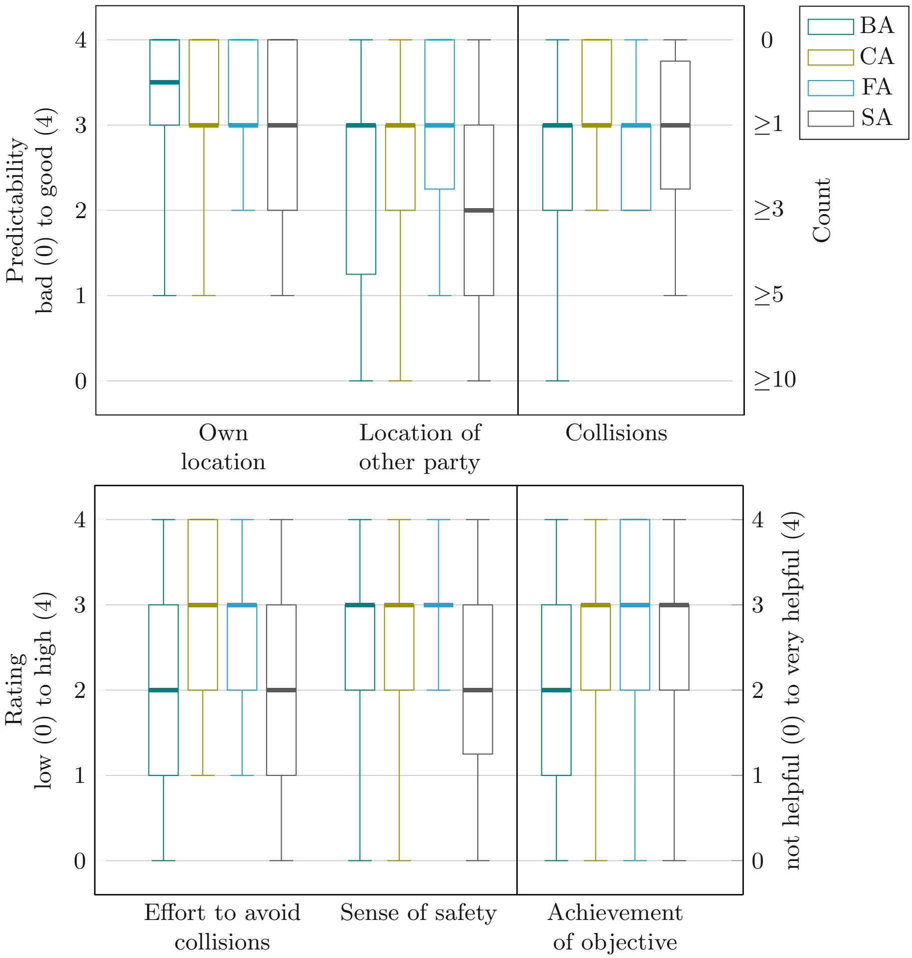

Fig. 3. Questionnaire with box-and-whisker plots for the different avatars.

The results of the questionnaire (see Fig. 3) show that the different avatars affect the number of collisions and the overall feeling of safety. Values of the

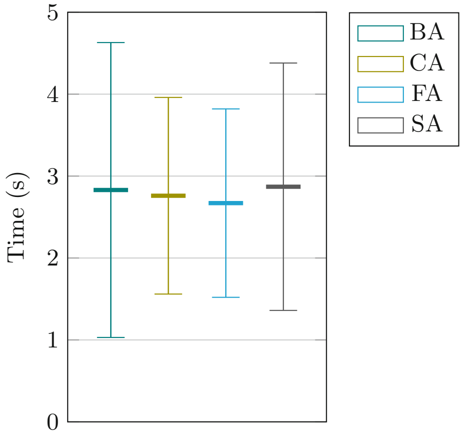

Fig. 4. Timings with average and standard deviation for the different avatars.

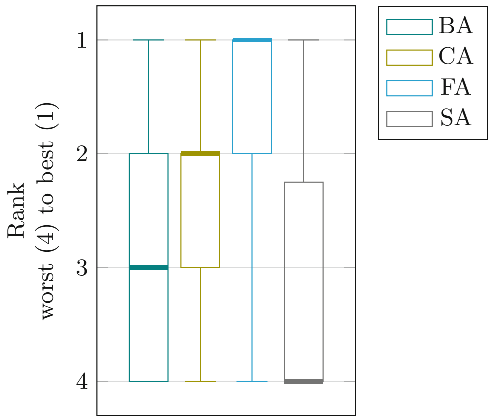

Fig. 5. Preference rating with box-and-whisker plots for the different avatars (only ratings of users that noticed the shift).

ordinal scales are compared using a pairwise Dunn-Bonferroni test with $\alpha = 0.05$ All avatars are appropriate to predict the user's own location with no significant difference. When asked how well the users could predict the location of the other party there are significant differences between FA-BA and FA-SA. Users counted the number of collisions with each other. The results show a significant difference between BA and CA. In addition to that, users were asked how much effort was needed to avoid collisions. There are significant differences between CA-BA and CA-SA. The participants assessed their sense of safety and evaluated the avatars with a significant difference between FA and SA. At last, users were asked how helpful the avatar representations are, when it comes to achieving the objective. They rated the avatars BA and FA significantly different. In conclusion, CA is better rated than at least on other avatar in the category effort to avoid collisions and number of collisions. FA is better rated than at least one other avatar in the category predictability of the location of the other party, sense of safety and helpfulness for the achievement of the objective. Both, CA and FA have the lowest number of collisions.

In addition to the questionnaire, the duration of each round was measured (see Fig. 4). The timings show no significant differences between the avatars.

To assess the effects of the shift of the SA, the participants were not told that the avatar of the other party was shifted towards them. 20 users (71.43%) noticed the shift of the fourth avatar and felt unsafe, since they could not estimate the real location of the other user. Those users ranked the SA lower than the other avatars (see Fig. 5). The full-body avatar is rated significantly better than BA and SA.

5 Discussion

The results of the user study show, that the representation of the avatar influences the number of collisions and the user's sense of safety. The minimal representation of the BA is not very suitable for local multi-user interaction, as it has the highest amount of collisions in the user study. In addition to that, it is rated worse than the other avatars in many categories and never rated better in any category. The CA shares the lowest amount of collisions with the FA[1]. Furthermore, the effort to avoid collisions is low. Its representation is very easy to implement and does not need any additional calculations for avatar animation or additional hardware setup. It can be integrated into an existing system very easily. However, the strong indication of the user might disturb the immersion of the VR experience. The FA leads to a high sense of safety and to a low amount of collisions and is preferred by the participants of the user study. Additionally, it facilitates the predictability of the other user's location. The representation of the avatar needs body pose tracking or inverse kinematic calculations. Yet, the implemented inverse kinematic calculations are only an estimate of the users body pose and contain a high error for the legs. A simple solution to this problem is a floating avatar without legs [4]. Another way to increase the accuracy of this method is to attach additional trackers to the user's feet [8] and other locations, like the hip [10]. The shifted version of the full-body avatar leads to a bad predictability of the location of the other user, since it is intentionally modified. However, this modification leads to bad ratings and insecurity among users. The shift is readily noticed and should be avoided.

6 Conclusion

Virtual reality applications allow multiple users collaborate to achieve the given target. Yet, even though users meet in a virtual room, their physical location

[1] It should be noted that the given task was designed to provoke collisions and it can be expected that a small amount of collisions always occurs.

can be either local or remote. If users collaborate in the same physical space, they need to be aware of the other parties to avoid collisions. We presented and evaluated four different avatars in a user study for their capabilities and support in the context of collision avoidance. The results show, that a basic representation of only the HMD and the controllers is not enough to achieve that goal. Further indications of the user's location, i.e. through an approximate cylindrical indication or a full-body avatar, help to avoid collisions and boost users feeling of safety. A shifted user representation, that acts as a safety buffer, did not serve its purpose and did lead to bad ratings and user insecurity. Therefore, local multi-user interaction should use sufficient user representation and always meet user expectations. For future work the legless avatar and other forms could be evaluated regarding their safety for local collaboration and immersion. Furthermore, the current setup does not allow users to independently teleport or move around. If they would do so, the virtual avatar looses sync with the real location of the user. To avoid collisions in this scenario, a *ghost* user could be displayed that shows the location of the other local users even though their virtual avatars might be at another location. To avoid breaking the immersion, the ghost could be displayed only if the two users are close to each other.

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Support Collaboration Across Geographically Distributed Users Using Heterogeneous Virtual Reality Systems

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Abstract. There still lacks a collaborative framework that integrates existing and new virtual reality systems supporting remote collaboration for data visualization. The collaborative framework currently available might limit the collaborators for collaboration because it is not developed to support interaction with diverse 3D applications while using heterogeneous virtual reality (VR) systems remotely in a synchronized way. We will present our collaborative framework that supports remote collaboration across heterogeneous VR systems to interact with multiple 3D applications. This system is independent of any VR systems and can be used to interact collaboratively in real-time on a shared task. Additionally, we conducted a pilot study to gain perspective on the usability of the system for collaborative work across heterogeneous VR systems. We will present the results on the usability of the system, and the results obtained from the users are motivating and encouraging. Our system has the potential to increase task effectiveness and workflow because it enables shared and real-time interaction while remotely collaborating with diverse 3D applications across heterogeneous VR systems.

Keywords: Collaboration · Heterogeneous · Remote collaboration
Virtual reality · Collaborative virtual environment

1 Introduction

Collaborative Virtual Environment (CVE) supports multiple collaborators either co-located or geographically distributed to work in a shared environment to achieve a common goal. However, CVE has mostly been used in a co-located space for a collaborative task [1–5]. With the availability of several resources, a collaborator wants to use hardware system for remote collaboration that is readily available to them. But currently available collaborative frameworks have been designed targeting few specific VR systems for remote collaboration and scaling of those collaborative frameworks for new and developing systems are difficult [6]. CVE with the flexibility to support diverse VR systems to visualize different 3D application for remote collaboration will help collaborators to be independent of VR system. They can use multiple VR systems to utilize

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them to their full potential and support each other for better understanding and sharing of information during collaborative tasks.

Our CVE provides a collaborative framework that has a simple and easy interface to integrate existing, new and emerging virtual reality system for collaborative task across geographically distributed collaborators and share their virtual workspace for achieving a shared goal. This CVE, which supports remote collaboration, is independent of VR systems. It combines existing algorithms and technologies in a novel way to provide collaborators with a collaborative framework that supports heterogeneous virtual reality systems across different geographical location.

This CVE has been tested and supports multiple users across diverse VR system for remote collaboration. The dataset used for collaboration is loaded in each collaborators system, and the system only sends and receives the changed information about the data and virtual environment so that it helps to decrease the network congestion, bandwidth problem, and latency during collaboration. It provides an additional layer of security with authentication system to avoid anonymous users to connect to the collaboration server. It also supports the use of 3D video avatar or web camera for video communication and furthermore, supports audio communication while collaborating across geographically distributed collaborators.

In this paper, we present the implementation details and features of our CVE for remote collaborators, which is independent of VR and tracking systems that can be used for multiple different 3D applications quickly and efficiently. Furthermore, we present the pilot study that we collected from researchers and scientists to evaluate the effectiveness and gather feedback on the usability of the CVE.

2 Background and Related Works

Uni-CAVE [7] is an add-on package for Unity3d software, which is freely available. It supports cluster-based VR displays, device tracking, and display synchronization but does not support remote collaboration. We have used Uni-CAVE to support the use of Unity3D in CAVE and IQStation. Unity Networking (UNET) [8] is used for networking between remote collaborators to supports collaboration. It provides us with high-level scripting so that we do not have to be worried about the low-level implementation. UNET uses network manager to control the state of the networked system to make remote procedure calls (RPCs) and networking events from the server to clients, message handlers and it uses a general-purpose serializer to serialize the data when sending through the networks. Virtual Reality Peripheral Network (VRPN) [9] is used as to map and provide an interface to connect the interaction and tracking system with the collaborative framework.

There has been growing work in integrating different VR system for remote collaboration. DIVE [10] has been used to support remote collaboration across desktop, head-mounted-display or projected displays. It also supports networked communication with the use of audio, video, whiteboards, text chat and simple graphical gestures. However, in our CVE it adds more existing and emerging VR systems to supports remote collaboration like smartphones, tablets, tiled walled display to increase the scope of the collaborative framework. Furthermore, this CVE supports 3D video avatar to provide face-to-face communication for an increased sense of presence while working with remote collaborators. MASSIVE-2 [11], which uses the third-party objects, provides a teleconferencing platform across the remote network, which also supports awareness between objects and environments. This CVE is different because it provides a platform to support authentication system for increased security level while joining the collaboration, remote collaborative data visualization to support large 2D or 3D datasets and furthermore adds support of 3d video avatar for video communication. SPLINE [12], which is a scalable platform, supports large interactive network platforms. It has not been used and tested with the handheld devices like smartphones and tablets. NSPNET [13], which is a 3D networked virtual environment, is built to support large-scale military training and simulation. This system is different because our CVE focuses on providing support for remote collaborative data visualization ranging from non-immersive to immersive display systems. CALVIN [14] supports multiple remote users for architectural design and collaborative visualization using large display systems like CAVE and ImmersaDesk and CAVEvis [15] also supports the CAVE-like display for distributed real-time visualization. However, our CVE is different from these platform as it supports large interactive to small handheld VR systems for remote collaborative data visualization in real-time. NICE [16], which is a collaborative virtual environment for young children, which presented a virtual island where the remote collaborator was presented in avatars and can use CAVE, ImmersaDesks or desktop computer. However, this NICE didn't support the use of other available semi-immersive and non-immersive VR system for collaboration which is supported by our CVE.

There has been increasing research work in the field of remote CVE for shared virtual workspace and data visualization using a heterogeneous VR system. It will help a collaborator use these tools and features available for collaborative visualization in a fully immersive display (CAVE) to support other collaborators using semi (IQStation) or low (Desktop, smartphone, and tablets) immersive display system to work collaboratively or vice versa. It will provide an effective and efficient platform to support the collaborative work across distributed users in geographically separate location.

3 Collaborative Architectural Framework

This collaborative architectural framework has been developed using Unity3D (version 5.5.2f2) [17] in C# language. Unity Networking (UNET) is used to support the networking across geographically distributed collaborators. Uni-CAVE, an add-on package, is used to support the use of Unity3D with CAVE and IQStation (Fig. 1).

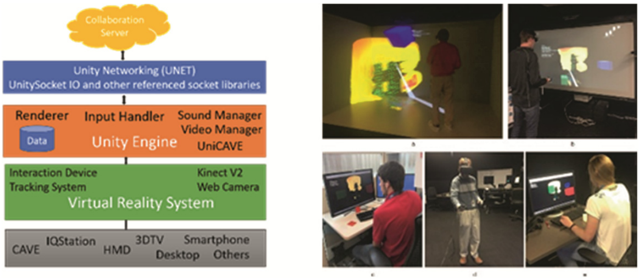

Fig. 1. (Left) Collaborative architectural framework. (Right) Collaborators using a. CAVE, b. IQStation, c. Laptop, d. HTC Vive, e. Desktop for working in heterogeneous VR system for collaboration

This collaborative framework comprises of a master client, which acts like other default clients but initiates, manages, maintains, and interacts during collaboration. This collaborative framework provides an added layer of an authentication system for security. Each collaborator when connecting to the collaboration server needs to provide the server name and authentication key, which is 32 bits generated using a random string, to restrict any anonymous user connect the server.

The data used for collaborative data visualization is loaded in the respective collaborator's VR system, i.e., each collaborator will have a copy of the data being used for collaboration. The reason behind having a copy of the data in each collaborator is to reduce the load on the server. Only the changed information of the data is sent and received across the network, which will help to reduce the network congestion. The viewpoint of the collaborator is data-centric, i.e., the collaborator's position in the virtual space is relative to the data. The master client initially has control over the shared data used for visualization. However, any client can request for control over the data while working collaboratively. Any changes made to the shared data will be cloned to all the clients connected to the collaboration. The master client is responsible for sharing the changes made to the shared data between the clients. The data used for visualization is stored as a Unity3D prefabs [18].

This collaborative framework also supports video and audio communication to help collaborators while working in geographically distributed locations. This framework supports the use of Kinect V2 camera or a web camera for video communication. Kinect V2 camera is used to generate 3D video avatar of a collaborator and is sent to the collaboration server as a point cloud. It is the responsibility of the master client to send the 3D video avatar information to the other clients connected to the server. This Kinect V2 avatar will provide collaborators with face-to-face collaboration, which will help to increase the sense of presence. Currently, we support the use of single Kinect V2 camera for each collaborator to create 3D video avatar. This framework also supports the use of web camera to support 2D video communication. Furthermore, this framework also supports audio communication using microphones. It uses.NET sockets to transport the sound data over the network. These sockets will use P2P multicast to transport the sound from one collaborator to all other connected remote collaborators.

This framework has implemented a class method, which receives information from the VRPN, which helps to connect the devices and systems and then map all the buttons of the interaction devices for respective VR system used by the collaborator. In the current implementation of this collaborative framework, this has been tested with flystick2 [19], flystick3 [19], Wiimote [20], HTC Vive Controllers, Gamepad Joysticks, and Keyboard/mouse.

4 Experimental Study

We conducted a pilot study (N = 15, #Groups = 7), with mixed experimental design, with the type of VR system as a between-subjects condition and the combination of the VR systems as the within-subjects condition to evaluate the usability of CVE with groups of participants on a collaborative task. In within-subject conditions, we compared the use of uniform VR system with heterogeneous VR system for collaboration. In addition, in the between-subject conditions, collaborators for uniform VR system were assigned desktop-to-desktop system or IQStation-to-IQStation for collaboration randomly. Similarly, for heterogeneous VR system we had CAVE to HMD, CAVE to Desktop, CAVE to IQStation, Desktop to HMD, HMD to IQStation, IQStation to Desktop system randomly assigned to participants for collaboration. We collected qualitative data through questionnaire and interviews with the individuals of the groups to evaluate the usability of the CVE.

4.1 Apparatus

HTC Vive used has a resolution of 1080 × 1200 pixels per eye. It has a refresh rate of 90 Hz and a field of view (FOV) of 110 degrees. Kinect V2 used had a resolution 1920 × 1080 (16:9) pixels, and the infrared camera had a resolution of 512 × 424 pixels. The CAVE used for the collaboration is a four-walled display system. Its dimensions is a 12 × 12 × 7.5-foot cube, which uses rear-projection to display computer graphics on three walls and front projection on the floor. IQStation uses a 3D projector to project on the screen. This Panasonic projector has a resolution of 1200 × 720 pixels. It uses a low-cost tracking system, i.e., smarttrack [21]. Wiimote is used as an input device to interact with virtual objects and environment.

4.2 Experimental Data and Task

We have used graphite billet (shown in Fig. 2, left) as a data set for collaborative immersive data visualization and analysis. We conducted an informal discussion with domain scientists to understand what different type of datasets they explore in immersive visualizations. We designed the collaborative task for participants in a group to sample the highest variation of density level of graphite, which is shown in the dataset using change in color gradient. Each collaborator is assigned to a cube randomly (shown in Fig. 2) and each collaborator has to use a cube for sampling the highest variation of density level. This cube can be manipulated and translated to determine the correct region in the dataset for sampling. The collaborator who initiated the server will have the control over the shared dataset first. This owner can manipulate the dataset for finding the correct region for highest change in density level, and this manipulation (i.e., change in position and orientation) of the dataset will be across the entire collaborator's environment. The collaborators will work together to determine the highest change in density level and have their cube translated to that position. Collaborators can communicate with each other using Kinect 3D Video Avatar/web camera for video communication and use headphones for audio communication.

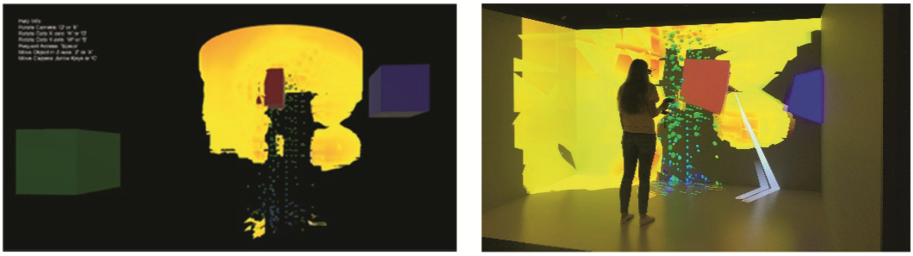

Fig. 2. (Left) Graphite Billet dataset rendered in the system for the experimental study. (Right) A collaborator working collaboratively and controlling red cube to sample the highest change in density value in the graphite billet (Color figure online)

A collaborator can choose any one of the cubes available in the environment in mutual consent while working in the collaborative environment. These cubes are uneven in size to encourage collaborative task by helping each other to sample the best density variation. Therefore, each collaborator will have his/her cube for sampling the dataset. Initially one of the collaborators who initiated the collaboration server will have the control of the graphite data set.

Moreover, during the collaborative task, if anyone of the collaborators who wants to have the control of the data set for manipulating the data, he/she can easily do so by pressing a button available to them in their interaction device and then get control of the dataset. Since this task is a collaborative task, it will be completed when both collaborators agree that they have the best-sampled density information from the dataset.

5 Results and Discussion

Participants completed a post-questionnaire to provide feedback on the usability and willingness to use the provided CVE for their collaborative work with geographically distributed collaborators. The graph (see Fig. 3) shows the desire of the participants to use the provided collaborative framework in future for their collaborative tasks. It suggests that majority of the participants were willing to use this system for remote collaborative work. 11 participants were ready to use, 4 participants could use, and there were not any participants who did not want to use the system in future. This result suggests that if we provide collaborators with a collaborative framework which is independent of any VR systems and is easy to use will encourage them to incorporate the system into their research work for more effective and efficient collaborative task. Furthermore, we also collected qualitative data about the usability of the system. This data will suggest how helpful the collaborative framework to complete the collaborative task effectively and efficiently was. One of the participants commented "Interested in using as a tool for data visualization in a user facility environment." Another participant commented that "Use of different systems allowed quicker movement for both the individual and the team." and furthermore, another participant commented "Going from the 2D desktop environment to the 3D virtual environment made it incredibly easy and incredibly fast to look, share, and discuss the data set we were looking at. In the future, I will definitely prefer the 3D virtual environments using different virtual reality system for collaborative work." This feedback from participants suggested that the CVE provided an effective and efficient platform for the collaborative task and they are encouraged to use this system for their work.

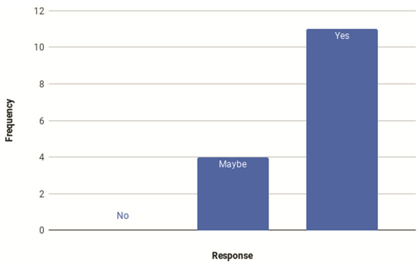

Fig. 3. Collaborators feedback on using this CVE for remote collaboration

6 Conclusion and Future Works

We presented our collaborative virtual environment that supports geographically distributed collaborators using heterogeneous VR systems for collaborative immersive data visualizations. Our CVE provides collaborator with a framework, which is independent of VR systems thus encouraging researchers and scientist to collaborate their work without any difficulties remotely. In our pilot study, we remotely collaborated with collaborators to work on real-world datasets. This study suggested that our CVE has the potential to increase the workflow, task effectiveness, and provide a better user experience while remotely collaborating across heterogeneous VR systems.

In future, we will evaluate the performance of our CVE across broader audience using diverse VR systems. In addition, we want to assess the network congestion, bandwidth, and latency while collaborating remotely with several collaborators who are using different VR systems. Furthermore, we also want to add interaction and rendering techniques to support visualization tasks to increase the scope of the CVE.

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Talon Metaphor: Grasp and Release Method for Virtual Reality

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Abstract. In this paper, we present a novel grasp and release method for direct manipulation in virtual reality. We develop a new grasp method in complementary to the proposed release method. Data gloves and smart sensors may achieve high accuracy and speed but users are prone to fatigue after a long use and devices can be expensive. Therefore, we focus our study to develop an algorithm to reduce fatigue and costs of the virtual system. We track the real hands using a depth camera and determine grasp and release states using virtual rays. Without wearing any devices, users are able to grasp and release a virtual object quickly and precisely. Just as eagles use their talons to catch prey, finite virtual rays from the finger tips are used to determine the grasp and release states. We present that our method improves on grasp time, release time and release translational error based on grasp and release tasks. In contrast to the natural interaction metaphor, measured grasp time, release time and the release translational error for our method do not depend on the object types and sizes.

Keywords: Virtual reality · Virtual grasp · Bare-hand interaction

1 Introduction

In recent years with the advancement of depth cameras, mid-air, bare-hand or free-hand interaction has received significant attention from the research community. Commercially available devices such as Kinect and WiiMote allowed researchers to produce interaction methods in virtual reality. Generally, there are two ways to provide the input for mid-air interaction. The first one is by wearing data gloves, sensors or markers that provide hand information to the system. The other one is device-independent bare-hand method, which does not require any wearable devices. Depth camera obtains the hand information and determines different poses of the hand in real time. One example of mid-air interaction is the natural interaction metaphor [1], in which users wear finger tracking gloves in a virtual reality system. Another example is the spring model, in which users wear data gloves for mid-air interaction in virtual environment [2–4]. Although previous works provided good solutions for manipulating an object in virtual environment, sticking object problem mentioned in [1] and tracked fingers residing inside of an object problem in [2–4] hinder users from experiencing naturalness, which is one of the requirements to satisfy from user's perspective [5]. According to

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Prachyabrued and Borst [3], both problems occur due to lack of physical constraints that users tend to close their real hands into the virtual objects. One way of solving the prob-lems is by wearing devices and sensors that give feedback to users when they touch the object. Many techniques take advantage of wearable data gloves, sensors and markers to track hands accurately and quickly but the wearable devices, sensors and markers can hinder users from being focused and experiencing naturalness. Our method only uses one RGBD sensor for both tracking hand and manipulating a virtual object yet, it enhances naturalness and reduces fatigue on users by solving sticking object problem and residing inside of an object problem. Similarly gesture based techniques, such as the handle bar metaphor [6], only require one RGBD sensor to manipulate multiple objects at once but users need to learn the predefined gestures before they can take advantage of such virtual systems. Our algorithm calculates optimal grasping and releasing states using finite virtual rays, which simply calculations and provide rapid and accurate selections in comparison to natural interaction metaphor. As long as users are familiar with grasp and release in real world, this method has low learning curve for average people to enjoy virtual reality tasks. In this paper, we present talon metaphor for bare-hand virtual grasp and release, which does not rely on any wearable devices, sensors and markers. We present experimental evaluation of our method to show speed and accuracy in comparison to natural interaction metaphor.

2 Talon Metaphor

2.1 Talon Metaphor Description

When we were researching about grasp and release mechanisms in virtual reality, we decided to take careful examination at biological beings in real world. We named our metaphor as talon after the claws on birds' feet because eagles, specifically, can grab and lift up their prey from water effortlessly. We were impressed at how quickly and firmly eagles can catch their prey. Therefore, we implemented finite virtual rays on virtual fingertips that mimics talons on eagles' feet in Fig. 1. Finite virtual rays project out from the middle of the tips of thumb, index and middle finger as shown in Fig. 3. When eagles grasp their prey, their talons penetrate the body of the prey. Similarly, our method calculates the intersection points of two pairs of virtual rays inside of an object for grasp. As eagles can rapidly and accurately grasp and release their prey, our metaphor also can grasp and release quickly and accurately.

2.2 Grasp Function

Our grasp function renders virtual rays from the middle of the three finger tips perpendicular to their distal joints. The basic idea is to check the shortest distance between the rays and compare it with the predefined threshold. The steps are shown in Algorithm 1. Figure 2 illustrates the moment of grasping an object. Let:

Fig. 1. Talon clenching fist.

$H \leftarrow$ User's Hand Coordinates,
$O \leftarrow$ Object's Coordinates,
$j \leftarrow$ longest length in the bounding box,
$k \leftarrow 2^{n}d$ longest length in the bounding box,
$d_{tm} \leftarrow$ distance between thumb and middle tip,
$palmSize \leftarrow$ average palm size.

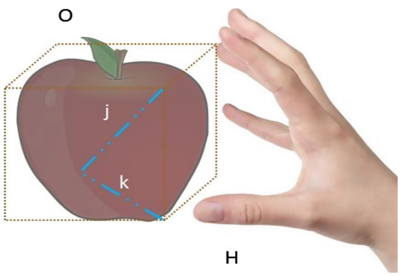

Fig. 2. Virtual rays are calculated and rendered from the midpoint of finger tips perpendicular to distal joints.

Algorithm 1 Grasp–Release algorithm
1: function Grasp–Release
2: while H contacts O do
3: CreateBoundingBox
4: CalculateRayLength
5: RenderRay
6: CheckGraspingPairs
7: end while
8: end function

Step 1: While H contacts O, create a bounding box. Our method checks for the moment when the user's hand contacts an object. Contact is valid when the user's thumb and one of the fingers are touching the object. Since we know the co-ordinates of the object and the hand, we can simply determine whether the contact is valid or not. When the contact is valid, a bounding box, which surrounds the object, is calculated using 3D point cloud coordinates of the object.

Step 2: Calculate length of the ray. This step as shown in Algorithm 2 calculates and renders the rays that are projected from the middle of the three finger tips. First we calculate the distance between the tips of thumb and middle finger, d_{tm}. If d_{tm} is larger than *palmSize*, it is considered to be wide grasp. Otherwise, it is considered to be narrow grasp. If it is the wide grasp, we set the ray length to be the half of the maximum length of the bounding box, which is j, otherwise we set the ray length to be the half of k. Rays are projected away from the palm at 90° from the distal joints. Figure 3 shows how rays are rendered.

Step 3: Check for grasping pairs. This step checks for valid grasping pairs and returns true if the grasping conditions are satisfied. First grasping condition is checking for a valid grasping pair. A valid grasping pair is either a pair of thumb and index finger or a pair of thumb and middle finger. Then the shortest distance between the virtual rays of valid grasping pairs is calculated and compared with the predefined threshold value. If the shortest distance is equal to or less than the threshold value, the second grasp condition is satisfied. Finally, an object is grasped when the two grasping conditions are satisfied. At each simulation frame that user is grasping an object, our system cycles through the above steps checking for validity of grasping conditions. Step 3 is shown in Algorithm 3.

Algorithm 2 CalculateRay Length

```
function CalculateRayLength
  if check WideGrasp( ) is true then
    Lk ← j/2
  else
    Lk ← j/2
  end if
end function
```

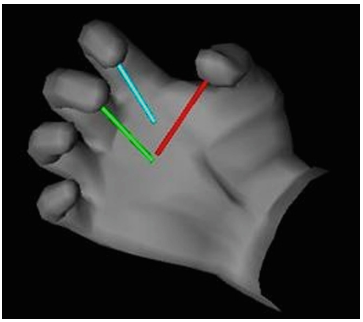

Fig. 3. Virtual rays are calculated and rendered from the midpoint of finger tips perpendicular to distal joints

Algorithm 3 CheckGraspingPairs

```
1: function CheckGraspingPairs(R_thumb, R_index, R_middle)
2:   if getShortestDistance(R_thumb, R_index, R_middle) ≤ Threshold then
3:     ShortCoords ← getShortestDistanceCoords
4:     if shortCoords in Object then
5:       Grasp
6:     end if
7:   else
8:       Release
9:   end if
10: end function
```

2.3 Release Function

Grasping of an object is valid as long as there is at least one valid grasping pair associated with the object. In each simulation frame, our system compares the predefined threshold with the shortest distance between the grasping pair as shown in Algorithm 3. If the check for grasping pairs returns false during grasp, the release state begins. However, we noticed unwanted drops of objects occurred in our system due to the finger sensing noise and unintentional movements. In order to solve the problem, we implemented low-pass filter. Note that the low pass filter level can be changed respect to the hardware.

3 Experiment

3.1 Experimental Setup

As shown in Fig. 4, our system consists of a desktop with Intel I7-4790 QuadCore at 3.6 GHz and 32 GB memory running on Windows 8 with NVidia GeForce GTX 780 graphics board. A Prime-Sense camera is mounted on the top facing downward to tack user's hands. A 40-inch 3D flat panel display is used as the monitor for 3D functionality with the compatible 3D glasses.

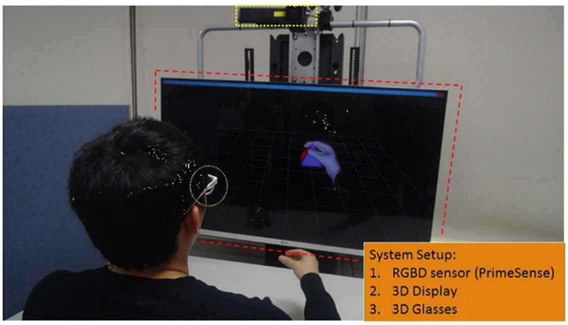

Fig. 4. System setup

3.2 Experimental Results

We measure the time to grasp an object, the time to release an object and translation error of an object during release using the talon metaphor. The measurements were compared with those of the natural interaction metaphor, which we implemented by following the descriptions on published work [1]. Natural interaction metaphor defines a collision pair which is a pair of two fingers holding an object. Collision pairs define a valid grasping pair when the friction angle of both collision pairs is smaller than a predefined threshold. When a user is grasping an object, the natural interaction metaphor calculates the distance between the grasping pair and the midpoint of the grasping pair, which is called the barycenter. The first release condition is when the distance between the grasping pair is larger than the predefined threshold. The second release condition is when the distance between the barycenter and the object's center is larger than the allowed threshold. If one of the two release condition gets violated, the release begins. We experiment with grasp and release task on various object size (small (length or diameter = 4.0 cm), medium (length or diameter = 7.0 cm), large (length or diameter = 10.0 cm)) and various object types (cube, polyhedron, sphere).

We performed an experiment with 16 males and 4 females, aged 23 to 31 years (average = 27). Almost all subjects graduated from engineering majors and had exposure to virtual reality systems.

We compared the results of our method to the results of the natural interaction metaphor and summarized in Table 1. Regard-less of the object sizes and types, our method was on average 30% faster than the natural interaction metaphor at grasping an object, on average 70% faster at releasing an object and on average 18% less in release translational error.

Table 1. Grasp time, release translation error, release time for different object sizes and types compare to natural interaction metaphor (unit = ms)

	Method	Size			Type		
		Small	Medium	Large	Cube	Polyhedron	Sphere
Grasp time	Natural interaction	1843.46	1593.02	1990.34	1764.77	2145.72	1516.33
	Talon	1221.96	1233.38	1284.21	1146.43	1292.25	1300.87
Release translation error	Natural interaction	18.13	23.30	25.61	22.46	26.15	19.13
	Talon	17.44	17.58	18.77	18.93	17.53	17.33
Release time	Natural interaction	1512.22	1637.63	2155.36	1636.96	2029.57	1638.68
	Talon	441.54	500.45	456.07	462.64	448.06	489.36

4 Conclusion

We propose a new grasp and release method called talon metaphor in virtual reality. We only use a commercially available and affordable RGBD sensor to track the real hands. It can directly manipulate an object without wearing any devices in virtual reality. The experimental results show that the talon metaphor successfully solves sticking object problem and fingers residing inside of an object problem and significantly improves in grasp and release time as well as release translational error. Using our method, normal users can enjoy and explore manipulation tasks that require precision and quick grasp and release method in virtual reality.

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Implementation of Educational Drum Contents Using Mixed Reality and Virtual Reality

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Abstract. Since the revival of the arcade game market in Japan, a variety of sensory rhythm games have appeared. Among them, KONAMI's 'Drummania', which provides a controller similar to a real drum, became a popular game that continued after its release in 1999. And 'Drummania' became the standard for later drum games. Conventional drum games provide players with information about their performances in GUI form through display. At this time, since the line of sight of the player is fixed on the game screen, recognition of each part of the drum is not intuitive. In this research, we propose more intuitive drum contents by applying mixed reality and virtual reality technology to solve this problem. In order to evaluate the intuitiveness of the proposed system, it is applied to the drum learning contents to verify the effectiveness.

Keywords: Augmented Reality · Virtual Reality · Drum · Educational contents Game · Tangible interface

1 Introduction

Augmented reality (AR) is an example of a virtual environment, and it is distinguished from a virtual reality because it shows a mixture of virtual objects in a real environment. In 1997, Ronald Azuma defined AR as complementing reality, not replacing reality [1]. In addition, Ronald Azuma proposed a combination of real and virtual, real-time interaction, and three-dimensional environment as conditions that enable augmented reality. AR technology has been extensively used in the general industrial field and is expected to be used more widely in the future [2].

The display used in the AR is classified into a head wearable HMD and a non-head wear non-HMD. A typical device of HMD is Microsoft's HoloLens. HoloLens is a display in which 3D objects are placed between real spaces and objects to create a new virtual space. Recent development engines provide AR technology with ease of use. Unity3D, a game development engine, provides a plug-in library to make it easier to use AR technology. When using AR technology in Unity3D, Vuforia, which is provided by Qualcomm, is the most commonly used [3]. Virtual Reality (VR) has been earnest in the 1960s Developed by Ivan Sutherland. Now, the market is growing rapidly all over

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the world. For each company, various HMD devices such as Samsung's Gear VR, Google's Cardboard, HTC Vive, and Sony's PSVR are being released. Many large corporations are developing and releasing new technologies in cooperation with their VR technologies, and most of the future content market is expected to be replaced with VR content [4].

With this trend, attempts have been made to incorporate AR/VR technology into other fields. Typically, there is a connection with games. Due to the nature of the game that seek fun, the game has become quicker combined with new technologies. Various games using AR/VR technology like Pokemon GO are released and are loved by users. Other areas include education and learning. Reported that when AR/VR technology was applied to education and learning, participants were more immersed and had a positive effect [5, 6].

In this research, we try to overcome the limitation of drum game by applying AR/VR technology. Since KONAMI's release of 'Drummania', 'Drummania' has become the standard for drum games. Existing drum games provide information on the performance to the player through the display. At this time, the perception of each part of the drum is not intuitive because the player's gaze is fixed on the game screen. In this research, we propose more intuitive drum contents through AR/VR technology. In order to evaluate the intuitiveness of the proposed system, it is applied to the drum learning contents to verify the effectiveness.

2 Related Works

2.1 Study on Educational Effectiveness

Choi Sung-ho studied differences in effects when experiencing educational contents with other devices [7]. In addition to the development of VR technology, various studies utilizing VR are underway. VR technology is attracting attention as a form of EduTech in the field of education. Here, EduTech refers to a method or technology that uses IT technology in education to enhance the effectiveness of education. In this study, experimentally verified whether there is a significant difference when learning the same educational contents on HMD and tablet PC (Fig. 1).

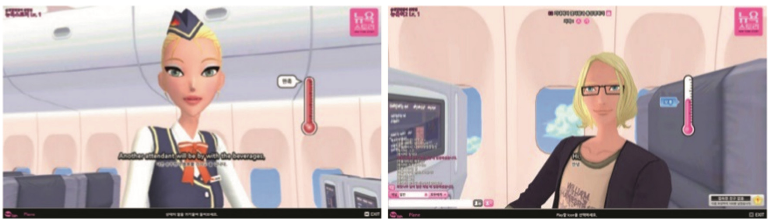

Fig. 1. Educational services 'Talklish' used in the study

In this study, used educational service called 'Talklish'. 'Talklish' is an English language education service, and it is conducted in a way that communicates with the character in an environment that can be encountered in everyday life. 'Talklish' is available on HMDs and tablet PCs, and the content configuration is the same for each environment. After experiencing 'Talklish' to the experimenter, the effect was verified through post - interview. Experiments were divided into groups using Gear VR and Galaxy Tab 10.1, two groups were taught the same chapter for 20 min.

In this study, hypothesized that the use of HMDs for virtual reality education services will lead to a higher level of commitment and learning motivation than using a tablet PC. The T-test was used to analyze the experimental group and the comparison group and analyzed using the IBM SPSS Statistics 24 statistical program. The results showed that the group using HMD showed higher commitment and learning motivation than the group using tablet PC.

2.2 Drum Training System with Multimodal Guidance

Hong Kyung-pyo proposed a drum performance education system using multi-sensory guidance [8]. Here, Guidance is an example in which a learner directly demonstrates an action that a leader cannot easily explain in order to improve learning efficiency in the process of learning something. The effect of guidance is revealed through various studies, but it is limited to visual and tactile. In this study, presented an educational system that added touch to provide useful information through various senses. The purpose of this study is to improve learners' drum performance by using multi - sensory guidance.

The drum training system consists of a one 6-inch drum pad and a drumstick. A 24-inch LCD monitor, headphone and vibrator (MVMU-A360G) were used for multiple sensory stimulation and a separate laptop computer was used to control the system. It is a form that provides visual information to the learner and provides visual, auditory, and tactile feedback to the learner's feedback (Fig. 2).

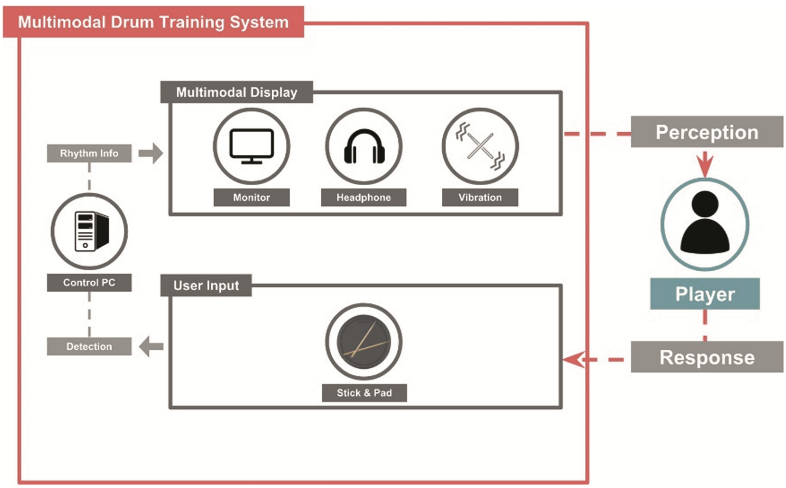

Fig. 2. System composition of this study

Proposed method of guidance was constructed by reference to the traditional rhythm game. Visual guidance tells you when you need to input the drum. You should input the drum when the rod-shaped Note comes down from the top and reaches the baseline. Notes comes down from the left or right relative to the center of the screen. The Note on the left side of the screen means the left hand, and the Note on the right side of the screen means the right hand. The hearing guidance plays a beep sound in the direction of the headphones corresponding to the moment when you need to input a drum. Finally, the tactile guidance vibrates the corresponding drumstick when you need to input a drum.

If the learner input the drum and the stimulus presentation is synchronized, it can be said that it is learned correctly. In order to evaluate the system, 120 BPM tempo training was conducted and the study confirmed the positive effect. Attempts to use various senses were good, but the intuition of visual information transfer was not resolved because the line of sight was fixed to the monitor without facing the drum.

3 Purpose of Research

In the rhythm game, music is expressed through 'Note', which is a unique symbol that can visually recognize music. In general, Notes show the height, length, strength, and feel of sounds [9]. The rhythm game also provides the player with a GUI that consists of a Note and a form of the result and benchmark. Here, the benchmark refers to a criterion that indicates at what instant the player should inputted, A result is information that tells how precisely the player inputted. In a traditional drum game, a Note indicates how many times player must hit a certain drum at what speed (Fig. 3).

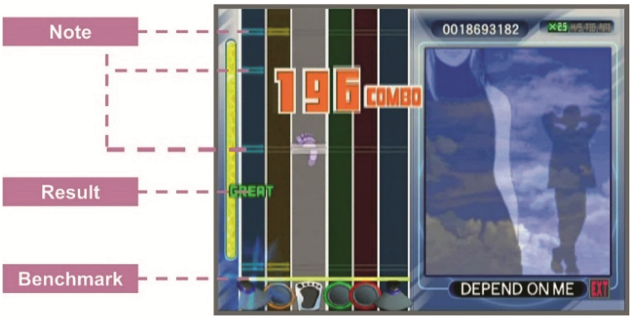

Fig. 3. Examples of providing information in a drum game

In this research, it is aimed to improve the intuitiveness by referring to the GUI of the existing drum game, and providing it in a form suitable for the AR/VR environment. In the AR environment, we intend to increase the intuitiveness by visually matching virtual information to the real drum. It is expected that the intuitiveness of play will be improved because it can be played by looking at the actual drum without going through the display. In the VR environment, we try to provide the player with tactile feedback by spatially matching real and virtual drums. If player feel the touch of hitting the actual drum when hit a virtual drum, player will be more immersed (Fig. 4).

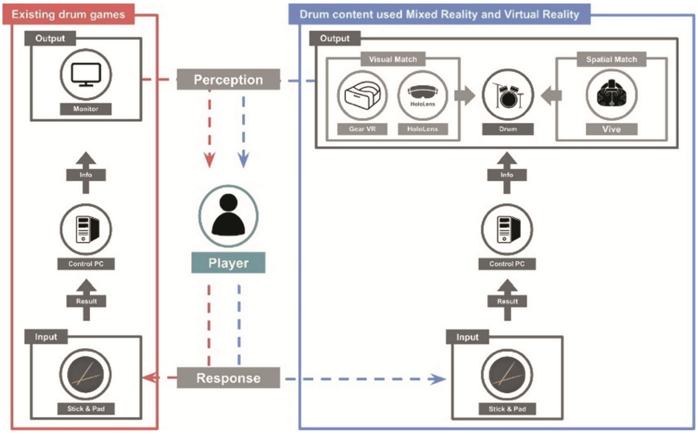

Fig. 4. System configuration with augmented reality and virtual reality

4 Implementation

The purpose of this study is to implement an intuitive interface by matching the real world drums to AR and VR, respectively. The Yamaha DTX400 K, an entry-level electronic drum, is used to provide an experience similar to that of a real drum, and is controlled via a separate PC.

Rhythm game implementation was made through Unity3D engine. Unity3D is a game development engine that makes program implementation relatively fast and easy. It offers a variety of functions and multiplatform, and it is used in many fields besides games. We created two versions of AR and VR, and created a separate Note-making tool for writing Notes that are suitable for music.

For the convenience of development, development tools suitable for each environment were used. In the AR environment, we used the Vuforia SDK supported by Unity3D. Vuforia SDK supports related functions to make AR technology easy to use. In the VR environment, we used the Steam VR plugin provided as a Unity3D asset. The Steam VR plug-in provides objects that are basically used in VR, such as VR cameras and controllers. AR equipment uses AR function of Gear VR considering viewing angle. When player play the game, should be able to see the generated Notes at a glance. The AR function of Gear VR is selected as equipment because it has a comparatively wide viewing angle than HoloLens. VR equipment employs Vive, which comes with a controller.

In rhythm games, Notes are used to provide information about the performance. Different Notes were used depending on the environment of AR and VR. For the AR environment, this research uses marker-based AR technology. Marker-based AR technology refers to the extraction of relative coordinates using markers and the synthesis of virtual graphic images into reality. Markers were placed on each drum and the benchmark were augmented. When a Note is created, a circle is created outside the benchmark. The generated circle rapidly decreases toward the benchmark. Drums should be input when the circle and benchmark are adjacent (Fig. 5). In the VR environment, a Note is created based on a point in front of the drum. The generated Notes quickly approach the drum. Player must input the drum when the Note and drum are adjacent (Table 1).

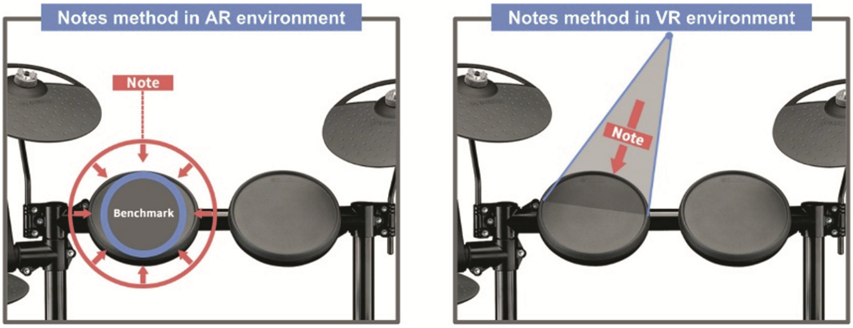

Fig. 5. Examples of notes used in an AR/VR environment

Table 1. Development environment summary.

	AR environment	VR environment
Drum used	Yamaha DTX400 K	
Development engine	Unity3D	
Notes production	Self-production tool	
Equipment used	Gear VR	HTC Vive
Tools used	Vuforia SDK	Steam VR plug-in
Target of matching	Visually match real drum and virtual information	Spatially match real drum and virtual drum

4.1 AR Environment

Overview. The goal of the AR environment is the visual matching between real drum and virtual information. Provides virtual information to each part of the drum to allow the player's attention to focus on the drum out of the display.

Implementation Contents. In this research, we used marker based AR technology. Markers were placed on each part of the drum for visual matching. The player recognizes the marker of each part of the drum before the start of the game and proceeds to the game.

Implementation Result. As a result of implementation, it was hard to recognize the Notes during game play. When the Notes were created on the drum, it was not enough for the player to recognize the Notes if multiple notes were created. It is necessary to implement an intuitive UI through continuous research. Also, the AR function of the Gear VR was not able to see all the drums at a narrow angle of view. When a note is created where the player does not look at it, need a way to tell it that it was created (Fig. 6).

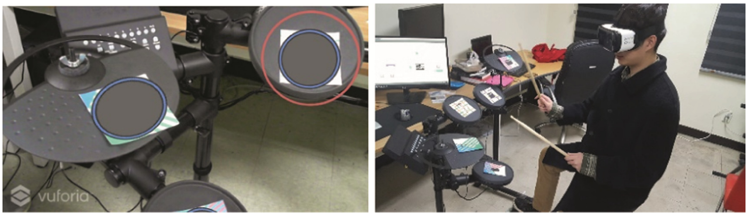

Fig. 6. Drum play in an AR environment

4.2 VR Environment

Overview. The goal of the VR environment is spatial matching between real drum and virtual drum. In the VR environment, there are games that play drums through the controller. The existing VR drum game is only playing the controller in the air, so player do not feel like hitting the drum. To solve this problem, the virtual drum and the stick are matched to the same position as reality, and the reality and the virtual are spatially matched. It is possible to provide tactile sensation through spatial matching and to provide a better immersion feeling.

Implementation Contents. For spatial matching, the virtual drum was placed in the same position as the real drum before the start of the game. Place the Vive controller on each part of the drum and input the controller, then a virtual drum is placed. The Notes used in the game are created in the same position in front of the player's view, and the Notes approach each drum.

Implementation Result. As a result of the implementation, the player could see and play the virtual drum without seeing the real drum. When player hit a virtual drum, player could hit the real drum, and the immersion feeling of the performance was improved. We fixed the controller on player wrist and played the game to match the virtual drumstick with the real drumstick. n future studies, it is expected that the feeling of immersion will be improved if the integrated controller is used (Fig. 7).

Fig. 7. Drum play in a VR environment

5 Conclusion and Future Work

In this research, we attempted matching to match the AR/VR environment to overcome the limitation of drum game. Spatial and visual matching resulted in meaningful results.

In the AR environment, we tried to visually match real drum and virtual information. Through visual matching, we intend to improve the intuition of information delivery that could not solve in existing games. However, due to the limitation of the viewing angle of the Gear VR, the player could not recognize the visual information at once. We needed a new UI that would let us know what notes were created where players did not look. In addition, the note UI used in this study was hard to recognize correctly when several notes were created at the same time. Future research should refer to this point and make more intuitive Note UI.

In the VR environment, we attempted spatial matching of the real drum and the virtual drum. Through the spatial matching, we were able to provide a feel that was not felt in the existing VR drum game. The player was more immersed in the game through the touch. In this environment, providing a drumstick integrated with the controller would provide a more immersive feeling. It is expected that it will be more effective educational contents if it is corrected considering the problems found in this study.

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Development of Authoring Tool for Extended Interaction in Mixed Reality Environments

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Abstract. Augmented Reality and Mixed Reality technologies make us feel the real world and the virtual world are mixed with each other through visual matching. However, existing mixed reality contents using these technologies have a limitation that interact only with virtual objects and cannot interact with real objects. If a dynamic real object need to be influenced by a virtual object, or vice versa, illusion of Mixed Reality can be broken by the incongruity of the interaction. If these limitations are improved, real objects, which were always static, can operate dynamically and interact with virtual objects, so becomes difficult to distinguish between real objects and virtual objects. In this paper, we propose extended interactions in a mixed reality environment that can give illusion which is difficult to distinguish between real objects and virtual objects. And to confirm this, we implement authoring environment based Hololens.

Keywords: Mixed reality · Extended interaction · Virtual object · Real object Authoring environment · Hololens · Tangible interface · Virtual reality · Game

1 Introduction

Recently, interest in augmented reality and mixed reality technology is increasing, and global companies are also carrying out various research and development to preoccupy the market [1]. Mixed reality technology visually matches virtual objects to markers or spaces that exist in the real world, giving illusion that objects in two different worlds are in the same space. In this case, the visually-matched virtual object can interact with other virtual objects, but there is a limit in that the interaction with the dynamic real objects existing in the real space. Since the operations of the real objects and virtual objects cannot be influenced by each other, unnatural situations may occur and this may interfere with illusion of mixed reality.

In this paper, we propose a system that adds the concept of 'extended interaction' that connects the reaction and action of real objects and virtual objects to improve these limitations. Then, we implement the authoring tool to study the 'extended interaction based on the Hololens which is a mixed reality HMD.

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2 Related Works

Lee et al. conducted a study on immersive authoring tools in augmented reality environment. [2, 3] A 2D image marker was used and a authoring tool was created to display, control and transmit the information of the augmented object. This research implemented interaction to manipulate and arrange 3D objects using enhanced virtual objects. Each virtual object has elements such as ID, Position, Rotation, etc., so that it can check the value of the object or control the value through the other virtual object. In the authoring tool implementation of this paper, we refer to UI interface part (Fig. 1).

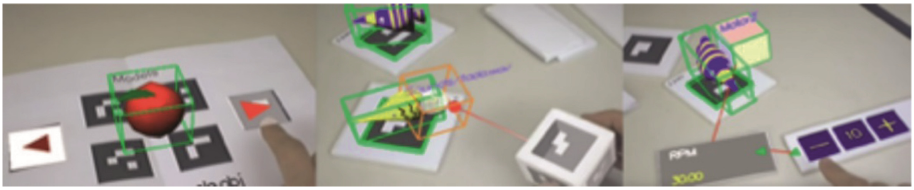

Fig. 1. Screenshot of immersive authoring tool by Lee et al. [2]

Kang et al. conducted a study on the interaction between real objects and virtual characters in the Augmented Reality environment. [4] The study proposes an augmented reality system for virtual characters to track or control real objects and implements examples to confirm them. The proposed system supports the interaction between the virtual character and the real object and allows the virtual character to manipulate the real object directly.

Park et al. carried out researches on the guidance system using Augmented Reality for solving the cube [5–7]. First, we developed a guide system using tablet. Next, we conducted a guide system study using HMD and gesture controller to improve user experience of guide system. Through the previous two studies, user experience improvement factors were investigated, and user experience comparison experiments and questionnaires were conducted based on these factors (Fig. 2).

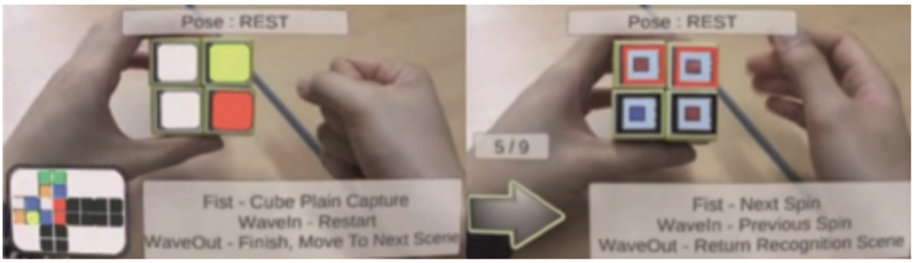

Fig. 2. Screenshot of guidance system using AR by Park et al. [5–7]

3 System Overview

Existing mixed reality contents are characterized by recognizing a marker or a space in reality and acquiring a reference position of the real world and enhancing a virtual object at the corresponding position to visually match the reality and the virtual. This makes the virtual world appear to exist in the same world, giving a user experience that feels like a mixture of reality and virtuality.

However, in this study, since only one Arduino object was used as a dynamic real object, it was difficult to confirm the interaction with a larger number of real objects. Further research using more IoT devices is required. Also, it is necessary to apply the proposed mixed reality system to contents such as game or guidance system where interaction between objects is more active.

3.1 Extended Interaction

In this paper, a mixed reality system is proposed to provide an interaction by exchanging state information through data transmit between real objects and virtual objects. To do this, real objects must be capable of network communication including IoT technology. Every object has state information related to its own action. It can detect the state of another object through data transmit without real or virtual distinction or can transmit its state to another object. In this paper, we propose that this action is 'extended interaction' between real and virtual objects (Fig. 3).

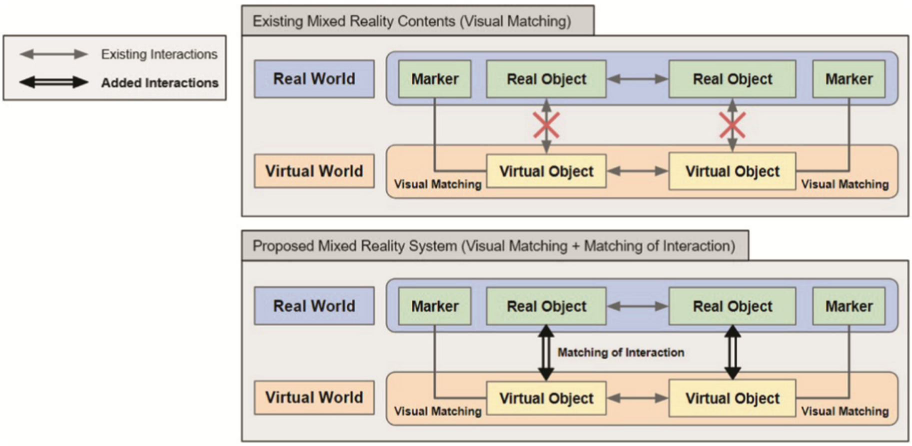

Fig. 3. Comparison of existing mixed reality contents and proposed mixed reality system

The proposed mixed reality system is expected to increase the fidelity to the mixed reality by reducing the unnatural situations that interfere with the illusion of the mixed reality, because the extended interaction is added to the visual matching of the existing mixed reality. It is expected that the connection of reaction and action can be seen as the matching of the interactions to different worlds and it can give the illusion that it is difficult to distinguish between the real objects and the virtual objects in addition to the visual matching of the existing mixed reality

3.2 Object Model

An extended interaction object has a sensor or an actuator, and both elements exist in the form of a node inside the object. Inside the node, state information whose values can be changed exists in the form of a field.

A sensor is an element that can detect changes in the state or behavior of an object. The detected content is internally processed through arbitrary processing and returned as a meaningful result. An actuator is an element that changes the state or behavior of an object. Depending on the data that you have or have received, there may be changes in the state or behavior of the object that owns the actuator.

A field is an element that has a sensor and an actuator and contains a data value. This is the state information of the object and can be thought of as a programming variable. The field contains an element called a Port in order to transmit data. By connecting ports in different fields, data can be transferred in a specific direction. There is an In port that can receive data from another field and an Out port that can transfer data to another field. It is possible to set which port to include according to the type of field.

Each object can communicate data values, that is, state information, by associating its own fields with fields of other objects, thereby constructing the interaction of objects (Fig. 4).

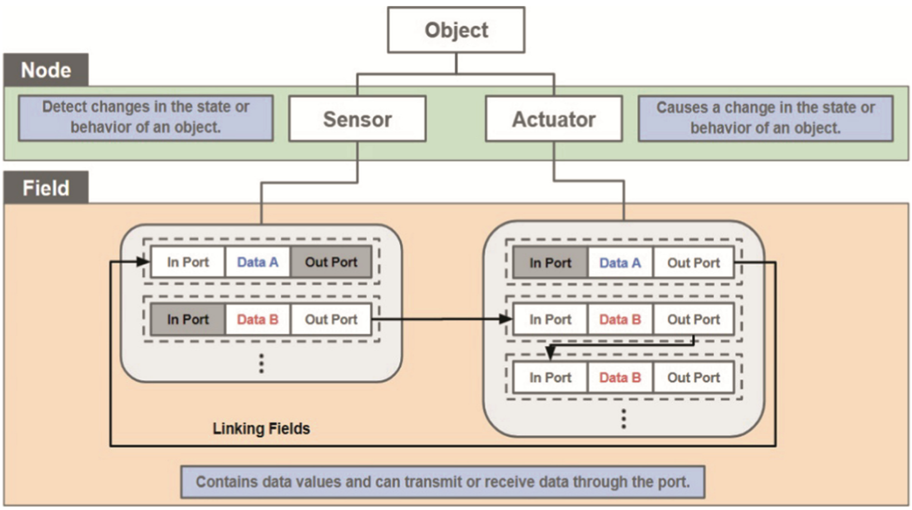

Fig. 4. Object component of proposed mixed reality system

4 Implementation

We used Microsoft's Hololens to construct a mixed reality environment and run authoring tools. Hololens has the advantage that it can recognize real space quickly and precisely by including various sensors for mixed reality. It also supports a gesture input interface called Air-tap. Arduino was used to create real objects including IoT technology. In this study, Arduino UNO R3 board was used and Wifi Shield was installed to enable network communication [9]. Also, It can be transmitted as data the intensity of light measured by illuminance sensor, and the result of ON /OFF about servo motor.

We used the Unity3D engine to implement the authoring tool. Unity3D is an official development tool for developing Hololens application. In addition, we used the Mixed Reality Toolkit plug-in, an unofficial Hololens development library, to easily develop various functions of the Hololens [8]. We used PTC Vuforia SDK as an augmented reality plugin. The Hololens can recognize the real space, but cannot find the position information of individual real objects. Therefore, Image Marker function is used to recognize the location of real objects in real time (Fig. 5).

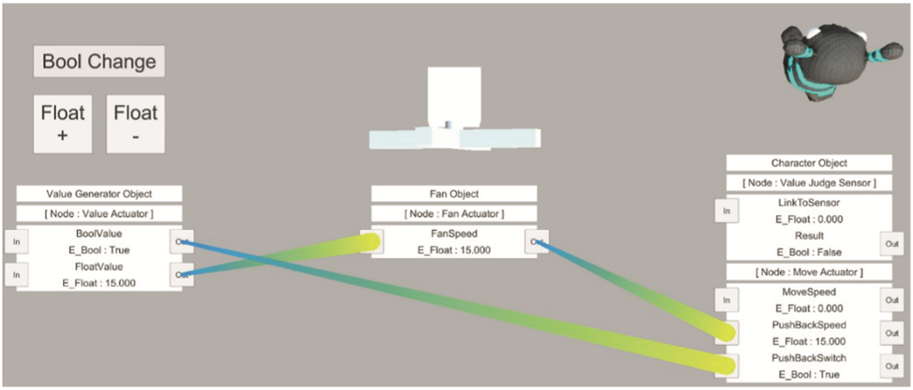

Fig. 5. User interface of authoring tool

A UI showing status information is displayed at the bottom of each object and updated in real time. It is categorized into information about object name, node, and field, and there are in-port and out-port buttons on both sides of the field. You can select the out-port button and then the In port button to link the two fields to transmit data. In order to check the link information of the field, two linked fields are connected by a line. If you select the in-port button of the linked field, you can unlink the field.

We implemented the network functions to exchange data between Arduino and Hololens. For Arduino, SimpleWebServerWiFi example which is provided as default is modified and used. For Holelens, Windows 10-based UWP apps use compatible asynchronous APIs and can send or receive strings to a linked server (Fig. 6).

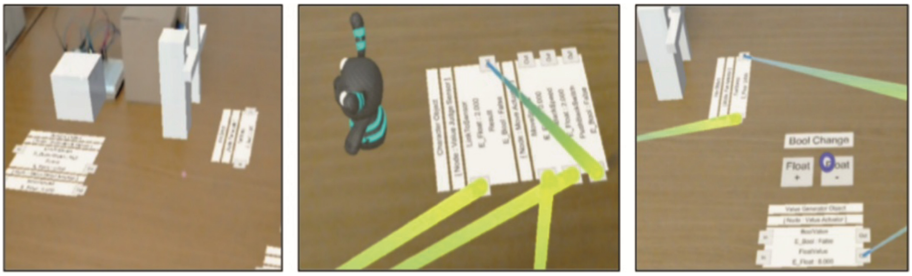

Fig. 6. Screenshot of authoring tool running on Hololens

An Arduino object is used as a real object of the authoring tool, a character object, a value generator object, a virtual fan object, and a car object are used as virtual objects. The interaction between the fields of each object is constructed, and the state information is updated in real time, and it is confirmed that the real object and the virtual object interact with each other. We have constructed various interactions, such as a virtual fan object that changes the speed of the fan according to the amount of light received through the illuminance sensor of the Arduino object, a character object whose forward /reverse state changes according to the ON /OFF state of the servo motor of the Arduino object, servo motor of Arduino object whose ON /OFF state changes according to speed of car object, etc.

5 Conclusion & Future Work

In this paper, we propose a mixed reality system that combines matching of interaction to improve the limitation of existing mixed reality contents that there is little interaction between real objects and virtual objects. Then, to verify this, we implemented a authoring tool based on Hololens. As a result, we confirmed that the interaction between the dynamic real objects and the virtual objects can be directly configured and interacted with each other through the implemented authoring tool.

However, in this study, since only one Arduino object was used as a dynamic real object, it was difficult to confirm the interaction with a larger number of real objects. Further research using more IoT devices is required. Also, it is necessary to apply the proposed mixed reality system to contents such as game or guidance system where interaction between objects is more active.

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ExProtoVAR: A Lightweight Tool for Experience-Focused Prototyping of Augmented Reality Applications Using Virtual Reality

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Abstract. The exciting thing about augmented reality (AR) as an emerging technology is that there is not yet a common design language, nor a set of standard functionalities or patterns. Users and designers do not have much experience with AR interfaces. When designing AR projects for customers, this is a huge challenge. It is our conviction that prototypes play a crucial role in the design process of AR experiences by capturing the key interactions of AR and delivering early user experiences situated in the relevant context. With *ExProtoVAR*, we present a lightweight tool to create interactive virtual prototypes of AR applications.

Keywords: Prototyping · Design · Augmented reality · Panorama 360°

1 Introduction

With the advent of more powerful mobile computing power, AR has received increasing attention in industry and in the consumer market. New platforms and new devices create an expanding design space of AR systems [3].

While others have used AR to support general user centered design processes [4,14], we are using virtual reality (VR) to support the user centered design of AR applications specifically. DART [9], as an early approach for AR prototyping, was very successful at its time, providing a toolchain enabling designers to create working prototypes as a result. This, however, brought about a stronger focus on the technology side in the design process, restricting the designer to what was possible with the technologies provided with DART. With ExProtoVAR (**Exp**erience **Proto**types in **V**R for **AR** applications) we want to abstract

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away from specific hardware solutions and software implementations and focus on the design of the user interaction with the AR system and the experience of the users.

Important aspects, that have to be considered when designing for AR are: (1) the context (spatially) of the situation, (2) the dynamics of the situation (temporally), (3) the user's whole body in the loop, and (4) the features of the AR device. While (1) and (2) depend on the application scenario, (3) depends on the user, the task and her experience with AR. The choice of the AR device (4) may be part of the design or fixed, however it will always influence (3).

The situational aspects (1+2) will often be very specific, e.g. when designing for AR maintenance of a certain machine, and they might cover several locations and states (representing task progress). During design and prototyping, it is thus essential for the designers to have a realistic representation to work with. The choice of the AR device (4) will, at least in industrial settings, depend on the interaction between 1, 2 and 3 to achieve a certain performance goal.

We try to address these challenges with ExProtoVAR: a lightweight tool to create interactive virtual prototypes of AR applications. The central idea is to cover situations (1+2) using sequences of 360° panoramas. In contrast to other tools, ExProtoVAR is primarily used in VR, giving the designer an immersive editor at hand, with which virtual tours and state transitions can easily be defined in close interaction with the users. Areas of interest can be defined and sketches or HTML prototypes of AR content can be integrated to design the AR application. Different presentation modes, such as in-view (attached to the screen) and in-situ (attached to the environment), can be defined (see Fig. 3). Different AR devices (iPhone, Samsung Tablet, Google Glass, Microsoft HoloLens) are simulated (4) to support an informed choice. In evaluation mode, users can immerse into the prototype, try it out and use audio and text annotations to comment on certain features.

2 Related Work

The topic of AR is only scarcely addressed by the design community (e.g. [6]) and little to none design patterns and principles addressing AR applications exist. This makes it even more important to support the early phases of prototyping, as designers and users can only rely on minimal shared experiences.

The idea to use panoramic images or videos for prototyping AR has been introduced before (e.g. [2]). Others have used 3D simulations in immersive virtual reality [1] with expensive hardware for AR prototyping. In a sense, we are using VR to simulate AR. This is a quite successful approach applied by the AR community to explore designs for AR hardware and basic mechanisms (e.g. displays) [7,8,11,12,15,16].

ExProtoVAR concentrates on holistic AR experiences produced with a low technical barrier and low developmental costs. Regarding the distinction between low-fidelity and high-fidelity prototypes (see e.g. [13] in the mobile context), our work ranges in the medium-fidelity range. One way it extends upon

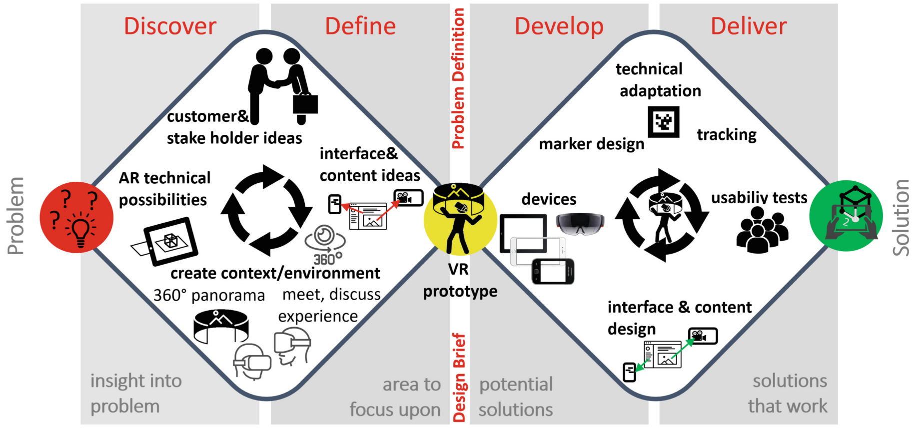

Fig. 1. The double diamond model for prototyping processes adapted to the design of AR solutions supported by ExProtoVAR.

PARnorama [2] is, that it immerses the user into the situation rather than showing only a snippet of the situation on the screen of the AR device.

3 Motivation and Approach

To build prototypes for AR applications a tool is needed to support users, designers and developers in different steps of a prototyping cycle. In the ProFI project [10], we orient ourselves on the *double diamond model* [5]. This model divides the design processes into four distinct phases called *Discover*, *Define*, *Develop* and *Deliver*. The prototyping process for AR can be seen as a special case leading to several challenges on the way to a product (see Fig. 1).

Discover. In the first phase, designers try to look at the world in a fresh way, notice new things and gather insights. Here it is important to make customers acquainted with the possibilities of AR. The first phase is characterized by a creative divergent thinking and a tool is needed to make AR concepts come alive, providing broad ideas on what could be possible. As AR is very dependent on the situation, access to the environment the application is planned for, is crucial. A tool is required to meet and immerse into the environment and discuss possible augmentation ideas.

Define. In the second phase, designers need to determine the best and feasible approaches identified in the discover phase. The goal here is to develop a clear creative brief that frames the fundamental design challenge. To this end, a tool can be of great benefit which enables the designer to create an interactive prototype in an easy way and within a short period of time. The prototype of this phase can function to convey the central ideas to the designers in the next phase and can be seen as a representation of the convergent thinking process of this phase.

Develop. Several prototypes are created, tested and iterated in the develop phase, targeting at a concrete prototype. This process of trial and error helps designers of the user interface and the AR markers to improve and refine their ideas. Additionally, technical adaptations and solutions need to be developed and tested as well as usability tests need to be performed. As different people are working an different aspects e.g. designers on interface design and technicians on which device to use, these aspects always need to be integrated in one prototype, so that side effects can be accounted for. A shared tool is needed which is able to integrate the different prototypes and ideas.

Deliver. In the last phase, the resulting project (a product, service or environment) is finalized, produced and launched. A prototype with notes and additional explanations can help to serve as benchmark for the solution offering a tool representing the different ideas and stages of the prototype process.

4 ExProtoVAR

With ExProtoVAR, we present a lightweight tool to create interactive virtual prototypes of AR applications. The central idea is to cover context situations using 360° panoramas. This serves two purposes; on the one hand, it helps the user to immerse in the situation the application is developed for and thus gets a feeling for using the application in the relevant context. On the other hand, the environment can be used to identify the areas later used as AR markers. Consumer panorama cameras are sufficient, small and easy to use. We wanted to create a tool with which a situation can be modeled in less than an hour and with which it is easy to deal with several alternative images. Also, the VR environment simulating the AR scenario is not supposed to be too complex, as its purpose is to serve as an early prototype. Figure 2 displays the interface and two examples of content being displayed during an ExProtoVAR session.

The main part of prototyping happens immersed in VR. Only sketches which are to be used as AR content have to be created in a traditional 2D way. The designer can easily structure the experience by putting panorama pictures and AR content (e.g. images, HTML pages) in folders on the smartphone. To create the VR experience, the designer puts on the VR headset (Samsung GearVR, see Fig. 2) and uses the controller to define the logical, temporal and spatial aspects of the situation by use of *situation-links*. She then marks areas in the panoramas and links them to the prepared AR content (we call this event-links). Here, she can decide whether to present the content in-view or in-situ (see Fig. 3). For the latter, the anchoring of the content in the environment can be defined as well.

Integrating Devices. Different simulated devices can be used to experience the AR content, e.g. a Samsung Galaxy phone, an Apple iPad, an Apple iPhone, a Google Glass or a Microsoft HoloLens. They are simulated with respect to their size, resolution and display type. Handheld devices are used in the virtual scene by moving the controller, glasses automatically follow the user's head movements. By this ends, the user is able to look around while scanning the environment for augmentations and develop a feeling for the behavior of the different devices.

Fig. 2. Example shots taken from within an immersive session in ExProtoVAR. TL: Samsung GearVR headset and controller; TR: Main menu of ExProtoVAR; LL: Samsung Gear 360 panorama camera; LC: In-situ information in a museum. LR: In-view presentation of product information in the supermarket.

Defining Device Interactions. ExProtoVAR supports not only a basic scanning for AR content, but also the modeling of interactive screens. For this, the device can be brought up closer to the user by the press of a button. The device is then filling almost all of the screen and detached from hand movements. The controller now instead operates a virtual cursor which can be used to simulate touch events on the AR device's screen. If the AR content is an interactive HTML page, e.g. a click dummy, HTML events can be triggered as usual and the content will interactively change. A fake "situation" protocol (scene://) is used to allow the HTML content to trigger situation transitions to new panoramas, e.g. to simulate actions that control a machine and evoke new states.

Annotations. After a prototype has been created with the ExProtoVAR tool, it can be reviewed by users. To enable the user to provide context specific feedback, it is possible to mark areas in the prototype and leave notes and audio notes. The notes will be displayed exactly in the chosen situation at the marked position and can be edited or complemented in subsequent sessions. This supports the feedback cycle and eases the communication about context dependent issues.

Videotaping an Interaction. An additional feature to provide a compressed version of a prototype consists of videotaping an interaction covering all relevant interactions with the AR application in the virtual world. This can then serve as a basis for the developmental phase or can be used to present the prototype to several people at once not using the VR equipment.

Fig. 3. Different visualizations of in-situ (left) and in-view (right) content.

5 Example and Evaluation.

ExProtoVAR itself has been subject to iterative prototyping in a user centered design manner and insights have been gained by 8 expert interviews in review sessions. *Personas* have been designed and example design tasks to decide upon were given to the experts. The experts agreed that ExProtoVAR immersed them into the applications environment and made them feel involved. This helped them to identify with the decision process. In the future, ExProtoVAR will be used in customer projects for further evaluation.

Figure 4 shows an example of the design phase of a customer looking for new ideas to convey information in her museum (1). After contacting the AR company (2), the customer is presented with impressions of AR technology. She gets to see a collection of relevant prototypes with the ExProtoVAR tool to demonstrate the potentials of using AR (3). As a preparation for the first prototype, panorama pictures of the museums exhibition rooms are taken (4) and used to create an individual panorama prototype (5). This prototype serves as a basis for designers and developers to prototype an application fulfilling the requirements and desires of the customer (6). To this end, different interface and content designs are prototyped to convey the information in the best possible way. To raise funds for the museums AR application, the customer presents a video of the prototype to the city council (7). As a last step, the application is subject to refinement processes before being released (8).

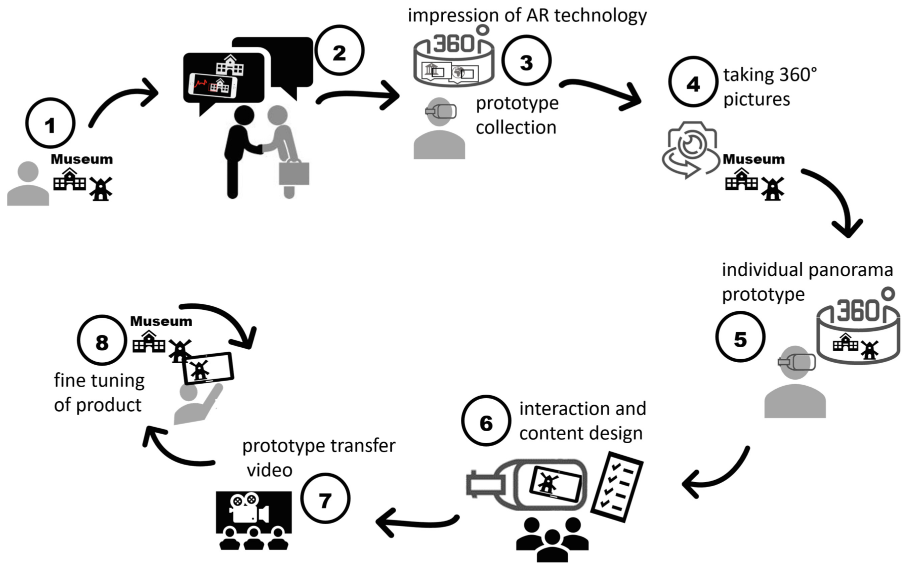

Fig. 4. Using ExProtoVAR to prototype an AR exhibition guide for a museum

6 Conclusion and Future Work

Designing contextualized (AR) applications requires a careful consideration of the situation. We have presented ExProtoVAR, which combines VR and panorama imaging technologies to immerse designers and users in the situation while defining and evaluating different interaction designs. Simulations of AR devices and different visualization styles allow for a functional evaluation, while the immersion supports an emotional evaluation at the same time.

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AR-Based Mobile Applications for Exposure Therapy

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Abstract. Facing one's fears could be a way forward for people whose anxieties debilitate them. Exposure-based treatment is an evidence-based approach to reducing pathological anxiety. As a part of treatment, therapists who practice exposure therapy create environments to provide opportunities for patients to experience (and ultimately, overcome) the anxiety that arises for patients in feared situations. More than 50% of anxiety patients, however, never receive treatment. We developed an Android application that uses augmented reality (AR) for providing opportunities for exposure to spiders, a relatively common presentation of specific phobia. With this app, users can engage with exposure therapy without visits to a therapist. In the next phase, we will conduct a user study to determine whether mobile applications equipped with augmented reality technologies can be used to reduce the anxiety response to a feared stimulus (i.e., a tarantula), and whether the app is considered easy to use and acceptable. In this poster, we will provide details about the mobile app and describe the study setup.

Keywords: Mobile · Augmented reality · Spider · Anxiety
Exposure therapy

1 Introduction

People are often surprised to learn that approximately 1 in 4 people will experience an anxiety disorder at some point in their life [1]. Although these conditions are debilitating, more than 50% of people with an anxiety disorder will not receive any treatment during their lifetime [2,3]. Although clinical science has spent the past 30 years developing and refining effective psychotherapies, the overwhelming majority of people experiencing anxiety disorders will not access these treatments, highlighting the importance of developing interventions that are accessible.

Clinical research has established that cognitive behavioral therapies (CBT) effectively reduce symptoms of anxiety disorders, in many cases to non-clinical status [4]. A core component of CBT in the treatment of anxiety disorders is exposure, or systematically facing feared situations or stimuli [5]. As such,

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this treatment involves routinely conducting planned exposures to increasingly anxiety-provoking stimuli or situations to provide patients an opportunity to recognize that their symptoms of anxiety habituate over time and gain a sense of mastery over these feared situations or stimuli. For example, an initial exposure exercise for a patient with significant anxiety about social interactions may involve asking a cashier at a store check-out how their day is going, whereas an exposure much later in treatment may involve presenting a speech to an audience. However, exposure therapy treatments have several challenges. One, therapists need to locate the appropriate stimuli or create a situation that triggers anxiety for the patient. When patients fear stimuli that are either difficult to locate or recreate (e.g., rare insects or flying on airplane, respectively), generating effective exposure situations can be particularly challenging. Two, creating exposure situations of graduated intensity is a particularly important challenge given participants may choose not to engage with the stimuli or participate in the situation due to fear [6]. Encouragingly, virtual reality (VR) based techniques offer enormous potential value to the work of exposure therapists since virtual reality allows patients to engage with a variety of potential feared stimuli gradually. In this way, VR technology provides an important capacity for clinicians to tailor treatment to target both the nature and the intensity of a patient's fear [7].

Suppose we could provide people with a way to experience these environments and allow them to track the way they engage with the environments when they are at their homes. Immersive technologies such as virtual and augmented reality allow people to experience situations as if they were physically in them, and although there has been initial work testing the efficacy of these approaches in the lab and in the context of clinician-supported psychotherapy, there is little work addressing the potential for these approaches to be effective independent of a structured clinical environment. The latest smartphones support augmented reality (AR) technology and make it possible for users to experience immersive technologies outside of a clinician's office.

The goal of our research is to conduct an initial test of the acceptability and efficacy of a mobile application that provides opportunities to engage with a feared stimulus in an augmented reality environment without the guidance of a therapist. In this paper, we present the design and implementation of the app.

2 Related Work

Immersive Technologies for Exposure Therapy. Prior research has shown great promise when using immersive technologies for treating anxiety. Previous work demonstrates that virtual reality can elicit distress when interacting with virtual spiders [8,9], with public speaking in front of a virtual crowd [10] and when standing on a plank[11]. Researchers also demonstrated that a VR-based one-session therapy (OST) for spider phobia is not inferior when compared to a traditional OST [12,13]. However, this previous work has relied on virtual reality, in which patients immerse themselves in virtual environments rather than scenarios in which patients interact with a feared stimuli or participated in the feared situation in their current environment but they immersed themselves in a virtual environment. For example, in VR exposure therapy studies on arachnophobia, users wore a headset to observe virtual spiders in virtual rooms [8,9]. In another exposure therapy study, participants used a TPAD phone that gave haptic feedback when they touched a spider on the phone screen [14].

In more recent studies, researchers developed interfaces that allowed patients to interact with stimuli in their current environment. A system called the therapeutic lamp allowed for face-to-face therapy involving direct confrontation and interaction with a virtual animal in a real environment, but with a therapist present [15]. In a similar study, researchers developed a system where participants could pick up everyday objects with virtual cockroaches on them [16]. Researchers also developed an interface to help therapists monitor and control the virtual spiders during a session [17]. Ben-Moussa et al. proposed the design of Djinni, a system based on wearable glasses, to help patients with social anxiety disorder to give them feedback in stressful situations in their real life; although the researchers have not yet evaluated a study to determine the acceptance of this system [18]. Our app, similar to Djinni, is designed for use without the presence of a therapist or researcher.

Mobile Apps for Anxiety Disorder. Given the growing demand for mobile apps and the rapid adoption and popularity of mobile health, there are a large number of mobile health apps available on online app distribution platforms; research showed an estimate of over 200,000 mobile health apps in 2017, which is predicted to grow up to over 600,000 by 2025 [19]. Out of these apps, the American Psychiatric Association estimates that there are around 10,000 anxiety and depression related downloadable self-help apps. Unfortunately very few of these have undergone rigorous evaluation to test their efficacy and study their outcomes. Dekker et al. discovered 20 mobile apps that were designed as games to engage user while treating their anxiety and/or depression [20]. There is initial work implementing an AR mobile app in which AR was used for one patient as a way to reduce her fear and anxiety before a VR exposure therapy session [21]; in this case, however, the mobile app was a game involving virtual spiders to help ease the patient's anxiety before the exposure therapy session with a therapist. In a recent study, participants used an AR app similar to ours to interact with virtual spiders for an entire month, but this study was also conducted in a lab setting in the presence of a researcher [22]. In our study, participants will use the mobile app to interact with virtual spiders on their own, so that we can determine whether it is acceptable for use by patients who cannot get to formal treatment or in the context of clinician-supported psychotherapy.

3 App Design

Our mobile app allows users to view and interact with virtual spiders that are projected on to the user's environment using augmented reality (AR). As shown in Fig. 1 below, the spider is projected on to the printout of an image provided with the application; in this case, an image of rocks. The image is placed in front of the user and the spider appears on the image when the image is in the view of the phone's back camera.

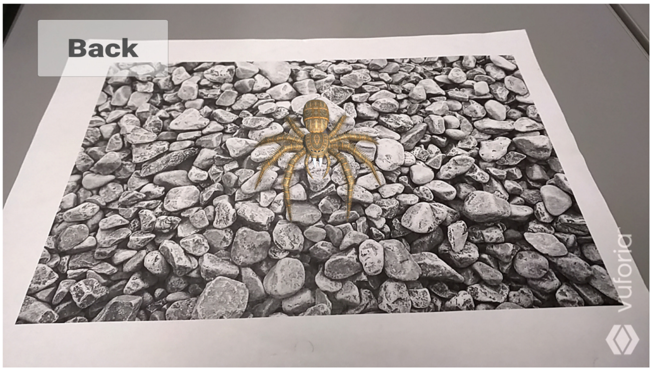

Fig. 1. Screenshot of the spider on the mobile app prototype

The user can interact with virtual spiders in seven different scenarios on the app. In the first scenario, the spider is stationary, but of moderate size. Since it is stationary, it does not respond to any user interaction. In the second scenario, the spider is much larger in size but remains stationary. There are two moderately-sized stationary spiders in the third scenario. In the fourth scenario, the spider "attacks" by jumping towards the user when the user places their hand below or on the virtual spider. In the next scenario, the virtual spider's gaze follows the users as they move the phone around the image; the spider also attacks or jumps towards the users if they move the phone closer to the image. In the next scenario, the spider turns towards the user, walks towards the user and crawls up their hand; once the spider goes off the screen, it turns around and walks back towards its original position and repeats. In the final scenario, there are multiple spiders and most of them are stationary; a random spider attacks when the user brings the phone closer to the spiders.

The scenarios were chosen to present graduated exposure scenarios consistent with evidence-based practices for exposure therapy. The application gives them feedback to keep the patients engaged in the app and try something they have not done before. The application also keeps track of the user's progress, such as the time the user spent on each scenario, the distance between the phone and the virtual spider as well as the time the user spent interacting with the spider. The application also uses gamification to encourage the patient to beat their "best" interaction, by listing the most time they interacted with spiders and spent on different scenarios, as well as the closest they brought their phone to the virtual spider.

4 App Implementation

The application prototype was developed using Unity3D and Vuforia and tested on a Nexus 6 phone. Unity3D is a game engine used to create video games with built-in features for 3D object creation and user interfaces. Vuforia is an augmented reality (AR) software development kit (SDK) that supports AR on mobile devices [23]. Vuforia utilizes a database of images, chosen by the developer, along with computer vision to recognize these images, for e.g., the picture of the rocks. The images are tracked using the camera from a mobile device and virtual objects, for e.g., the spiders, are then rendered on the images in such a way that the virtual objects appear to be part of the real world scene, viewable on the screen of the mobile device. Vuforia is supported by Unity3D, and so the virtual objects to be rendered correspond to the scenarios designed in Unity3D. We also developed C# scripts using MonoDevelop IDE to add interactivity to the virtual objects rendered by the Vuforia software and to monitor the user's interaction with the virtual objects.

5 Study Design

We will use our mobile application in a user study with participants who scored in the top 50% of the distribution on the Fear of Spiders Questionnaire (FSQ) [24]. The user study will have three phases: in the first phase, participants will have their fear of spiders assessed using the FSQ and a Behavior Avoidance Test (BAT) [25]. In the second phase, participants will use the mobile application on their own. In the final phase, their fear of spiders will be re-assessed using the FSQ and BAT, followed by an open-ended interview describing their experience using our mobile application. With this study, we expect to determine the ease of use and acceptability of our application as well as determine whether it can indeed reduce the participants' anxiety response to spiders.

6 Summary

The recommended first-line treatment for anxiety disorders is exposure-based psychotherapy. We developed an Android application that uses augmented reality (AR) for providing exposure therapy, so users without formal access to psychotherapy can benefit from it. Next, using the app, we plan to conduct a user study to determine whether mobile applications equipped with augmented reality technologies can be used to reduce the anxiety response to a feared stimulus without the guidance of a therapist, and whether the app easy to use and acceptable.

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Development of Concussion Evaluation Tools Using Life-Like Virtual Reality Environments

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Abstract. Concussions are a common type of traumatic brain injury that can have severe consequences. They are often induced by sports injuries, car accidents, and even falls. The high acceleration in these situations exert rotational forces on the brain that result in biomechanical injury and a malfunctioning metabolism. We propose a method to diagnose and check the progression of a concussion using virtual reality (VR) in conjunction with electromyography (EMG) and centre of mass (CoM) trajectory. The study will primarily focus on concussions sustained by varsity hockey players, with the hopes of expanding to athletes of other sports in the future.

Keywords: Virtual reality · HMD · EMG · Concussion

1 Introduction

Concussions occur frequently among athletes [2], with increased recurrency in contact sports such as ice-hockey, for which concussions can occur without the loss of consciousness [11]. The resulting symptoms of concussions include headaches, nausea, confusion, memory loss and fatigue [12]. Despite the alleviation of these symptoms, it is still not safe to assume that athletes should return to their active lifestyles. Beyond the aforementioned general symptoms, concussions impact the visual-auditory systems [6], impede information processing [3], and affect gait stability [14]. These latter symptoms are the focus of this paper.

Participants will be immersed into a life-like hockey environment using virtual reality. Furthermore, their leg muscle movements will be measured using an EMG measurement system. Additionally, the motion of their centre of mass will be measured using motion capture technology. Virtual reality based neuropsychological testing has been shown to have a high ecological validity and so is more applicable to real life settings [13]. This enables us to create an environment in which the hockey players are exposed to familiar and realistic conditions. To do this, a 360-degree camera and ambisonic microphone are used to record real life hockey scenarios in a hockey rink, where players simulate intercepting passes as well as attempting to check the virtual player. These recordings

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are then inserted into a virtual world to perfectly recreate the desired situation with accurate 360-degree video and audio. It is important to include ambisonic recordings to recreate 360-degree audio, as this helps immerse the participant into the scenario and creates a more ecological experience. While participants are partaking in the virtual experience, the EMG recordings are used to measure how their muscles react to the different scenarios presented. Additionally, motion capture, via infrared cameras and markers, are used to track the centre of mass of the participant. This allows for the analysis of imbalance during gait, which is known to be an issue among concussed patients. Signal processing and statistical methods are then utilized to help analyse the data for statistical significance. The end goal is to be able to use this data to identify a quantitative marker for diagnosing patients with concussions and tracking their progress.

This paper is organized as follows: Sect. 2 presents the background research undertaken in preparation for this paper, Sect. 3 discusses methodology, Sect. 4 presents current results along with the analyses and discussion, and finally, Sect. 5 concludes the paper and presents future work aimed at tackling the limitations of the current research.

2 Background

Several concussion assessment tools have been developed in the past to aid in clinical evaluation of concussions. The Sport Concussion Assessment Tool (SCAT) survey is an example of such a tool, and has been incorporated in this experiment to aid the researches in analysis. However, SCAT scores have been found to vary with age and sex, the significance of which is not known. Similar surveys, such as the Military Acute Concussion Evaluation (MACE), also display the same limitations in that the diagnosis of non-extreme concussions is unreliable [10].

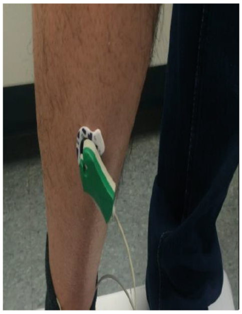
Neurocognitive tests, such as the Automated Neuropsychological Assessment Metrics (ANAM), have also been developed to measure cognitive parameters such as attention, concentration, and reaction time [4]. Further investigation, however, has questioned whether the ANAM test is accurate in long-term assessments of patients [5].

The current paper is interested in identifying all anthropometric variables that could affect the results, as well as identifying the validity of the process for long-term testing.

3 Methodology

The methodology undertaken throughout the experiment is divided primarily into four subsections. The first deals with participant selection and exclusion criteria, along with collected anthropometric data. The second discusses the materials and instruments used throughout the experiment. The third outlines the procedures and protocols. Finally, the fourth discusses data processing techniques. For each participant, six surface EMG (sEMG) electrodes, placed on the lower body, are used to collect data from several leg muscles throughout the experiment. This paper will only discuss the response of the rectus femoris muscle for the sake of brevity and accuracy, as larger muscles are subject to less crosstalk contamination [1,9].

Figure 1 demonstrates the standard setup for the Oculus Rift headset and the EMG placement. Figure 1a shows the placement of one of the sEMG electrodes on the tibilias anterior. Figure 1b demonstrates the Oculus Rift and IR marker placement as positioned on a participant.



(a) EMG placement on the tibialis anterior

(b) Oculus VR setup with 3 head-mounted IR markers

Fig. 1. Experimental setup sample

3.1 Participants

The inclusion criteria for the sample pool was limited to adult amateur hockey players in the Kitchener/Waterloo region in Ontario, Canada. This will allow the experimenters to follow up with the participants in order to monitor their recovery should they suffer a concussion.

3.2 Instrumentation

An Oculus Rift head-mounted display, with 3 IR markers placed on the back, is worn by the participant, as shown in Fig. 1b. The VR headset displays video recordings of 24 different hockey scenarios on an ice rink captured by a Samsung Gear 360 camera. Eight sEMG electrodes are placed on the lower body to capture muscle activity during dynamic movement. A velcro fastener is used to attach 3 more IR markers around the participant's lower back.

3.3 Procedures

Upon entering the lab, the participants are asked to fill out two questionnaires detailing current nausea and dizziness levels, as well as information regarding their concussion history. The first questionnaire is the Sport Concussion Assessment Tool (SCAT) and the second is the Acute Concussion Evaluation (ACE) [10]. Once completed, the participants are asked to change into loose fitting clothing, to allow for ease of movement during data collection. In order to ensure integrity in EMG measurements, the participants are asked to shave hair off all the points where the EMG electrodes are to be placed. The participants are then instructed to wear their skates and a short hockey stick is given to the participants to assist in the immersiveness of the VR environment. The Oculus VR headset is then placed on the participant's head, along with six IR markers divided equally between the participant's head and back. Five Optitrack cameras are placed in the room to constantly capture the movements of the IR markers. This allows for the tracking of the participants COM trajectory. An example scene, in which several players pass a puck in an ice rink, is then shown to the participants. The participants are told to become accustomed to their surroundings and to behave as if they were on a normal ice rink. Once the participants become familiar with the environment, 24 scenes are shown in succession. The scenes involve the puck being passed towards the participant, with several skaters constantly in motion, and with only one skater charging towards the participant with imminent contact. Data is recorded when each scene starts. When the scene ends, the participants are reoriented to their starting default position and the next scene ensues. It should be noted that before the scene is played, the participants are given enough time to become acquainted with the current scenario. Once the participants make known that they are ready, the scene is played. This procedure is repeated for every scene.

3.4 Data Processing

The EMG signals are low-pass filtered at 500 Hz, sampled at 2 kHz and are then imported into MATLAB. A bandpass filter is further implemented in MATLAB to attenuate frequencies below 20 Hz and above 500 Hz [7]. This helps with eliminating high frequency noise and removing low frequency tones generated by the scenario trigger signal that interferes with the EMG signals. Due to the sharp changes in the EMG waveforms, wavelet transforms are utilized for curve smoothing and de-noising, also using MATLAB. Wavelet transforms also posses the ability to demonstrate data both quantitatively and qualitatively, making them ideal for data analysis in an understandable format. Both the raw signal and the filtered signal can be seen in Fig. 2.

4 Results

The graphs shown below represent the EMG data collected from the rectus femoris for a single non-concussed participant. This muscle is ideal for presentation since it is large enough to minimize the error due to crosstalk between muscles and to provide a reasonably large signal, that's visually distinguishable from noise. Figure 2 shows the raw EMG data collected from the rectus femoris,

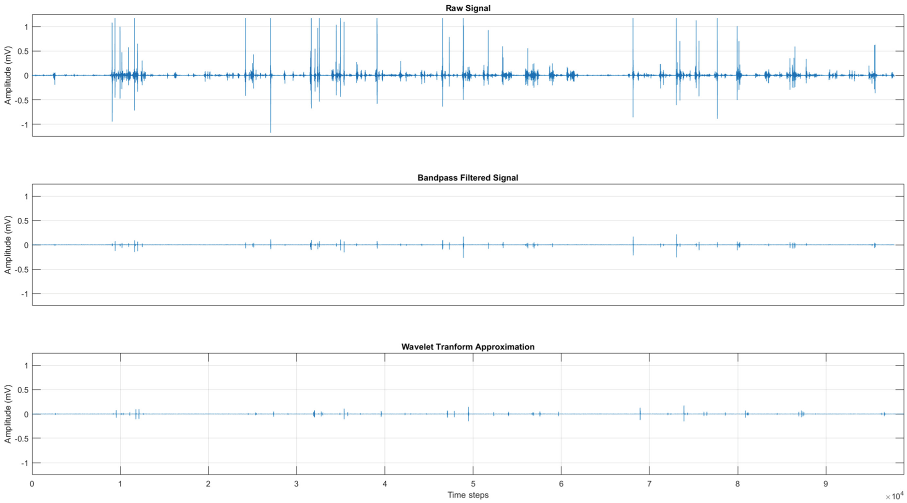


Fig. 2. Raw signal, bandpass filtered signal, and wavelet approximation shown respectively for the rectus femoris collected from a single participant

followed by a sub-plot of the same signal after being band-passed, and in the final sub-plot, after having applied a wavelet transform.

Figure 3 demonstrates the time-frequency analysis using continuous wavelet transforms of the rectus femoris. Unlike Fourier transforms, the time-frequency analysis with wavelet transforms is well localized in both time and frequency. A brief 6 second time window is displayed for the sake of brevity; however, it is apparent that the predominant frequencies occur at approximately 50 Hz with the highest intensity between 19.70 and 19.71 min. This corresponds to high intensity dynamic movement in anticipation of contact. In contrast, between 19.73 and 19.74 min, a much smaller amplitude and lower frequency response appears, which can be attributed to muscle relaxation post contact. Frequency analysis provides an initial step in validating the model since we can compare these values against previous validated EMG recordings of muscles. Time analysis provides information regarding reaction time, where the reaction time would be subtracted from the time trigger when each scenario began.

4.1 Analysis and Discussion

No definite claims can be made regarding the EMG patterns generated by concussed and non-concussed participants until data from concussed participants is collected. The participants are monitored throughout the hockey season by their coaches, and if a concussion were to arise, the players would return to undergo the experimental procedure. This paper outlines the preliminary techniques used for signal processing and analysis. The primary goal of the preliminary experiment and methodology is to verify the use of EMG data in the case of dynamic movement, to validate EMG results in the frequency domain, and to establish a dataset for non-concussed participants.

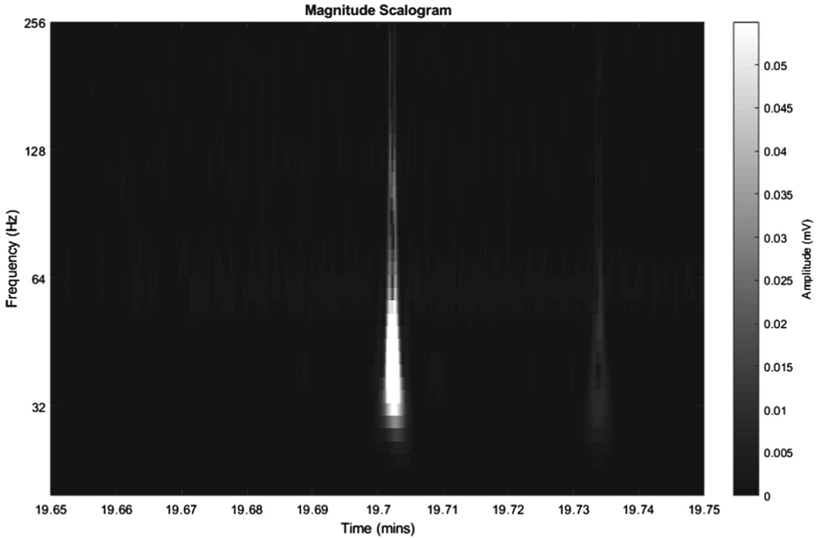


Fig. 3. Rectus femoris scalogram time sample

5 Conclusion

The outlined procedure is still in its genesis and verification and validation are of the utmost importance to ensure integrity of results. Validation will be done when comparing extreme cases of concussion with the qualitative assessments of doctors and physicians. The participants will then be monitored throughout their recovery. As the decrease in concussion symptoms become noticeable, a decrease in response time should ensue. This is a longitudinal study, and will therefore require time before the work can be verified and validated. However, it should be noted that the use of wavelet transformation in the field of biomedical imaging has promising potential, in that it can provide both qualitative and quantitative information.

5.1 Future Work

Future work aims to improve minor faults in the current procedure. A trigger signal is used to mark the beginning and end of each scenario. However, this signal interferes with the EMG responses, and while the noise developed due to the interference was filtered out, a hardware solution is needed. The cables extending from the electrodes to the central EMG hub are not sufficiently long, there have been several incidences where the electrodes have peeled off the participant resulting in data jitter.

For further future steps, it is of immense importance to recruit concussed participants in order to conduct some preliminary tests to quantify any correlation between EMG measurements and concussion symptoms during immersive dynamic activity. Integration of clustering algorithms for pattern recognition is a key future step in identifying differences between response times. This process will involve a trial and error approach, however, applying principal component analysis (PCA) followed by K-means clustering as described by Ding will be used as a starting point [8]. Furthermore, data from the Optitrack system will also be incorporated to provide insight into gait and motion stability. This will help identify the play style of participants, and whether they tend to embrace or evade impact. Artificial ice will be utilized to mimic the behaviour of a real ice surface to make the experience more immersive for participants.

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Vestibular Display for Walking Sensation in a Virtual Space

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Abstract. This paper describes characteristics of walking sensation created by a vestibular display (a motion seat). An active input was introduced to a passive presentation of a walking stimulus. The participant triggered one step motion repeatedly by a game-controller button to introduce agency of motion. First, the magnitude of the seat motion was optimized to increase the walking sensation. Then, passive and partially active seat motion was evaluated. As a result, it was shown that added activity increased the walking sensation .

Keywords: Vestibular stimulation · Motion seat · Active input Walking sensation

1 Introduction

Locomotion is one of the important functions of experience in a virtual space [1]. The display for the bodily sensation of locomotion in a virtual space has been studied mostly in the form that the user moves his/her body in the real space. The display cancels the user's physical movement in the real space typically by treadmill [2]. Otherwise, the real walk motion was modified to keep the user within a limited area as walk-in-place [1] and redirect walking [3]. The present study proposes a different approach in that the user does not walk in the real space, but sits on a seat and receives the sensation of walking from a multisensory display. It creates the sensation of virtual body motion as well as the environmental reality. It is designed to have the user relive the other person's walking [4] and feel the sensation that was received by the person. Reliving here means to project someone's bodily experience to oneself. This is useful for skill transfer or bodily learning as well as entertainment such as a sightseeing tour.

Although a steady walk is almost automatically repeated motion without conscious control, adjustment of motion is performed consciously following to the environment as well as motion error [5, 6]. The real walk is an active motion in that sense, however it is not a completely conscious-controlled motion as being observed passive. Therefore, it is considered that walking in a virtual space should be both active and passive as the real walk.

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In this paper, we discuss the effect of introduction of an active control within a passive reception of a walking stimulus. The vestibular display (Fig. 1) was developed originally to stimulate the user's body passively (as watching a movie) to have he/she feel like walking. We added a game-controller button that input a trigger one step motion at a time to give the sensation of agency on the walking motion. The participant evaluated nine factors of walking sensation as well as the sensation of agency (activity) and the sensation of walking evoked by passive and partially active motion of the vestibular display.

Fig. 1. A vestibular display (motion seat) of three degrees of freedom (lift, roll, pitch motion)

2 Optimization of Motion Stimulus

2.1 Objective

The optimum amount of motion of the seat to produce the sensation of walk was measured when the participant controlled the start timing of the seat motion.

2.2 Participants and Optimization Procedure

The participants of the measurement were ten undergraduate and graduate students at the average age of 23.1 years.

They walked a flat floor for more than 20 m at a 1.4 s walk period (0.7 s each step), and remembered the sensations of the body motion of lifting, pitch and roll rotations during the walk. Then they sat on the motion seat and adjusted the amplitude of the 3-dof motion (lift, pitch, roll rotation) and velocity to produce the optimal sensation of walk using game-controller buttons, with closed eyes and noise emitting earphones.

The motion of the seat at around 1.4 s period was activated by the participant who pushed the buttons periodically. The period depended on the participant's memory. The seat motion was either ipsilateral or contralateral. The ipsilateral motion means that the same side (e.g. right side) of the seat as the pushed button (right) lifted to make a roll motion. The contralateral motion means that the opposite side was lifted.

2.3 Result of Motion Optimization

The optimal motion for the ipsilateral input was 1.28 mm lift, 0.15° roll rotation, and 0.183° pitch rotation with a lift speed of 6.5 mm/s rise and 6.29 mm/s fall. Those for the contralateral input was 1.32 mm lift, 0.155° roll rotation, 0.146° pitch rotation with a lift speed of 6.63 mm/s rise and 6.88 mm/s fall.

As a result of Friedman's test, these values were not significantly different from the optimum value obtained when passive stimulation without input of the participant was rated where the number of participants was nine with the average age of 23.5 years.

3 Evaluation of Walking Sensation in Nine Factors

3.1 Objective

Walking sensation produced by the optimum stimulus adjusted in the previous section was rated as compared to the sensation of a real walk. Rating was performed in terms of nine factors related to the walking sensation.

3.2 Participants and Procedure

Participants in the evaluation were ten undergraduate and graduate students with the average age of 23 years. They evaluated the optimum stimulus in the nine factors shown in Table 1.

Table 1. Factors of walking sensation.

Factors of walking sensation	Definition of factors (awareness)
Power (acceleration)	Sensation of applied force to make the body forward. Sensation of lifting the body at stairs
Walk velocity	Sensation of walking speed
Periodicity (repetitive motion)	Sensation of repetitiveness of the motion
Lateral alternation (lateral sway)	Sensation of the alternated contact motion of legs on the ground
Muscle tension (perceived)	Sensation of muscular effort of lower extremity to support the weight of the body
Continuous body motion	Sensation of total amount of continuous motion of the body
Regularity of continuous body motion	Sensation of regular continuous motion of the body
Balance control (posture maintenance)	Sensation of maintaining/controlling posture to continue a balanced walking
Sole taction (tactile sensation) at the foot	Sensation of sole skin when the foot contacted to the ground

First, the participant realized nine factors of walking sensation after they walked a flat floor for more than 20 m at a 1.4 s walk period (0.7 s each step). Second, they sat on the vestibular display and played the stimulation optimized beforehand with closed eyes and noise emitting earphones. Finally, they evaluated the walking sensation using VAS (Visual Analog Scale) ranging from no sensation (0) to very definite (100). Both the ipsilateral and the contralateral inputs were evaluated.

3.3 Result

The results are shown in Fig. 2. Ratings of the real walk and the passive stimulus are from the previous studies. The Kruskal-Wallis test was applied in terms of four stimulations since the data lacked the normality and the equal variance based on Shapiro-Wilk and Bartlett's tests. The four factors indicated significant difference: Walk velocity ($p = 0.0312$), Muscle tension ($p = 0.003$), Continuous body motion ($p = 0.006$), and Sole taction ($p < 10^{-06}$).

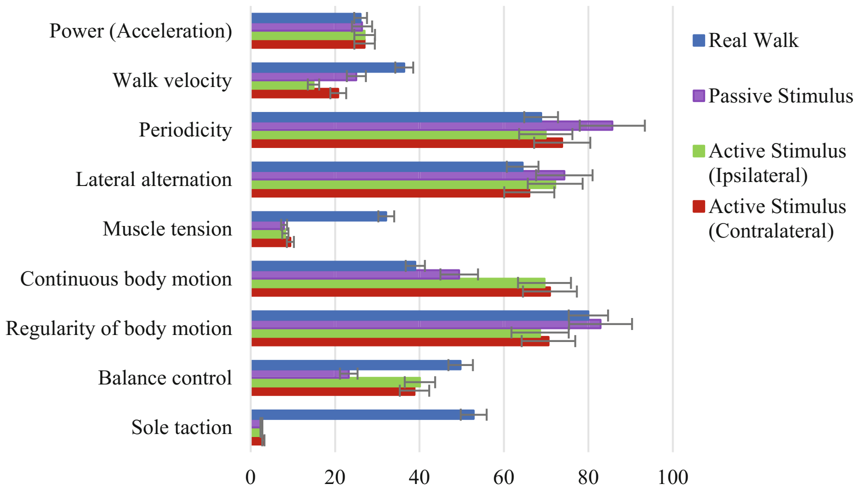

Fig. 2. Result of sensation (awareness) ratings of a real walking on level floor and VR walking by the seat motion presentation (SE error bar)

The sensation of walk velocity was weaker in the three stimulus conditions than the real walk. The reason might be the visual vection that was involved only in the real walk. The large difference in the muscle tension and the sole taction is due to lack of the active muscle motion and foot sole stimulus that occurred in a real walk. The continuous body motion in the active stimuli exceeded the real walk. This may be caused by increased attention to the body (seat) swing motion that was induced by input of the participant. Other factors indicated that stimulation by the motion seat could impart almost equivalent sensation to the real walking.

4 Evaluation of Sensations of Activity and Walking

4.1 Objective

The contribution of active and passive seat motions to the sensation of activity (voluntariness) and the sensation of walking was investigated, since the walking experience involves both active and passive aspects of motion sensation.

4.2 Participants and Optimization Procedure

Eleven university students (average age 22.9) participated in the evaluation to compare three stimuli. The passive seat motion, the active seat motion in ipsilateral input, and the active seat motion in contralateral input were evaluated in terms of the sensation of activity and the sensation of walking. They walked as the previous experiment to memorize the sensation, and rehearsed periodic active input before the rating session with more than 30 steps of the seat motion. The stimulation was added only by seat motion.

4.3 Result of the Sensation of Activity

Figure 3 shows the result of activity rating. A significant difference was observed ($p < 0.05$, Friedman's test). The activity rating was higher in the active stimuli than passive stimulus ($p = 0.012$, Holm's multiple comparison). The difference between the ipsilateral stimulus and the contralateral stimulus was not significant. The sensation of activity was increased markedly by introducing voluntary trigger input by the finger. However, the finger input did not sufficiently substitute for the leg motion in walking.

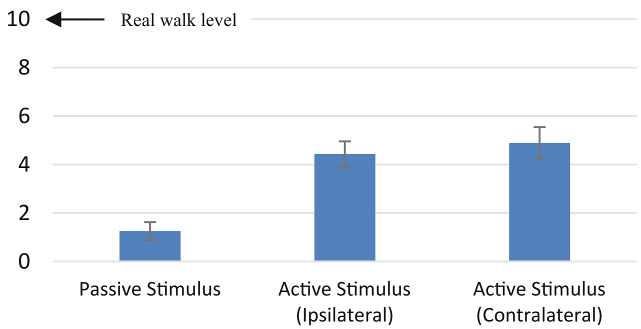

Fig. 3. Sensation of activity by vestibular stimulation (single modality)

4.4 Result of the Walking Sensation

Figure 4 shows the result of walking sensation. A significant difference ($p < 0.05$) was observed (Friedman's test). The rating of the active stimuli was higher than the passive stimulation ($p = 0.026$). There was no significant difference between the ipsilateral and the contralateral stimuli (Holm's multiple comparison). The sensation of walking was effectively raised by the active trigger input that might have cognitively imitated active aspect of walking motion.

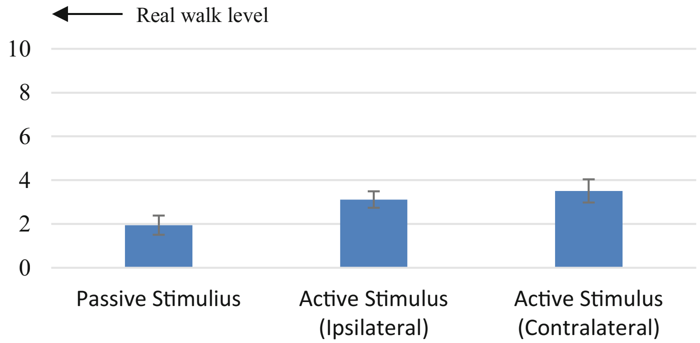

Fig. 4. Walking sensation by vestibular stimulation (single modality)

5 Conclusion

The periodic active input to trigger each of the single step motion of the vestibular display could increase the sensations of both walking and activity (agency). The active aspect of a real walk may have been provided by this input performed along with passive awareness of seat motion as body acceleration during walking.

Further studies are needed to clarify the relationship between passive and active sensations of a real walk, and their substitutes by a seat motion.

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Verification of Stereoscopic Effect Induced Parameters of 3D Shape Monitor Using Reverse Perspective

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Abstract. In the field of optical illusion, reverse perspective is used to draw a scene that is opposite to the actual perspective. When the viewing position is changed, a farther object seems to be always coming toward and following the viewer instead of going away. Therefore, we considered whether the reverse perspective can be applied to a dynamic representation of computer animation using multiple combined monitors. In this research, we arranged three monitors in the shape of a corner cube and tried to determine whether the viewer can recognize the concave corner of the cube as the convex corner through the reverse perspective illusion. Furthermore, we developed a virtual environment that enabled us to simulate the reverse perspective illusion by changing the position, angle, and shape of the screen using a head-mounted display and controllers.

Keywords: Stereoscopic · Optical illusion · 3DCG

1 Introduction

Reverse perspective is a drawing technique in which closer objects are drawn small and farther objects are depicted large. The technique is used to draw a scene such that it is opposite to the actual perspective, in the field of optical illusion. When the viewer changes their viewing position, a farther object seems to be always coming toward and following the viewer instead of going away. In recent years, the reverse perspective has also been used in the field of trick art. In the field of art, Patrick Hughes' "Reverspective" [1] is well known. In addition, Cook et al. investigated the reverse perspective from the viewpoint of psychology and observed that the depth illusion is induced by the density of grid lines rather than shadows and textures [2].

Many artworks using the reverse perspective method can change their appearance in conjunction with the movement of the user; therefore, it is easy to attract the user's interest. If the pattern of their appearance can be dynamically changed using projector/monitors, it will be possible to enhance the reverse perspective effect. In this research, we propose a reverse perspective method that can change the image on the surface. To realize our approach, we arranged three monitors in the shape like a corner reflector and

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tried to determine whether the concave corner of the cube appears to be the convex corner to the viewer as a result of reverse perspective illusion. It is necessary to distort the images for the monitors to strongly induce the reverse perspective effect. Therefore, the projective transformation was utilized for distortion correction, and the deformation parameters that can further enhance the effect were explored.

2 Development of a Corner Cube-Shaped Display

We developed a corner cube-shaped display by combining three LCD monitors. When configuring corners with three monitors, it is preferable to use three regular square monitors without an edge, from the viewpoint of effectively utilizing pixels. However, because it was difficult to find square-shaped bezel-free monitors, we used a square monitor (Eizo EV2730Q, 1920 × 1920) on the front and narrow bezel monitors (Eizo EV2455, 1920 × 1200) on both the left and right sides. Figure 1 shows a combination of displays. The orientation of the monitors was such that the bezel and the wiring are difficult to see.

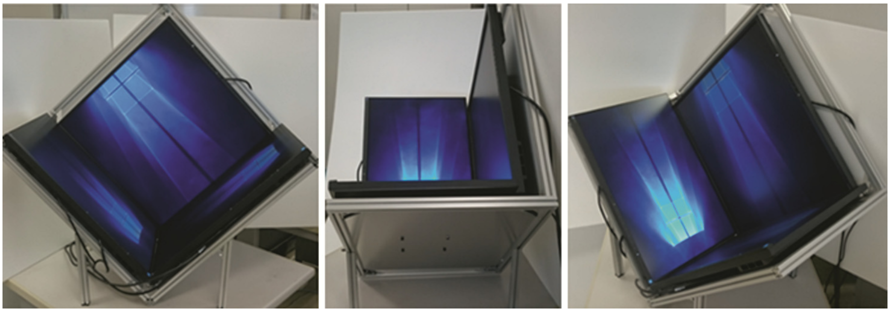

Fig. 1. Overview of a corner cube-shaped display

3 Visual Representation of the Reverse Perspective Effect

It is necessary to draw the created image on each monitor. For example, in the representation of a cube using the reverse perspective method, it is necessary to transform all projection points of the displayed object. However, for the purpose of displaying arbitrary shapes, we decided to utilize projective transformation for distortion correction. In this study, we used a homography transformation that allowed us to project a plane on to another plane by projective transformation. Affine transformation can be used to transform a plane into a parallelogram, but homography transformation has an advantage in that it can to transform the plane into a trapezoid. The distortion ratio was defined as the length of the diagonal divided by the length of one side of the original regular square (Fig. 2). Generation of video including homography transformation was implemented using Unity. The lattice pattern is used because the grid line density increases the optical illusion effect.

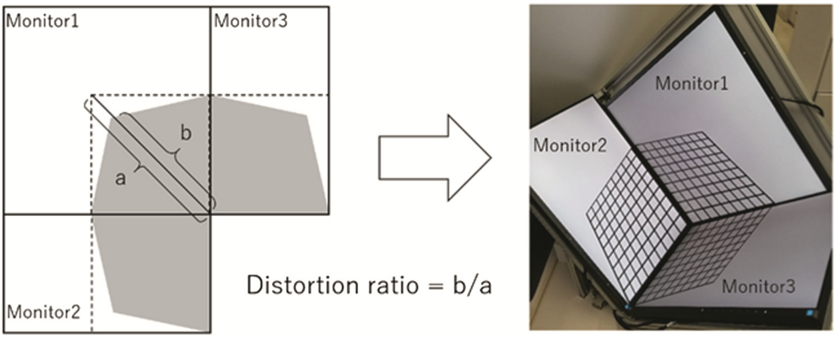

Fig. 2. Definition of a parameter of distortion ratio

Figure 3 shows results if the distortion ratio is changed. The effect of the reverse perspective is greater in the right photograph. The ratio of the photograph in Fig. 2 and the right photograph in Fig. 3 are the same but both photographs were captured from different angles. This means that with changing viewpoint, the cube appears to rotate such that the vertex moves toward the viewer.

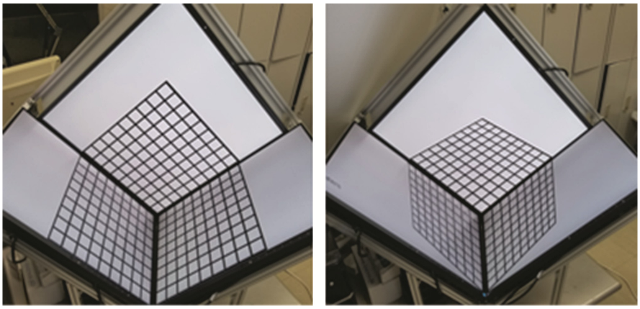

Fig. 3. Results of distortion ratio is changed (left: 100%, right: 80%)

4 Evaluation Experiment of Distortion Ratio

The effect of reverse perspective depends on a parameter of the distortion ratio. We verified the range of distortion ratios that causes optical illusion using our corner cube-type monitor. In this experiment, we examine whether the displayed cube is perceived as distorted and whether the corner is recognized as convex.

4.1 Procedure

The experiment is based on the adjustment method. First, the image on the left side of Fig. 3 is displayed as an initial image to the participant in the experiment. Then the participant decreases the distortion ratio until the cube is perceived without distortion. Next, they reduce the ratio until the object is not recognizable as a cube. Finally, they adjust the ratio until the concave corner is not perceived as the convex corner. The criterion of distortion and perspective is based on the subjectivity of the participants. They stood at a position approximately 80 cm away from the center corner of the display and were instructed to see with both eyes. In this study, we conducted the experiment for ten participants aged 19 to 22.

4.2 Results

In Fig. 4, hatched squares represent the range of distortion ratios for which the participants perceived the pattern as an undistorted convex cube. Error bars indicate the range for which the corner is recognized as convex. Individual differences are substantial, but the average of the distortion ratios for which they began to perceive the pattern as a convex cube without distortion is 83.6%. The average of the lowest limitation when they began not to perceive it as a convex cube is 67.9%. The average ratio when they recognized the corner as a convex shape is 54.5%. Figure 5 shows the displayed patterns used in the experiments.

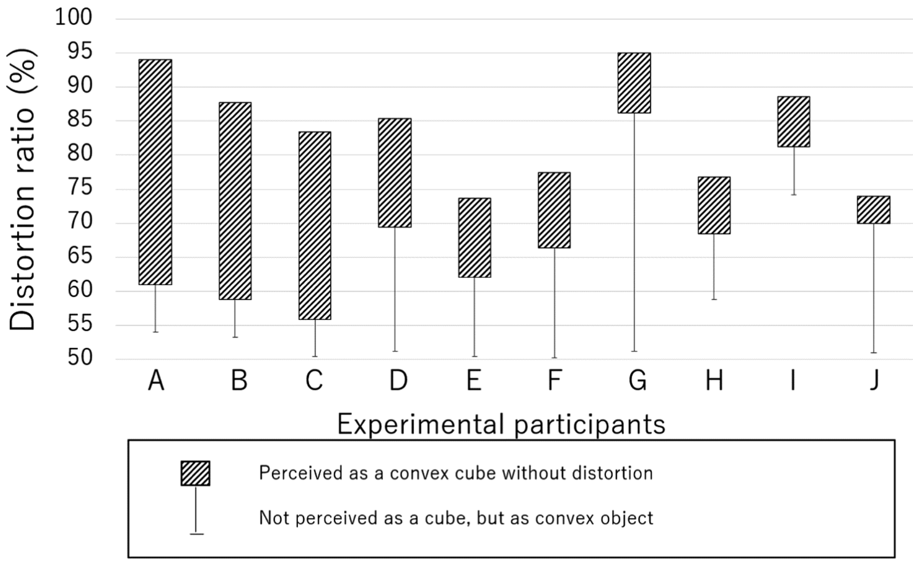

Fig. 4. Perception range of illusion

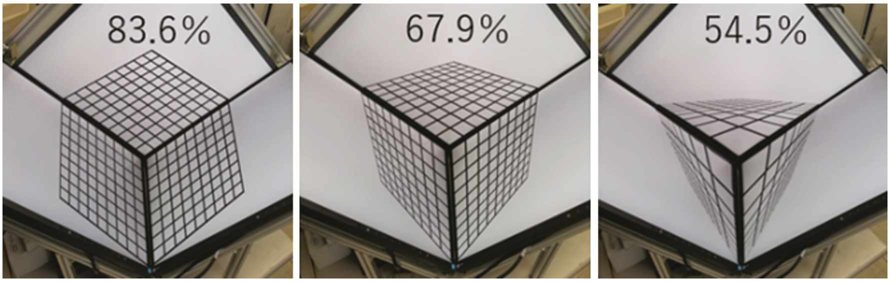

Fig. 5. Actual appearance of each parameter

4.3 Considerations

According to the survey results, although there are individual differences in the tolerance of the distortion ratio, most users can perceive the reverse perspective illusion between 83.6% and 67.9%. This result is the same illusion as the environment created by paper.

Moreover, even if the user can not recognized the pattern as a cube, they can see that the vertex continues to jump out. From the survey conducted by changing the gazing point, if the user's line of sight can be fixed at the vertex, the illusion can be more reliably induced.

5 Simulation in VR Space

From the opinion of the participants of the evaluation experiment, it became apparent that the contents presented on the corner cube-type monitor using the reverse perspective method need improvement in screen size, shape, and texture.

However, because the monitor is fixed with an aluminum frame, it is heavy and not easy to move; therefore, we conducted a simulation in a virtual environment using a head-mounted display. In the preliminary survey, we confirmed that the virtual environment can evoke the same illusion of reverse perspective with monitors.

6 Conclusion

In this research, we created a corner cube-type monitor by stereoscopically combining three monitors and presented contents using reverse perspective using Unity, with many people stereoscopically watching the contents through a reverse perspective. We investigated the distortion ratio that can be made. In addition, we have constructed a virtual environment that can simulate the improvement method of the corner cube type monitor. In future, we propose to verify the combination of monitors and the type of presentation video via a demonstration using a head-mounted display and demonstration by projection mapping and to aim to develop a monitor that can always show information toward to many users at the same time. At present, it is limited to displaying a convex cube using a corner cube-type monitor, but the virtual environment enables us to simulate various shapes such as polyhedrons or spheres.

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Emotions, Anxiety, Stress and Well-being

VEO-Engine: Interfacing and Reasoning with an Emotion Ontology for Device Visual Expression

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Abstract. In order for machines to understand or express emotion to users, the specific emotions must be formally defined and the software coded to how those emotions are to be expressed. This is particularly important if devices or computer-based tools are utilized in clinical settings, which may be stressful for patients and where emotions can dominate their decision making. We have reported our development and feasibility results of an ontology, Visualized Emotion Ontology (VEO), that links abstract visualizations that express specific emotions. Here, we used VEO with the VEO-Engine, a software API package that interfaces with the VEO. The VEO-Engine was developed in Java using Apache Jena and OWL-API. The software package was tested on a Raspberry Pi machine with a small touchscreen display that linked each visualization to an emotion. The VEO-Engine stores input parameters of emotional situations and valences to reason and interpret users' emotions using the ontology-based reasoner. With this software, devices can interfaced wirelessly, so smart devices with visual displays can interact with the ontology. By means of the VEO-Engine, we show the portability and usability of the VEO in human-computer interaction.

Keywords: Ontology · Emotions · Semantic web · mHealth
Affective computing

1 Introduction

Emotions affect our intentions, perceptions, behaviors, and decision-making. From a patient's perspective, emotions can influence decisions that impact his/her health. Such decisions may involve care situations wherein a patient's loved ones must choose to continue or to end care, or they may influence whether or not a patient accepts immunizations So, when interacting with patients or health consumers, it is important to account for the role emotions play. Providers must be conscious of emotional contagion [7], where he or she could sway the patient by expressing an emotion that could affect or inspire the patient's own emotions.

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Inspired by the use of intelligent agents in health care, we surmised that if such tools were to be used with patients, they would need to include emotions as a factor. In this paper, we discuss and demonstrate a proof-of-concept software engine, VEO-Engine, that could add emotional responses to intelligent agents using ontologies and semantic web technologies.

Briefly, an ontology is a semantic-driven electronic artifact that formally represents concepts, links between concepts, and domain knowledge in a machine-readable format. This artifact is published in a machine-based syntax that assists machines to structure domain knowledge and manifests the knowledge in a format that can be shared and processed by machines. One of these syntax languages is Web Ontology Language (OWL) [13], which is the language we used in this work. OWL provides language features that perform high-level machine reasoning based on coding. Theoretically, when a machine can define and structure knowledge and concepts from a specific domain, it can further understand the domain.

1.1 Summary of Previous Work

We investigated a spectrum of emotions and how to define them for machines to understand. We translated the Ortony, Clore, and Collins' (OCC) model of emotions [11] and the proposed revised version by Steunebrink et al. [12] into what we called the Visualized Emotion Ontology (VEO) using OWL [10]. In addition, while all but one emotion overlapped with the Paul Ekman classifications of emotions [4], we also included *surprise* into the ontology. In brief, the OCC model defines emotions based on emergent conditions using a composite of behavior and situations. For example, the emotion of *fear* is defined as a negative feeling that involves a situation pertaining to displeasure of a probable consequence. Further, OCC utilizes some semantics and logical structures that can be easily rendered to create an ontology using OWL. Lastly, we created visualizations based on evidence from published research for each of the emotions described, and each visualization linked to an emotion using the ontology. Overall, the VEO semantically defined and visualized 25 emotions [9].

We then assessed the representation of emotions by evaluating the VEO structure using semiotic theory-driven metrics and assessed the visual representations of the emotions using Amazon Mechanical Turk. The initial assessments yielded a structurally and semantically sound ontology, compared with other cognitive-related ontologies, and the individuals surveyed ($n = 1082$) agreed that most visualizations represented specific emotions [9].

Next, we endeavored to use the VEO in machines. This could demonstrate the usefulness of the ontology, and semantic web technologies in general, in machines that could host intelligent agents.

1.2 Research Objectives

The objective of this study was to show that, for small devices, we could use an emotion ontology to reason and query emotions. This study could further our work in developing conversational agents that include emotions in interactions with humans. Also, this may further interest in using ontologies and the semantic web to help machines express and interpret emotions with humans users.

To support our objective, we performed the following:

1. Developed the proof-of-concept engine that harnessed the VEO to allow for querying and interpretation of emotions using an application programming interface (API)
2. Tested the VEO-Engine's functionality to query and perform reasoning for emotions.

2 Materials and Method

The VEO-Engine was developed in Java and employs the following libraries: Apache Jena [2], OWL-API [8], and the HermiT reasoner [5]. The VEO-Engine software library carries an application-specific version of the VEO, which is the core knowledge base without the imported ontologies from our previous studies. With a simpler form of the VEO, this would make it easier to test and to experiment. Also, the VEO-Engine hosts local versions of the visualized emotion images. It was deployed as a distributable JAR[1] file that could be integrated with existing software applications.

We also added sample Java GUI[2] that enabled a demonstration of two basic functionalities of the VEO-Engine-querying emotion visualizations and machine-based reasoning. SPARQL [6] was used to query emotion visualizations. Each SPARQL query was executed on the VEO, and each VEO emotion was linked to an image in the JAR file. Figure 1 shows the VEO emotion visualization for *relief* defined in Turtle syntax [3]. The link to the image file is handled by the property *veo* : *has_local_image_file*. In Fig. 1, *relief* visualization is assigned to the image file "relief.png".

Fig. 1. Sample encoding (in Turtle) of VEO's emotion concept of *relief*. The last three lines denote the linked image and web files.

[1] executable Java archive file.
[2] Graphical User Interface.

The second VEO-Engine function involved machine-based reasoning that harnessed the HermiT API. In order to interpret the emotion, the VEO-Engine required an input for the emotional valence (positive or negative emotion type) and the contextual data for the situation or the psychological state. Formula (1) describes the format for the reasoner to define an emotion.

$$[positive \mid negative]\ and\ [concept\_property_1\ [\ldots and\ concept\_property_n]] \quad (1)$$

For example, *love* is defined by VEO as a [*positive*] emotion that involves liking something familiar *[concept property := "concernsAspect some Familiar_Aspect"]*. In order for the software to determine whether love is being expressed, it would need data of *positive* for its emotional valence parameter and the parameter for a VEO concept property(ies) of *concernsAspect some Familar_Aspect*.

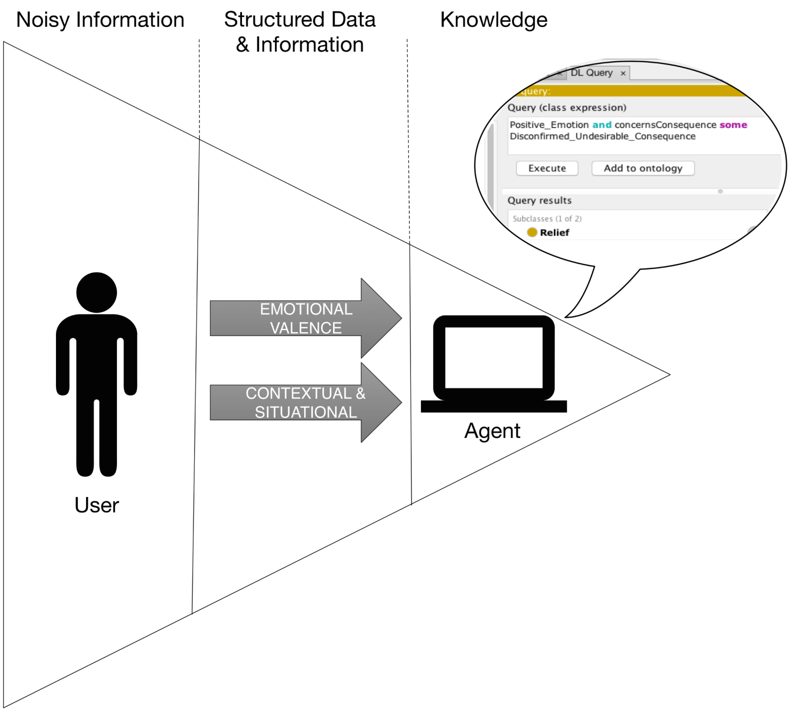

Fig. 2. Interpreting user's emotional information.

Figure 2 shows the broad process wherein an intelligent agent consumes the emotional valence data and the contextual situational data from a human user. Using the entered parameters, the HermiT reasoner enabled the VEO-Engine to determine the precise emotion based on what has been defined in the VEO.

To test the software library, we used a Raspberry Pi 3 Model 3 board with Raspian version 9. Specific to Raspberry Pi, the device was also connected to 7" touchscreen display with 800×400 pixel screen resolution. The VEO-Engine was deployed to the device, and we executed sample tests through the command line to assess both the visualization query and the emotion reasoning of the library.

3 Results and Discussion

Aside from the input parameters we provided through the command line, the entire library was executed locally on the Raspberry Pi device and performed its functions without any connection to external software services.

Through a command line input for a specific emotion, the VEO-Engine queried for the corresponding image file and displayed a sample window showing that the visualization was linked to the emotion. Figure 3 shows *anger* displayed from the VEO-Engine on a Raspberry Pi device.

Fig. 3. Touchscreen device displaying results of a visualization query for the emotion *anger*.

We tested the VEO-Engine's reasoner by feeding a string of data describing an emotion. To test, the input required:

$$reason\ [positive|negative]\ [concept\_property_n]$$

For example, the input parameters of *reason [positive] [concernsConsequence some Prospective_Consequence]* was revealed to be the emotion of *hope*. Figure 4

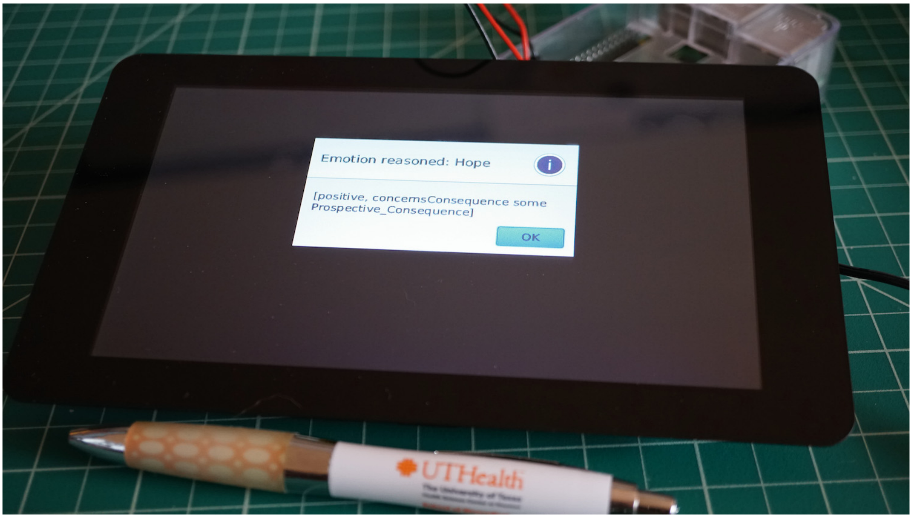

Fig. 4. VEO-Engine performed a reasoning task based on parameters for the emotion of *hope*.

displays the result of a sample parameter input for *hope* to demonstrate the reasoning capability of VEO-Engine on a small device.

While our results show promise for semantic driven technologies, there are still opportunities for improvement. One would be to allow for synonymous emotion input in visualization queries, for example, *fondness* in place of *love*. To permit this, we would need to expand the ontology to link similar terms with each emotion and then modify the SPARQL queries. These improvements are possible because ontologies are graph-like, and therefore they can be changed easier than, say, a relational database [1].

To perform reasoning functions, the VEO-Engine required structured data input, so for this technology to be further applicable, it must map or translate the noisy contextual information from the human user into structured data. Therefore, if we looked at unstructured, free text from a person's utterances, we would need to parse out the information and then map that information to the appropriate parameters for emotional valences and concept properties to then input into the VEO-Engine. In this scenario, natural language processing might offer a direction.

4 Conclusion and Future Work

Our work exemplifies how semantic-encoded emotions could be utilized by software and small devices to assist machines in understanding human emotions. Based on our previous VEO work [9,10], we developed VEO-Engine, a software library that interfaces with the emotion ontology. The VEO-Engine was able to query for visualizations associated with an emotion, and it was able to deduce an emotion based on sample input parameters. The combination of having emotions semantically defined and a software wrapper to interface with the ontology makes semantic web technologies a feasible option for affective computing. In the future, we will look to incorporating this work into conversational agents for health care applications. Specifically, this could enhance how machines react and respond to patients' or health consumers' utterances to improve their outlook and well-being.

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MobileDNA: Relating Physiological Stress Measurements to Smartphone Usage to Assess the Effect of a Digital Detox

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Abstract. The ever-connected world created by smartphones has led to initiatives like a 'digital detox', in which smartphone users consciously disconnect from email, social media and internet in general for a certain period of time. Since research based on subjective self-reports indicates that extensive smartphone usage and stress are often related, we checked whether a digital detox is effectively associated with a decrease in stress in the short-term and whether this could be measured with objective markers of both smartphone usage and physiological stress. More particularly, we monitored participants for two consecutive weeks: one week of normal smartphone usage and one week of digital detox. We asked them to continuously wear a state-of-the-art wristband device, measuring physiological stress based on skin conductance (SC). In addition, we developed an app called 'mobileDNA' to capture detailed information on which apps participants use throughout the day and how much time they spend on them. Although this was a pilot study with a rather low sample size, we found decreased levels of stress during a digital detox week. This finding provides evidence that a digital detox can be an interesting coping mechanism for people experiencing problematic smartphone usage and that further and more extensive research with our methodology has a lot of potential in the future.

Keywords: Mobile DNA · Smartphone usage · Digital detox · Stress Technostress · Physiology

1 Introduction

Over the last couple of years, smartphone usage has increased dramatically, infiltrating every aspect of our life [1, 2]. Its usage is often highly enjoyable and feels so naturally that people are often not conscious of their 'constant connectedness' [3–5]. Whereas most smartphone users do not experience this constant connectedness as problematic, some studies have shown that smartphone overuse and constant connectedness can have a substantial negative impact on people's daily life activities and well-being [1, 5]. For

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instance, smartphone overuse has been found to be associated with poorer sleep quality [6], professional performance [7], personal relationship quality [8] and lower well-being in general [9]. In addition, the constantly connected world created by smartphones blurs the boundary between work and home, reflected in expectations of employers to be 'always online', to immediately reply to emails and to keep up with online conversations [10].

When users experience their constant connectedness as an exceeding environmental demand that threats their well-being, they can experience *technostress*. Technostress is a specific type of stress that results from the use of modern technology [11]. Based on the Transactional Model of Stress (TMS), technostress can be defined as an imbalance between an individual's resources and demands by the environment related to technology use [12]. In order to deal with technostress, people will develop certain coping abilities [12]. One technostress coping strategy is a digital detox, which entails an entire and conscious disconnection from e-mail, social media, news and internet in general. Smartphone digital detox is an increasing practice [2], for which people have indicated that they do it because they prefer not to be reachable for a while or to have more time for other things. The behavior of disconnecting oneself has not limited itself to the individual, also in work-contexts there is a debate whether employees should go offline after the working hours. For example, emails that are received after working hours are either put on hold or deleted in certain companies [13].

In this study, we wanted to investigate whether a smartphone digital detox effectively decreases stress in the short-term. This research question is especially interesting because two opposing hypotheses can be put forward: whereas a digital detox is likely to decrease stress because people are less preoccupied by notifications and emails, it can also increase stress because of withdrawal-like symptoms and the loss of interconnectedness [14]. In order to investigate both opposite hypotheses, we made use of an in-house developed smartphone application ('mobileDNA') to log smartphone usage. In addition, we used a wearable wristband device that can objectively and continuously measure skin conductance (SC) and skin temperature as a proxy for stress with high temporal precision. For decades, it has been known that increased skin conductivity can be a sensitive psychophysiological index of changes in autonomic sympathetic arousal and stress [15]. An important objective was to be as less intrusive as possible and monitor participants' behavior for fourteen consecutive days, consisting of seven days of normal smartphone usage and seven days of digital detox.

2 Method

2.1 Participants

In the context of a student assignment on smartphone usage and stress, fifteen participants were asked to wear a stress wearable and to allow us to log all their smartphone activity for two consecutive weeks. These participants were recruited in the student population and were on average 22 years (range: 21–24 years) and mostly female (10 out of 15). Unfortunately, there were some technical problems with some of the sensors, so we had to exclude the physiological data of 4 people from further analysis. In addition, for one participant, we were not able to link the logging data to the physiological data, so his/her data was excluded in the analysis of the physiological data. All participants signed an informed content before participating and were paid 30 euros after two weeks.

2.2 MobileDNA: Logging Smartphone Usage

In order to collect data on one's actual smartphone usage, a logging application (mobileDNA, available in Google Play Store) was used. MobileDNA allowed us to capture precise information on which apps participants used, how much time they spent on using them and how frequently they received notifications. This app can be both used as a research tool (outputting raw data) and a way to raise awareness for personal smartphone usage. With respect to the latter, users of the app can log in on https://mobiledna.be/ and check their personal data throughout the day (see Fig. 1).

Fig. 1. mobile DNA – screenshot of the application interface on https://mobiledna.be/. Vertical lines indicate app events (opening an app and using it for a certain time), whereas the dots represent notifications. The color indicates which app is used (Color figure online).

For this study, we analyzed the raw data and simply counted the total number of app events during the first four days of both the normal and detox week. We specifically limited the scope of our app event data to those apps that require a data connection. An app event can therefore be defined as the self-initiated act of opening an app and using it for at least a couple of seconds. This means that app events for apps like Facebook, Facebook Messenger, Instagram, Twitter, Whatsapp or the browser were counted, whereas apps for traditional messaging (SMS), camera or system settings were not.

2.3 Physiological Measurements

With respect to objectively measuring stress, we used the Imec Chillband. This wearable was specifically designed for long-term stress measurements (>1 week battery autonomy, storage capacity of 30+ days of data) and is attached to the lower side of the wrist. Skin conductance (i.e. galvanic skin response or electro dermal activity) and skin temperature are measured with high dynamic range (0–20 μs) and sampled at 256 Hz and 1 Hz, respectively. However, skin temperature was not analyzed for this study. Participants had to wear the sensor the entire day but could take it off during the night and while taking a shower. Data was internally stored on the sensor and uploaded to a computer via USB afterwards. Since this wearable does not have a display, participants were not aware of their current physiology and stress level, avoiding effects of self-adjustments during the normal smartphone usage week.

With respect to the analysis, features were calculated based on the raw skin conductance signal in a window of 5 min, with a step size of 1 min. Data quality was assessed based on the wearable's internal confidence indicator (CI), leaving out all samples with a CI lower than 0.8 [16]. Just like [17], we chose to look at the skin conductance response rate (SCRR) instead of the absolute skin conductance level. The SCRR reflects the number of SC responses in a time window divided by the total length of the window (in this case 300 s) or the number of SC responses per second. Then, SCRR was averaged across the entire duration of the day, starting when people woke up and put on the wristband until they went back to bed.

2.4 Procedure and Design

A within-subjects design was used to compare stress between the regular and detox week. In contrast to a between-subjects design, this type of design is less affected by intersubjective and baseline variability. All participants started with the normal smartphone usage week and were asked to use their smartphone like they always do. After this week, they got a new sensor and were asked to use their smartphone as a "dumb phone": they were allowed to take pictures, send texts or make calls, but had to switch off their mobile data (3G, 4G, 5G) and Wifi connection. In addition, they were asked to make a note in a diary whenever they experienced stress that was not related to their smartphone usage (e.g. relationship arguments or traffic jams), which allowed us to control for alternative explanations of stress during both weeks. In this study, we excluded the data of participants who experienced highly unusual stressful events, but did not use the subjective data to exclude portions of data within subjects. Because not every participant started at the same time of the day, we took the next day of data collection as day 1. In order to have a balanced amount of data for each participant and because there were some participants who dropped out after 5 days, we only analyzed 4 out of 6 days per week (normal and detox).

3 Results

3.1 MobileDNA

A repeated-measures ANOVA with factors week type (normal vs. detox) and day of the week (day 1 to 4) was performed on the average number of app events. Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of day and the interaction effect, $\chi^2(1) = .18$, $p = .02$, and $\chi^2(2) = .15$, $p = .01$, respectively. Therefore, for these effects, Greenhouse-Geisser corrected tests are reported. The main effect of week was significant, $F(1, 9) = 26.80$, $p < .001$, $r = .87$ (*large* effect according to [18]). The main effect of day was not significant, $F(1.57, 14.10) = 1.64$, $p = .23$, $r = .39$, just like the interaction between week and day, $F(1.57, 14.12) = 1.25$, $p = .31$, $r = .35$. As Fig. 2 illustrates, the average number of app events was on average much higher during normal days ($M = 69.45$, $SD = 51.25$) than during detox days ($M = 2.53$, $SD = 2.71$).

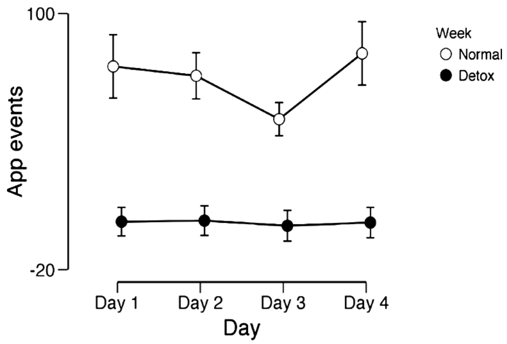

Fig. 2. Mobile DNA – average number of app events per day of each week (normal vs. detox). Participants used their smartphone significantly less during the detox week.

3.2 Physiological Measurements

A repeated-measures ANOVA with factors week type (normal vs. detox) and day of the week (day 1 to 4) was performed on the average SCRR. Mauchly's test indicated that the assumption of sphericity had been violated for the interaction effect, $\chi^2(2) = .26$, $p = .04$. Therefore, for this effect, a Greenhouse-Geisser corrected test is reported. The main effect of week was significant, $F(1, 10) = 5.63$, $p = .04$, $r = .6$ (*large* effect according to [18]). The main effect of day was not significant, $F(3, 30) = .7$, $p = .56$, $r = .25$, just like the interaction between week and day, $F(1.69, 16.9) = .26$, $p = .74$, $r = .16$. As Fig. 3 illustrates, the average SCRR was on average higher during normal days ($M = 0.042$, $SD = 0.029$) than during detox days ($M = .029$, $SD = 0.018$).

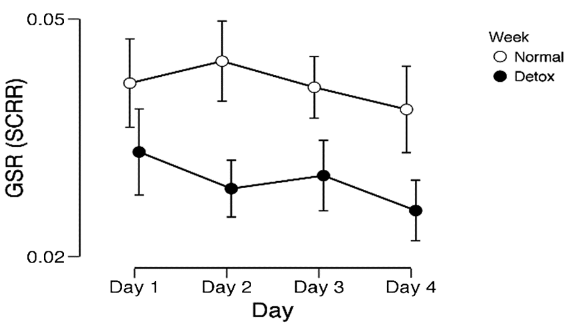

Fig. 3. Main effect – average skin conductance response rate per day of each week (normal vs. detox). Participants experienced significantly less stress during the detox week.

Violin plots showing the full distribution of each cell in the design (2 weeks × 4 days) indicate that this significant main effect of week was not driven by outliers and that most participants did indeed show a decreased SCRR on average during the detox week (Fig. 4).

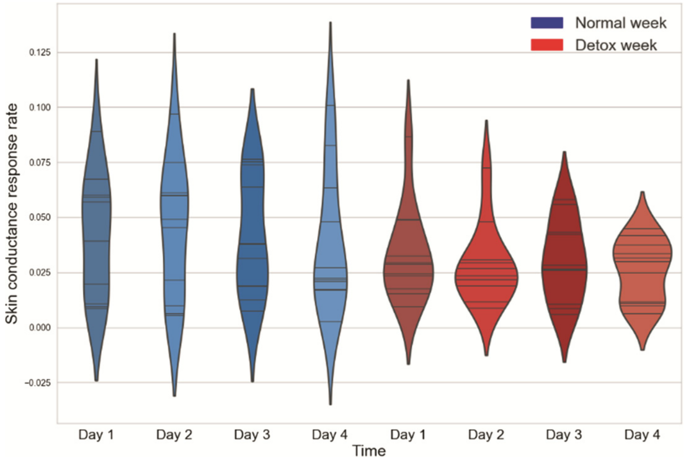

Fig. 4. Violin plots. Each horizontal black line indicates the average skin conductance response rate throughout the day during the normal and detox week, respectively. The outer sides of each violin plot represent a rotated kernel density plot, showing the probability density of the data at different values.

4 Discussion

Recently, *digital detox* or the coping strategy to deal with smartphone overuse, constant connectedness and increasing technostress has become more and more popular [2]. When digitally detoxing, people consciously decide to disconnect entirely from email, social media, news and internet in general and use their smartphone as a "dumb phone". However, at the moment it is not clear whether this coping strategy effectively decreases stress, since it can also be argued that detoxing could lead to an increase in stress because of withdrawal-like symptoms and the loss of interconnectedness with other people [14].

In order to investigate whether or not a digital detox is associated with changes in stress-levels in the short term, we measured smartphone usage and stress in an objective way. In essence, we made use of an in-house developed smartphone application ('mobileDNA') to measure smartphone usage in great detail and used the Chillband to measure skin conductance (SC) as a proxy for stress. Our goal was to monitor participants' behavior for fourteen consecutive days, consisting of seven days of normal smartphone usage and seven days of digital detox (although in the end only four days were used in the analysis). Interestingly, the data showed some clear patterns. First, as a manipulation check, we were able to verify that participants effectively used less apps requiring a mobile data/wifi connection during the digital detox week. In contrast to a normal week with on average almost 70 app events a day (i.e. opening an app and using it), people refrained from using their smartphone most of the time during the detox week. Interestingly, we found a highly significant main effect of type of week in the physiological data: during the detox week, the physiological stress signal based on the skin conductance response rate (SCRR) was lower than during the normal week. This main effect was present for each of four consecutive days during the normal and detox week, making it unlikely that the effect was driven by a certain event or day of the week. In addition, we based our stress measurements on SCRR instead of the absolute skin conductance signal, likely minimizing confounding effects of physical effort and large baseline differences between participants. Our findings add to the literature, especially in the light of studies showing that smartphone overuse and constant connectedness can have a substantial negative impact on people's well-being [1, 5]. If a digital detox effectively decreases stress, this means that it can be an effective coping mechanism for people who experience this negative impact on a daily basis and that more research is needed on how employers have to deal with constant connectedness outside the office hours.

However, although this study demonstrates that there is good evidence for significant beneficial effect of a digital detox on stress, it is important to note that the sample size was rather small. More participants were initially recruited, but the number of participants we had to exclude was quite high because of sensor issues, people forgetting to wear the wristband during one or more days and synchronization issues with the mobileDNA data. In addition, the low sample size made it impossible to do correlational analyses and to check whether large decreases in stress were also associated with large decreases in smartphone usage. Another issue relates to order effects: because each participant started with the normal week followed by the detox week, our main finding can also be explained by the fact that participants were initially stressed out about wearing the wristband and got used to it during the detox week. One way to rule this out, is by setting up an experiment in which we monitor three weeks (normal week – digital detox week – normal week). For these reasons, we consider the results as preliminary and are rather cautious with over-generalizations.

Nevertheless, we think this pilot study indicates it is quite promising to collect additional data, in which we need to strive for a larger number of participants, a counterbalanced design and the inclusion of subjective annotations. Research on smartphone overuse and the beneficial effects of digital detox has only just begun.

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Emotion Recognition and Eye Gaze Estimation System: EREGE

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Abstract. In this paper, we proposed EREGE system, EREGE system considers as a face analysis package including face detection, eye detection, eye tracking, emotion recognition, and gaze estimation. EREGE system consists of two parts; facial emotion recognition that recognizes seven emotions such as neutral, happiness, sadness, anger, disgust, fear, and surprise. In the emotion recognition part, we have implemented an Active Shape Model (ASM) tracker which tracks 116 facial landmarks via webcam input. The tracked landmark points are used to extract face expression features. A support Vector machine (SVM) based classifier is implemented which gives rise to robust our system by recognizing seven emotions. The second part of EREGE system is the eye gaze estimation that starts by creating the head model followed by presenting both Active Shape Model (ASM) and Pose from Orthography and Scaling with Iterations (POSIT) algorithms for head tracking and position estimation.

Keywords: Face emotion · ASM · Gaze estimation · SVM · POSIT
RANSAC

1 Introduction

EREGE is a real time face analysis package including face detection, eye detection, eye tracking, emotion recognition, and gaze estimation. EREGE system can be utilized for monitoring health through recording gaze direction and combined with other health related measurements such as skin color. The EREGE system provides a tool for monitoring emotional behavior of Autistic children by tracking their eye movement and recognizing their face expression [1]. The EREGE system can be used also as a tool to analyze how a customer views advertisements and what product catches the eyes in online or public stores. EREGE does consider the affective states of its users and maintain the communication and interaction information. Therefore, EREGE is a good example for a successful human-computer interaction (HCI). A Deep Neural Network (DNN) followed by a Conditional Random Field (CRF) is used for facial expression

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recognition in videos [2]. A method to aggregate features along fiducial trajectories in a feature space that deeply learnt is proposed to distinguish the deceptive expression among a set of genuine expressions [3]. Several kinds of eye and head gestures, such as smooth pursuit, saccades and nod-roll are presented as interaction methods in a head mounted virtual reality (VR) device. A head mounted show coupled with an eye tracker is utilized to find better user experience gestures result in a VR environment [4]. Based on our knowledge, the only available visual inspection system with the standard camera is the open source Opengazer. Its main disadvantage is that the system is rooted. The user is completely still during the program operation. There are many commercial systems for eye gaze estimation and emotion recognition, the disadvantage of these existing systems is the need to have special equipment, starting with dedicated mounted on infrared cameras. We make the following contributions:

- Design, build and test a complete system for both emotion detection and eye gaze estimation to be used for many useful applications and fields.
- EREGE system does not require any expensive hardware for eye gaze and emotion recognition.

2 Algorithm

2.1 Emotion Recognition Algorithm

The emotion recognition algorithm has been applied the proposed method in [1], which includes the following steps;

Pre-processing and Using ASM for Face Detection and Triangulation Points Tracking. One of the most prevalent triangulation points detection and tracking is Active Shape Model (ASM) introduced by Cootes et al. in 1995 [5]. In order to identify the triangulation points in an image, first the location of face is detected with an overall face detector called Viola-Jones [6]. The average face shape which is aligned according to position of the face constitutes the starting point of the search. Then the steps described below are repeated until the shape converges.

1. For each point, best matching position with the template is identified by using the gradient of image texture in the proximity of that point.
2. The identified points are projected from their point locations in training set to the shape eigenvalues which is obtained by Principal Component Analysis (PCA). ASM tracking is developed by asmlibrary developed by Wei [7].

Regions Finding. ASM-based tracker tracks 116 triangulationpoints as shown in Fig. 1(c), tracker works sturdy on eyebrows, eyes, chin and nose points however, since it cannot track flexible lip points correctly, it is not reasonable to directly use the location of this points as attributes. There are two reasons for this phenomenon, first reason is ASM's holistic modeling of all triangulation point's locations, and second reason is losing small changes in location of lip points to constraints made on shape with PCA. Further, the difference in intensity at lip edges is not as significant as other face components. Therefore, instead of directly using the locations of triangulation points being tracked, attributes appear of Fig. 1(b). First three attributes are obtained by Mahalanobis distance of the corresponding triangulation points to each other. For the other attributes, the image is first smoothened by filtering with Gauss core, then by filtering with Sobel vertical and horizontal cores separately, edge domains are calculated. Next, absolute value corresponding to each region is calculated. For motivation on selecting attributes, movement descriptions corresponding to emotional expression given in Table 1 can be examined. These clues are based on leading research done by Ekman and Friesen [8].

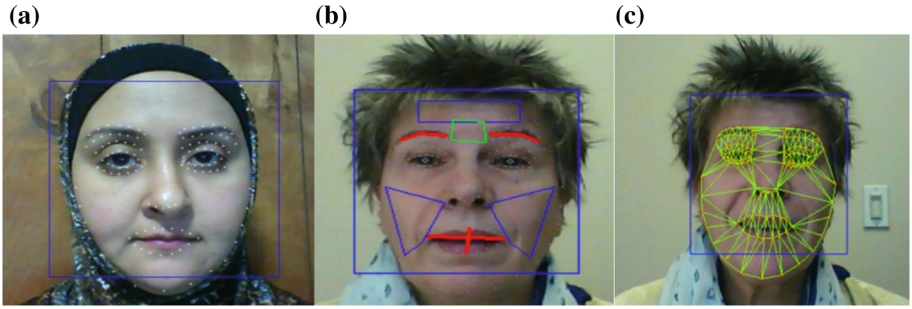

Fig. 1. Facial landmarks (a), attributes that are used to extract the region of interest (b) and facial triangulation points (c)

Table 1. Emotional expressions and their descriptions

Emotion	Description
Surprise	Rise of eyebrows, sight opening of mouth, slight fall of chin
Anger	Frowning of eyebrows, tightening of lips and standing out of eyes
Happiness	Rise and fall of mouth edges
Sadness	Fall of mouth edges and frowning of inner eyebrows
Fear	Rise of eye brows, standing out of eyes and slight opening of mouth
Disgust	Rise of upper lip, wrinkle of nose, fall of cheeks

Emotion Classification. In this process an average of derived attributes is calculated and in frames following that, in order to enable system to act independent of environmental variables, attributes are normalized by division to their average [1].

2.2 Eye Gaze Estimation Algorithm

The algorithm presented in [9] is used to estimate the eye gaze. The proposed algorithm consists of the following steps:

Head Tracking. The process starts by detecting an eye using a classifier. Open Computer Vision Library (OpenCV) [11] is used for algorithm implementation. The Active Shape model from the face expression algorithm explained in pervious section is used to detect and track the head. Creating a model starts with building an object pattern using a set of labeled points representing a given shape. The grid is determined using the Deluannay triangulation method [12] on the set of characteristic points. Texture g for each input image is defined as the pixel intensity in the image.

$$g = [g_1, g_2, \ldots, g_m]^T \tag{1}$$

The columns of the G matrix are the normalized texture vectors of the training images g. The covariance matrix, where N indicates the number of Images in training set is calculated as follows:

$$\sum\nolimits_g \frac{1}{N-1} G^T G \tag{2}$$

The new texture is generated by a linear combination of eigenvectors of the covariance matrix, where Φ is a matrix containing the eigenvectors.

$$g = g_0 + \Phi_g \mathrm{b}_g \tag{3}$$

Where $\mathrm{b_g}$ is a parameters vector. The obtained 2-D points of features are used in next section to construct the 3-D head model.

3D Head Model Initialization. Lucas-Kalman algorithm is the gradient method that is used to transform an image into the next image in the same sequence. The performance of the algorithm is based on three basic assumptions; The brightness of the image does not change much between successive sequence frames. The motion of objects in the image is minor. Points that are within a short distance of each other move similarly. The brightness of the image is determined by function of time.

$$f(x, y, t) \equiv I(x(t), y(t), t) \tag{4}$$

The following equation shows that the brightness of the image does not change significantly in time.

$$I(x(t), y(y), t) = I(x(t + dt), y(t + dt), t + dt) \tag{5}$$

This means that the intensity of the tracked pixel does not change over time:

$$\frac{\partial f(x, y)}{\partial t} = 0 \tag{6}$$

Using this assumption, it is possible to record the optical flow condition by u the velocity vector in the x direction, and v the velocity vector in the y direction

$$-\frac{\partial I}{\partial t} = \frac{\partial I}{\partial x} u + \frac{\partial I}{\partial y} v \tag{7}$$

The assumption of the program is to perform in real time, so we cannot choose a complicated method that would be too heavy for the processor. One of the most commonly used edge and corner detector was introduced by Harris and Stephens [13]. The definition of the second-degree Hessian matrices is based on the image intensity at the point p (x; y):

$$H(p) = \begin{vmatrix} \frac{\partial^2 I}{\partial x^2} & \frac{\partial^2 I}{\partial x \partial y} \\ \frac{\partial^2 I}{\partial x \partial y} & \frac{\partial^2 I}{\partial y^2} \end{vmatrix} \tag{8}$$

The Hessian autocorrelation matrix M (x, y) is determined by the following equation:

$$\begin{vmatrix} \sum_{-K \le i,j \le K}^{n} \mathrm{I}_x^2(x+i, y+j) & \sum_{-K \le i,j \le K}^{n} \mathrm{I}_x(x+i, y+j) I_y(x+i, y+j) \\ \sum_{-K \le i,j \le K}^{n} \mathrm{I}_x(x+i, y+j) I_y(x+i, y+j) & \sum_{-K \le i,j \le K}^{n} \mathrm{I}_y^2(x+i, y+j) \end{vmatrix} \tag{9}$$

The obtained features vector during the head model creation, is used for tracking and determining the 3D head position. To improve the accuracy of the initial parameters, the algorithm RANSAC [14] (Random Sample Consensus) is being used. Usage of the RANSAC algorithm is reliable and resistant against the noise in the results. The head position is determined by six degrees of space: three rotation angles and three translation values (x, y, z). Head rotation can be characterized by three Euler angles: around the z-axis (roll, θ) then around y-axis (yaw, β) and finally around the x-axis (pitch, α). The rotation matrix R is determined based on those three Euler angles.

$$R_y(\theta) = \begin{vmatrix} cos\theta & -sin\theta & 0 \\ sin\theta & cos\theta & 0 \\ 0 & 0 & 1 \end{vmatrix} \tag{15}$$

$$R_y(\beta) = \begin{vmatrix} cos\beta & 0 & sin\beta \\ 0 & 1 & 0 \\ sin\beta & 0 & cos\beta \end{vmatrix} \tag{16}$$

$$R_x(\alpha) = \begin{vmatrix} 1 & 0 & 0 \\ 0 & cos\alpha & -sin\alpha \\ 0 & sin\alpha & cos\alpha \end{vmatrix} \tag{17}$$

The algorithm determining the 3D position of the object is based on a simplified model of a camera called "camera obscura". The idea is to approximate the model parameters, estimating the projection characteristics of the best suited facility to the location of these features in the image. Using the simplified camera model, the projection $\vec{a}$ point of the 3D model into a $\vec{b}$ plan image, on the understanding that the lack of distortion caused by lens imperfections may be described in the following way:

$$\vec{b} = T\vec{a}, \quad u_x = f\frac{b_x}{b_z}, \quad u_y = f\frac{b_y}{b_y} \tag{18}$$

where T is a transformation matrix in a homogeneous coordinate system. The T matrix is a compound of following geometric operations: rotation around coordinate axis of angles θ, β and at the end α and translation by a vector M

$$T = M(x, y, z)R_z(\theta)R_y(\beta)R_y(\alpha) \tag{19}$$

The f factor represents the value of the focal length of the lens. After applying the simplifications, current head position p is described by six variables

$$\vec{P} = \{\mathrm{x, y, z}, \alpha, \beta, \theta\} \tag{20}$$

In general, the projection points of the 3D object on a 2D plan is a non-linear operation, assuming small changes between the known position, fixed in the previous frame, and the current one.

POSIT Algorithm. (Pose from Orthography and Scaling with Iteration) [10] serves into the estimation of the position in three dimensions of the known object. It was presented in 1992, as a method for determining the position (position determined by translation vector T and orientation matrix R) of the 3D object of known dimensions. The initial position estimation and iterative improvement of the result assumes that the designated image points are placed in the same distance from the camera and difference of the object size, related to distance change to the camera is negligible small. Assumption, that both points are in the same distance, means that the object is far enough from the camera and the depth difference can be omitted. Using the calculated position in the previous iteration, points go through projection 3D of the object [9].

Eye Center Detection. The direction in which the person is looking in, might be clearly established by examining the eye's pupil movement and the corners of the eye. The current movement and rotation of the head should also be taken into consideration. The best approach to track the changes of eyeball's angle is to examine the movement between the eye's pupil and the corners of the eye. The algorithms used to follow the change of the positions of the eye are possible to split into two main groups; the group basing on the features and the group basing on the current position of the eye. It requires to establish the correct criteria, dependent on the method that is being used which specifies the occurrence of the feature that is being looked. The choice of the criterium's values is most often provided by the system's parameter, which should be then set up manually [9]. To be able to establish the direction, in which the eyes are pointed, it is necessary to precisely specify the center of the pupil. The default formula defining central contour of the order (p, q) [9].

$$m_{p,q} = \sum\nolimits_{i=0}^{n} I(x,y)x^p y^q \tag{21}$$

Calibration. To appoint the direction of the user's gaze, the linear homographic mapping of the gaze vector's being used. The vector is the difference between the distance of the pupil's center and the projection of the eyeball center positions on the camera's plane. The mapping Hessian matrix is established basing on the set of connections between the gaze vector, and the line that is being displayed on the monitor. The Hessian Matrix includes 8 levels of latitude, and because of this fact, it is required to know at least 4 of those pairs. To increase the precision, during the process of the calibration 9 of those points are being registered. The Hessian Matrix establishing is based on the method of the smallest rectangles. The difference between the gaze vector and the point on the monitor is being minimized [9].

3 Results

The Child Affective Facial Expression (CAFE) dataset is used to evaluate and measure the performance of face expression recognition proposed algorithm. The proposed system achieved a correctness score of 93% [1]. The tests for eye gaze estimation were conducted on a group of 5 people. The test of indicating the gaze direction accuracy consists of defining a difference between a line direction on a screen and the gaze at

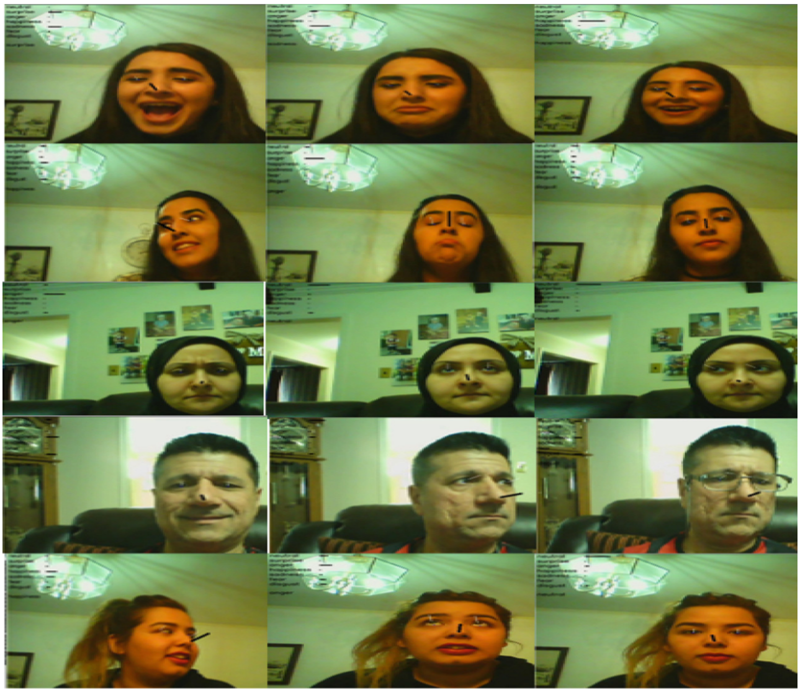

Fig. 2. Samples for the results

which an examined person is looking, and which is determined by the program as shown in Fig. 2. To achieve the goal, an examined person was requested to visually follow a point moving between determined locations [9].

4 Conclusion

This paper presented a real time face expression recognition and eye gaze estimation system. EREGE system aims to efficiently track the face triangulation points to detect seven emotions, neutral, surprise, anger, happiness, sadness, disgust, and fear. Simultaneously, EREGE system tracks the eye movements using PC's webcam only. The system is fully automated initialization, and the process of choosing the needed parameters is fully automated too. Tests were carried out on a 14-inch screen. A built-in webcam was used to record the image at a resolution of 1920 × 1080 pixels with a frame frequency of 15 frames per second.

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Towards Human Affect Modeling: A Comparative Analysis of Discrete Affect and Valence-Arousal Labeling

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Abstract. There is still considerable disagreement on key aspects of affective computing - including even how affect itself is conceptualized. Using a multi-modal student dataset collected while students were watching instructional videos and answering questions on a learning platform, we investigated the two key paradigms of how affect is represented through a comparative approach: (1) Affect as a set of discrete states and (2) Affect as a combination of a two-dimensional space of attributes. We specifically examined a set of discrete learning-related affects (Satisfied, Confused, and Bored) that are hypothesized to map to specific locations within the Valence-Arousal dimensions of Circumplex Model of Emotion. For each of the key paradigms, we had five human experts label student affect on the dataset. We investigated two major research questions using their labels: (1) Whether the hypothesized mappings between discrete affects and Valence-Arousal are valid and (2) whether affect labeling is more reliable with discrete affect or Valence-Arousal. Contrary to the expected, the results show that discrete labels did not directly map to Valence-Arousal quadrants in Circumplex Model of Emotion. This indicates that the experts perceived and labeled these two relatively differently. On the other side, the inter-rater agreement results show that the experts moderately agreed with each other within both paradigms. These results imply that researchers and practitioners should consider how affect information would operationally be used in an intelligent system when choosing from the two key paradigms of affect.

Keywords: Affective state labeling · Circumplex Model of Emotion
Inter-rater agreement · Intelligent tutoring systems · Affective computing

1 Introduction

Affect has become an important area of research within learning [1–3]. Data labeling is a preliminary step towards training machine learning models to provide affect-related analytics to teachers and learners. However, there is a lack of agreement in the related literature even for how affect is itself conceptualized. There are two major paradigms

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for affect representation: (1) Affect as a set of discrete states [4–9] and (2) Affect as a combination of a two-dimensional space of attributes [11].

There are several benefits to viewing student affect as a set of discrete states. One such benefit is easier understanding of students' actual states and driving customized interventions accordingly. However, labeling discrete affective states presents a challenge to observers in distinguishing between closely-related affective states. For instance, confusion and frustration are often treated as separate affective states (e.g., [8]), but Liu et al. [10] argue that they may simply represent different ranges of a continuum. Researchers using discrete sets of affective states often also struggle with how to distinguish neutral affect from mild affect and how to handle uncommon affect outside the core affect labeling scheme. These challenges can represent major risks to the quality of affect labeling in ways that are not easily seen in overall inter-rater agreement values that cut across large numbers of constructs. These issues may particularly emerge in situations where affect labelers have limited training or are asked to label data where video is sometimes ambiguous, due to factors such as facial occlusion, adverse pose variations, gum chewing, or many other factors.

In this paper, we study this issue in a focused fashion by examining a set of discrete affective states that can be reasonably expected to correlate to specific locations within the Circumplex Model of Emotion [11]. Specifically, we study (see Fig. 1): Satisfied, which can be hypothesized to map to Positive Valence (regardless of Arousal); Bored, which can be hypothesized to map to Negative Valence and Low Arousal; and Confused, which can be hypothesized to map to Negative Valence and High Arousal. Using the student dataset in [12] and Human-Expert Labeling Process (HELP) [13] as a baseline labeling protocol, we test these hypotheses (i.e., whether these mappings between discrete affective states and Valence-Arousal are valid) and if affect labeling is more reliable with discrete affective states or Valence-Arousal.

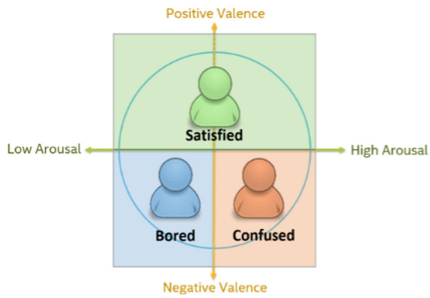

Fig. 1. Mapping of categorical emotions to the Circumplex Model of Emotion.

2 Data Collection

In this study, we used student data which was a subset of a larger dataset previously collected through authentic classroom pilots [12]. These pilots took place in an after-school Math course in an urban high school in Turkey. In these pilots, the students used an online educational platform to watch instructional videos and solve relevant questions. Meanwhile, our data collection application was running in the background to collect two video streams: (1) Student appearance videos from the camera (to monitor observable cues available in the student's face or upper body); and (2) student desktop videos (to monitor contextual information).

3 Labeling Tool, Human-Experts, and Training

A labeling tool was developed and customized for use in multiple labeling experiments. In Fig. 2, a sample view for labeling Valence is shown.

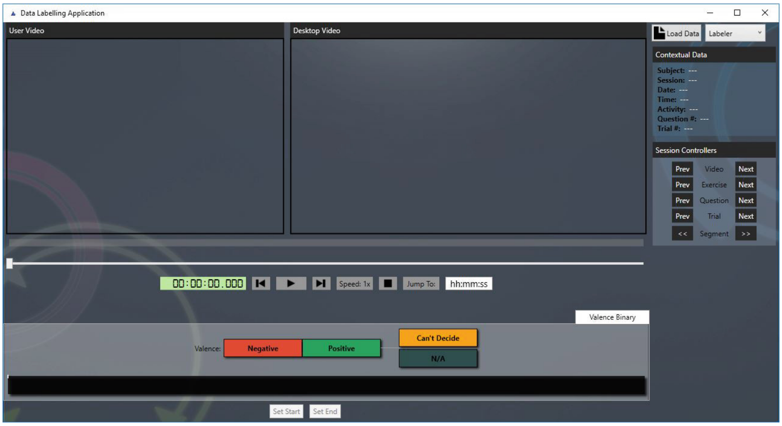

Fig. 2. Customized labeling tool (sample view), for labeling Valence.

Using HELP [13] as a baseline labeling protocol, five human experts with backgrounds in Psychology/Educational Psychology were recruited and trained (See Tables 1 and 2 for operational definitions of labels). Based on observed state changes, the experts provided their Valence-Arousal or discrete affect labels using all available cues (e.g., student video/audio, desktop recording with mouse cursor locations, and any relevant contextual information from the device and content platform).

Table 1. Operational definitions of discrete affect labels

	Operational definitions
Satisfied	If a student is not having any emotional challenges during a learning task. This can include all positive affective states from being neutral to being excited during the learning task; neutral is included here along with positive
Confused	If the student is getting confused during the learning task – in some cases this state might include some other negative affects such as frustration (argued by [10] to represent an increased level of confusion)
Bored	If the student is feeling bored during the learning task

Table 2. Operational definitions of Valence-Arousal labels

	Operational definitions
Valence	The direction of a student's affect during the learning process with two levels: ***Positive:*** The student seems to experience neutral or positive affect (e.g., s/he is feeling calm, satisfied, excited, etc.). Any neutral or positive affect is placed within this category. ***Negative:*** The student seems to experience negative affect (e.g., s/he is getting frustrated, stressed, agitated, bored, etc.). Any negative affect is placed within this category
Arousal	Level of activation in physical response of the student during the learning process with three levels: ***Low:*** The student does not seem to be emotionally activated, dynamic, reactive, or expressive of his/her affect. ***Medium:*** The student seems to be emotionally somewhat dynamic, reactive, and expressive of his/her affect. ***High:*** The student seems to be emotionally very dynamic, reactive, and expressive of his/her affect

In total, the human experts labeled seven hours of student data for Valence-Arousal labels first. One week later, we asked them to label the same data for discrete affect labels. Note that although the experts labeled Arousal using three different levels, we combined Low and Medium labels into a Low class for analysis of the labeled data based on the experimental results outlined in [14].

4 Comparing Discrete Affect Labels to Valence-Arousal Labels

4.1 Pre-processing of Label Data

To analyze labeling output data, both for discrete affect and Valence-Arousal labeling outputs, two pre-processing steps were taken: First, we applied windowing on the labeling output data to obtain aligned instance-wise labels of each individual expert. Second, to facilitate analysis, we derived a consensus label from all the expert labels for each instance, using majority voting in each case.

4.2 Metrics for Analysis

The derived consensus labels were then correlated to each other to measure the degree to which each discrete affective state mapped to each Valence-Arousal quadrant. Note that we already presented the hypotheses for how discrete affective states would map to Valence-Arousal in the Introduction section (Fig. 1). We calculated the degree of mapping using Precision, Recall, and F1-measures. For these calculations, the labeled set (e.g., discrete affective states) act as the true labels; whereas the mapped set (e.g., Valence-Arousal mapped to discrete affective states as hypothesized) serve as the predictions. Precision is calculated as the fraction of true predictions (i.e., true positives) to the number of all predictions (i.e., sum of true positives and false positives); whereas recall is calculated as the ratio of true predictions to all true labels (i.e., sum of true positives and false negatives). The F1 measure is calculated as the harmonic mean of precision and recall values, taking into account the trade-off between those two measures. In addition, we also checked inter-rater agreement measures for different labeling tasks (i.e., Discrete Affects, Arousal, Valence) to assess reliability of the obtained label data. As proposed in HELP [13], we utilized Krippendorff's alpha metric to compute inter-rater agreement among experts.

4.3 Methods for Analysis

To investigate whether the discrete affective states (i.e., Satisfied, Bored, and Confused) actually map to the hypothesized Valence-Arousal quadrants, the degree of mappings was computed using the final labels for the following mapping/comparison sets:

- Valence vs. Discrete Affect-to-Valence: We compared Valence labels to discrete affect labels, where affect labels were mapped to Valence labels using: Satisfied to Positive Valence, and Bored/Confused to Negative Valence.
- Arousal vs. Discrete Affect-to-Arousal: We compared Arousal labels to discrete affect labels, where affect labels were mapped to Arousal labels using: Bored to Low Arousal, and Confused to High Arousal. Note that Satisfied samples were disregarded in this case since we hypothesized that they could map to both Low and High Arousal on the Circumplex Model of Emotion (See Fig. 1).
- Discrete Affect vs. Valence/Arousal-to-Discrete Affect: We compared discrete affect labels to Valence-Arousal labels, where Valence-Arousal label pairs were mapped to discrete affect labels using: Low/High Arousal & Positive Valence to Satisfied, Low Arousal & Negative Valence to Bored, and High Arousal & Negative Valence to Confused.

5 Results

5.1 Mapping Between Discrete Affect and Valence-Arousal Labels

The Precision, Recall, and F1-measures calculated for each mapping sets are summarized in Table 3. As these results indicate, relatively higher F1 measures (consistent for both state-specific and overall results) could be achieved when discrete affect labels were mapped to Positive/Negative Valence (i.e., Valence vs. Discrete Affect-to-Valence). However, the F1 values were lower when discrete affect labels were mapped to High/Low Arousal (i.e., Arousal vs. Discrete Affect-to-Arousal). Although the overall F1 measures seemed reasonable when Valence-Arousal labels were mapped to discrete affects (i.e., Discrete Affect vs. Valence/Arousal-to-Discrete Affect), the state-specific measures highlighted the inconsistency. The reason behind that could be the fact that the distribution of High Arousal samples was lower than $\sim$1.2% in the data, and the samples that were labeled as Confused were therefore drawn mostly from the Low-Arousal samples. This issue was mostly visible when we investigate the Valence-Arousal vs. Discrete Affect mapping Recall and F1 results. Note that although we disregarded Satisfied samples in Arousal vs. Discrete Affect-to-Arousal case with the hypothesis that they could map to both Low and High Arousal, we also checked and observed that among all the Satisfied instances, 99.8% are mapping to Low Arousal and only 0.2% are mapping to High Arousal. Note that this issue is common in all three discrete affective states: Satisfied (0.2% High Arousal), Bored (2.2% High Arousal), and Confused (3.3% High Arousal).

Table 3. Precision/Recall/F1 measures for the mappings between discrete affect labels and Valence-Arousal labels

Mapping/comparison set	Precision	Recall	F1
Valence vs. Discrete Affect-to-Valence			
Positive (Satisfied)	0.99	0.71	0.82
Negative (Bored/Confused)	0.41	0.96	0.57
Overall	0.75	0.75	0.75
Arousal vs. Discrete Affect-to-Arousal			
Low (Bored)	0.98	0.49	0.65
High (Confused)	0.03	0.64	0.07
Overall	0.49	0.49	0.49
Discrete Affect vs. Valence/Arousal-to-Discrete Affect			
Satisfied (Low/High & Positive)	0.71	0.99	0.83
Bored (Low & Negative)	0.75	0.51	0.61
Confused (High & Negative)	0.73	0.02	0.04
Overall	0.72	0.72	0.72

5.2 Inter-rater Agreement for Discrete Affects and Valence-Arousal Labeling

The inter-rater agreement results for discrete affect labeling compared to the Valence-Arousal labeling are given in Table 4. The average of all confusion matrices computed for discrete affect labels provided by all pairwise experts (i.e., any two expert pairs among the five experts) is given in Table 5. As these results indicate, the inter-rater agreement was lower for discrete affect labeling, where the pairwise confusion results showed that the experts had difficulty differentiating between Satisfied and any one of the other two states (Bored or Confused).

Table 4. Consensus measures for Discrete Affects vs. Valence-Arousal

Dataset details		Consensus measures		
Student count	Total number of hours	Valence	Arousal	Discrete affects
5	7	0.495	0.602	0.437

Table 5. Average of pair-wise confusion matrices for discrete affects

	Satisfied	Bored	Confused
Satisfied	1016.7	171.5	221.6
Bored	231.4	365.9	44.2
Confused	328.6	36.8	319.1

6 Conclusion

In this paper, through a comparative approach, we investigated the two key paradigms of how affect is represented: (1) Affect as a set of discrete states and (2) affect as a combination of a two-dimensional space of attributes. We specifically examined a set of discrete affective states (Satisfied, Confused, and Bored) that can be reasonably expected to map to specific locations within the Valence-Arousal dimensions of the Circumplex Model of Emotion [11]. We tested two major hypotheses: (1) Whether these mappings between discrete affects and Valence-Arousal are valid and (2) whether affect labeling is more reliable with discrete affects or Valence-Arousal. To investigate these hypotheses, we used HELP [13] as a baseline labeling protocol. Using HELP, five human experts labeled seven hours of student data for Valence-Arousal and discrete affect labels.

The relatively low F1 measures (See Table 3) indicate that the discrete affect labels (i.e., Satisfied, Bored, and Confused) do not directly map to Valence-Arousal quadrants in the Circumplex Model of Emotion [11]. This shows that the human experts perceived and labeled these two relatively differently although we reasonably expected the discrete affects to map seamlessly on the model. On the other side, the inter-rater agreement results (See Table 4) show that the experts moderately agree with each other in both discrete affect labeling and Valence-Arousal labeling.

There are two important implications of these major results to researchers in learning analytics field. First, how affect is conceptualized in one paradigm could not be seamlessly transferable to another paradigm (i.e., discrete affective states do not directly map to Valence-Arousal quadrants). Therefore, researchers need to decide on affect labels of interest at the beginning of research considering this limitation. Second, both discrete affect labeling and Valence-Arousal labeling resulted in moderate consensus among the experts. Therefore, researchers should consider how affect information would ultimately be used in a learning system (e.g., affect-aware interventions, feedback to content, etc.) when choosing from Valence-Arousal or discrete affect labeling to generate ground-truth labels for model development.

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An Emotion Management System via Face Tracking, Data Management, and Visualization

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Abstract. There is a growing concern about students' psychological health at school with mounting pressure as students approach middle school or college age. In light of the fact that the current means of psychological intervention are basically manual intervention, this research explored the possibility of using technology to assist psychological intervention. An emotion management system is thus implemented to provide facial emotion cognitive service and video diary function. In addition to the advantage of keeping a normal diary, students benefit by regulating their emotion when they are recording videos. Teachers can keep track of students' emotion states so that they can provide corresponding psychological supports when students showed signs of mental disorders. We performed a small-scale pilot study at a local school with satisfying results.

Keywords: School · Students · Facial tracking · Emotion detection Video diary

1 Introduction

There are a variety of factors which can affect students' mental health, such as violence and school bullying [2, 6], parental divorce [4], etc. Research has shown these factors, which attribute from the lack of care by teachers and parents, could cause children's social anxiety problems, particularly for left-behind children in Chinese rural area [9, 10]. Emotion regulation is such a complicated procedure that involves decision making in each emotion generative process [3]. Untrained students may not handle their emotion regulation easily, which may result in the development of mental disorders. Previous research has shown that about 20% children have experienced mental disorders [1]. The typical mental disorders universally happened in children are a social anxiety disorder, selective mutism, obsessive-compulsive disorder and posttraumatic stress disorder [5]. Teachers or parents are suggested to have mental health training, since a number of previous research has shown positive results of mental health interventions at schools [2, 7, 8]. In the schools where there is a counseling center, the processes of tracing students' mental health, taking Hall-Woodward Elementary School for example, are: (1) teaching lessons of guidance on counseling; (2) having individual or group counseling; (3) holding relevant school events; and (4) organizing guidance curriculum program [11]. Some schools also take questionnaires at the beginning of semesters to

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obtain students' mental health condition. However, neither taking questionnaires nor providing courses could provide just-in-time intervention to help students manage their anxiety and stress which are common in schools worldwide. Once school bullying happens, we cannot expect questionnaire or psychology class can take effect immediately and pertinently. Some students incline to hide the fact of being bullied, which may trigger off a series of mental disorders like depression or anxiety.

Emotion regulation is a way to control and express one's emotion in both internal and external way appropriately to meet his or her social demands [13]. People are suggested to meet socio-affective needs, cognitive needs and action needs [14], among which the appropriate expression of emotion is a part of them. Self-statement is beneficial for emotion regulation, and it provides a space for students to estimate themselves.

Motivated by the aforementioned studies, we design a system that prompts students to reflect their emotion in time, and provides teachers and parents with just-in-time responding to and intervening the emotional disorders in an effective time period. What we especially design for students is a Universal Windows Platform (UWP) application of emotion video diary. This diary applies Microsoft cognitive service so that it has emotion cognitive function. So the whole system is an assistive tool for teachers and parents to care about students psychological conditions.

2 Related Work

A video diary can save children's time and help them to practice the ability of expression [15]. In some research, an electronic diary is used for analyzing emotions. Research such as [16, 17] predicts pain for children with Juvenile Idiopathic Arthritis by analyzing emotion regulation from an electronic diary. In our market survey, electronic diaries prompt users to accomplish questionnaires such as anxiety and depression scale [17], so that the applications can analyze the data from the questionnaires. Some other research read the facial emotion of children with autism and social phobia [18, 19]. This research motivates our system design in that video diary can be combined with an emotion recognition module to detect students' mental disorders in time.

3 Our System: Emotional Management System

3.1 Design Motivation and Goals

Our system mainly targets at two groups of people: students and teachers. The main design goals of our system are to help students acquire and practice emotion regulation skills, and give teachers an early warning of students' potential mental disorders.

3.2 Overall System Architecture

Figure 1 shows the overall system architecture. Students access this system from the application, called Our Happiness Index. It is a UWP application, requiring Windows 10 tablet or laptop with a front camera. We assume it can run Microsoft Emotion

Tracking API, but from our preliminary testing the real-time emotion tracking system causes a severe network latency. So we redesigned the application to capture students' facial image each 10 s, and analyze the facial expression based on the still images. Data comes out as a formation of scores of each affective categories (e.g. anger, contempt, disgust, etc. [12]). And the results will be stored in a local database. Students could access the application using their own mobile devices; in such case the local database only stores individual data containing personal information, video recording and emotion scores to ensure personal data protection. Only a few personal information which attempts to distinguish students and the emotion scores will be uploaded and synchronized on Azure Cloud SQL server. Scored emotion is visualized on a website (http://trickuth.azurewebsites.net/, last accessed 2018/01/27), where teachers can log into it to check students' periodical emotion states. At this moment, the daily emotion states of a student are their highest-frequency states in a day. In fact, teachers may see the complete states in a given day and compute the average states, minimum (negative) states, etc.

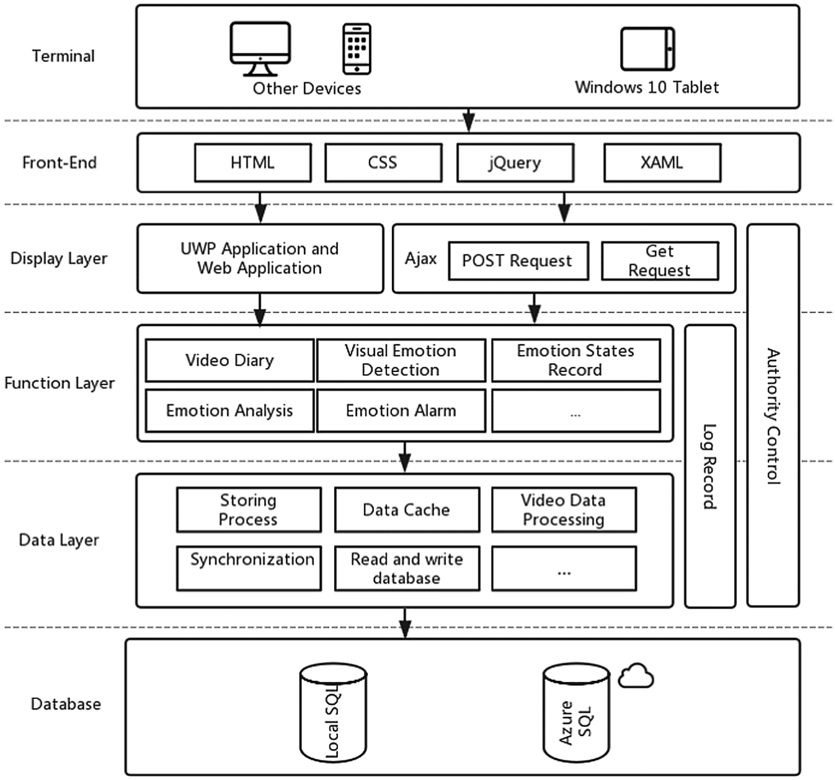

Fig. 1. The overall system architecture of emotion management system

3.3 Main System Feature on Emotion Computation via Face Tracking and Personal Video Diary

Figure 2 shows the general use of our system. The part of the system, the application named Our Happiness Index (Fig. 3), is designed for students. It is an emotion-oriented video diary application. We posit that when using the application, students not only make verbal expression but also facial emotion at the time when they are recording the video. Since the current application only uses face API, it provides a channel that allows students to express both positive and negative emotion. By expressing feelings, the application allows the students to observe their own emotion changes and raise the alarm when negative emotion continuously persists. The latter provides teachers windows of opportunity to work with the student to regulate their emotion accordingly.

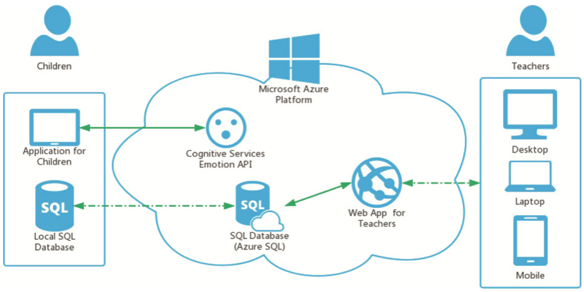

Fig. 2. System sketch maps with Microsoft Azure services

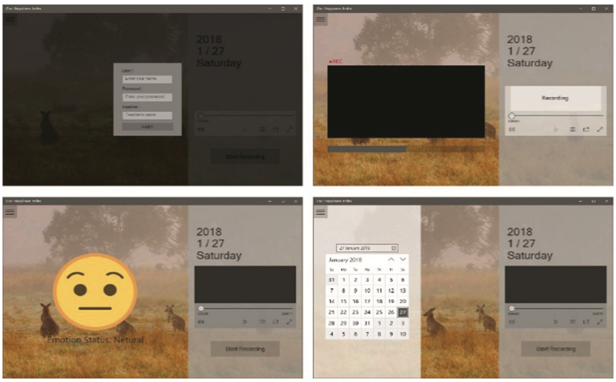

Fig. 3. Demonstration of Our Happiness Index for students

The other visual part of the system is a web application for teachers. In the website, teachers can see all students' emotion states at a time, and to check everyone's emotion state for a particular day or a longer-term (Fig. 4). Thus, when some students fall into a depressive state, teachers can have enough preparation of mental health intervention.

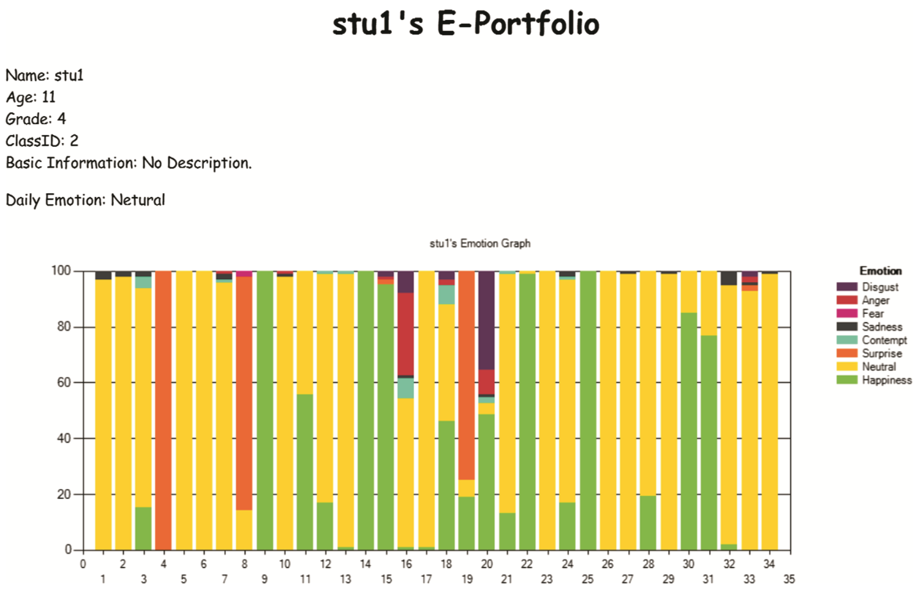

Fig. 4. Visualized report of a student's daily and long-term emotion

4 Discussion

Our system is a combination of video diary as a form of emotion cognitive service and mental disorder detection. Comparing with a paper diary, the video diary is more convenient and flexible for students. It also promotes students to speak confidently facing a camera, so that they reflect themselves and get to know how to regulate and manage their emotion. At the same time, teachers benefit from the system by acknowledging students' emotion state and prepare for psychotherapy intervention.

However, due to the operation mechanism of our system, the data we acquired from the emotion was not always accurate. Captured images cannot represent students' dominated emotion in the recording. What's more, emotion in the recording also cannot represent the emotion all day long. Hence it could only be an assistive system to help teacher judge students' emotion states at a glance, but we do not ensure the results from the system are absolutely right. In other words, professional psychotherapy is still essential for curing mental disorders without a doubt.

Moreover, the chances are that emotion regulation is related to trait resilience [6]. Therefore, we need to give students proper time, let them recover by themselves, then offer help when necessary.

5 Concluding Remarks

We present an emotion management system for assistive use on mental health tracking. The major group is students in schools because they lack the ability to regulate emotion and could easily have mental disorders. Our system is capable of picking up persistent negative emotion which thus provide windows of golden opportunity for teachers and parents to intervene on time.

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Stress-Mentor: Linking Gamification and Behavior Change Theory in a Stress Management Application

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Abstract. Gamification is widely accepted in mobile health applications as one way to enhance user experience. Moreover, linking gamification with insights from behavior change theory offers a promising approach to ensure user's adherence and long-term behavior change. Gamification is, however, hardly found in current stress management applications. To close this gap in research, we present Stress-Mentor, a stress management app that realizes established behavior change techniques within an extensive gamification framework.

The main gamification elements of Stress-Mentor are an avatar, an agent, the accomplishment of regular tasks, experience points, virtual currency, and badges. These features are activated consecutively to keep the user interested. Each gamification element is linked with several behavior change techniques. The regular tasks teach a broad range of proven stress management techniques.

Stress-Mentor's usage duration is limited by design to ensure the user's autonomy. After the three month usage period, users should be able to apply the stress management methods in their daily life without the app. The presented gamification concept can be easily adapted for other applications to support mental and physical health.

Keywords: Gamification · Mobile health · Behavior change

1 Introduction

The effective combination of insights from behavior theory and gamification in mobile health systems is a promising approach in order to ensure users' adherence and long-term behavior change. Recent reviews of stress management applications (apps) show, however, that the use of evidence-based content from behavior theory strongly varies across apps [1–4] and that gamification is even less often applied [5].

2 Stress-Mentor

To fill this gap, we designed and implemented a novel stress management application, named Stress-Mentor. It realizes effective behavior change techniques from psychological interventions using an extensive gamification framework. The respective behavior

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change methods are based on an established taxonomy [6]. They are highlighted within the text by quotation marks. Stress-Mentor's most distinctive characteristics are limited usage duration by design and the following tiered gamification methods to keep the user interested (Fig. 1).

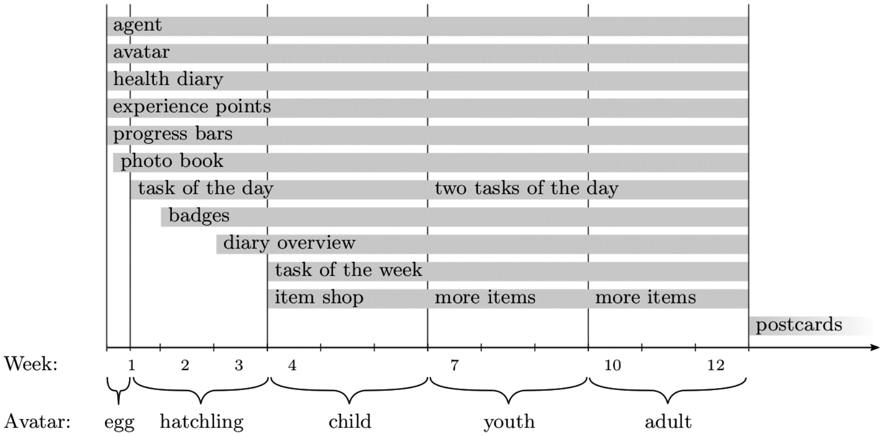

Fig. 1. Timeline of gamification methods in Stress-Mentor.

2.1 Avatar

The avatar, a bird-like cartoon animal residing in a forest scene, is used for vicarious reinforcement. Vicarious reinforcement describes the behavioral effects of observing and interpreting the rewards and punishments experienced by others [7]. To realize this powerful finding from social cognitive theory, the avatar's appearance is linked to a health diary. In this diary the user enters stress-relevant behaviors (sleep, nutrition, and exercise), well-being (subjective stress level, emotional state), and the occurrence of positive and negative events (daily hassles and social uplifts) in the past 24 h. Each diary category has an impact on the avatar's appearance depending on the last seven entries (e.g. less stress leads to a fuller plumage) to "provide information about consequences". The avatar's overall condition mirrors to what extent the health recommendations in the diary were followed during the past week ("provide contingent rewards"). This approach has been shown to support continuous usage behavior over a four week interval, compared to a control condition with a static avatar (see [8] for details). Moreover, the avatar's size mirrors the progress within the app ("provide feedback on performance").

In addition to this indirect feedback, direct feedback based on current health recommendations [9–12] is given through a color scheme analogous to traffic light colors, while the user is entering the data and in an overview diagram [13]. The avatar's size provides feedback regarding the user's progress within the app. To track the avatar's development and to counteract change blindness, the user is given the opportunity to make photos of the avatar (photo book, Fig. 2, left) and to share these photos with friends ("provide opportunities for social comparison").

2.2 Agent

The agent, a wise owl, serves as the user's mentor. It instructs the app usage and introduces new app features ("provide instruction"). It also "provides general information" about stress management and about the "consequences of behavior change" in form of short tips (Fig. 2, right). These tips also target "social support", "time management", and the "identification of barriers" (e.g. "It is important to identify barriers in our daily life which prevent us from reaching our goals. When you are aware of them you can include them in your plans"). It also shows encouraging quotations from prominent figures (e.g. "Success is falling nine times and getting up ten" by Jon Bon Jovi.) to "provide general encouragement". Moreover, at the very first start of the app, the agent entrusts the care of the avatar to the user, who in order to raise the avatar and prepare it for its future life, needs to fulfill the tasks given in the application ("agree behavioral contract"). The owl's daily reminders to complete the tasks and to fill out the stress-diary help to "prompt daily practice" and to "prompt self-monitoring behavior".

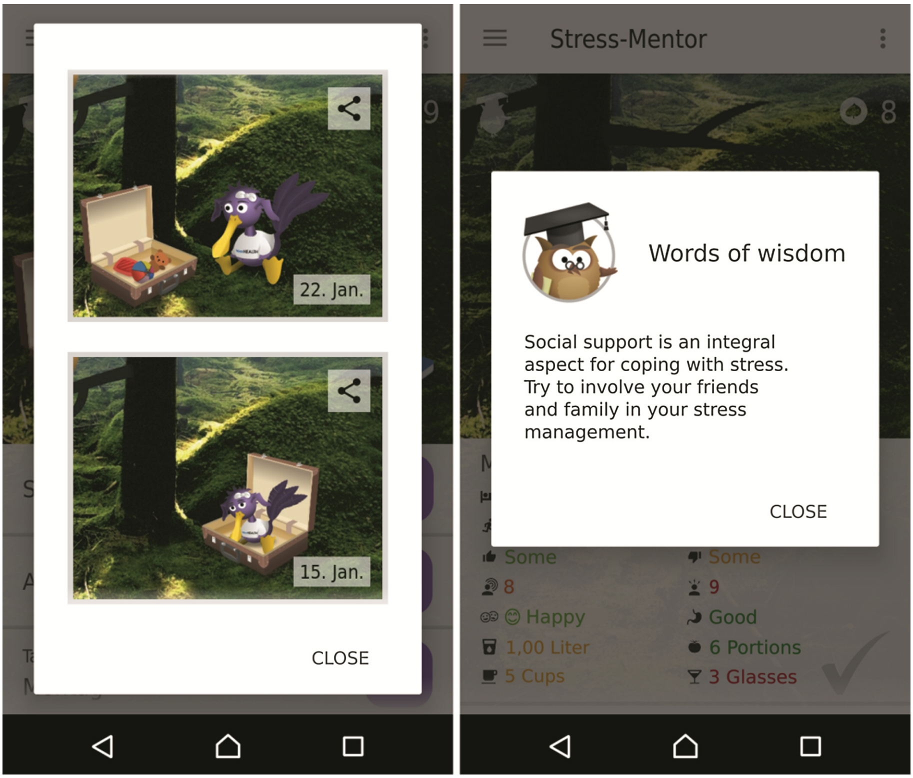

Fig. 2. Left: Example of the photobook to track the avatar's development. Right: The "wise owl" providing general information about stress management.

2.3 Task of Day/Week

In order to progress in the app and raise the avatar, the user has to complete a certain number of tasks which teach proven stress management strategies. These tasks vary from relaxation methods (e.g. breathing exercises, meditation) to tasks to support establishing priorities, learning to accept help from others and refuting irrational ideas. The corresponding behavior change techniques are described in Table 1.

Table 1. List of behavior change techniques according to [6] and how they are realized within the tasks of the day/week.

Behavior change technique	Realization within the tasks of the day/week
Provide general information	Health information for every diary category, e.g. how much caffeine should be consummated at the most
Information about consequences	Information about stress is linked to nutrition, regular exercise, emotions and the appraisal of events
Prompt intention formation	Every day the user can chose 1 task out of 3 which he or she wants to accomplish today
General encouragement	Praise at the end of the tasks
Set graded tasks	Task difficulty increases within the different categories, e.g. relaxation exercises start with detailed audio instructions, followed by shortened audio versions and expert versions with text instructions. By completing the easy tasks more difficult tasks will be available in future sessions
Provide instruction	Multiple types of instruction are used: text, audio files, multiple choice quizzes, and photos
Stress management	Task categories comprise relaxation methods, time management, revealing and refuting irrational ideas, assertiveness training, planning social support, general knowledge about stress management, euthymic methods, and physical tasks for muscle relaxation and stress relief
Model or demonstrate behavior	Physical exercises are demonstrated with different photographs, explaining each step in detail
Provide feedback on performance	The user's knowledge about stress management, irrational ideas and health is tested in quiz tasks with direct appraisal
Teach to use prompts	Embedded in the tasks for time management and relaxation, e.g. short breathing exercises can be performed each time before answering the phone
Prompt practice	Reminders to complete the tasks of the day and tasks of the week
Plan social support/social change	Separate task category, e.g. the user is asked to integrate help from friends and family in his daily life
Prompt self-talk	Used within some relaxation exercises
Relapse prevention	Separate task category, e.g. the user is asked to develop a plan in case symptoms are becoming extremely severe
Time management and prompt barrier identification	Separate task category which teaches effective planning and to set priorities

First the user is offered a selection of three stress management exercises per day ("tasks of the day"). These exercises are chosen based on the user's mental and physical symptoms, which are queried weekly. As the user progresses, a second "task of the day" and tasks spanning up to seven days ("task of the week") can be completed to support further practice.

2.4 Visualization of Progress

Each finished task rewards the user with experience points and virtual currency, which can later be exchanged for virtual items in a shop. These items are thematically fitting to the topic of preparing the avatar for its future life, such as a soft blanket, a calendar, or books. They support the visualization of the user's progress by being placed in a suitcase next to the avatar (see Fig. 3, left).

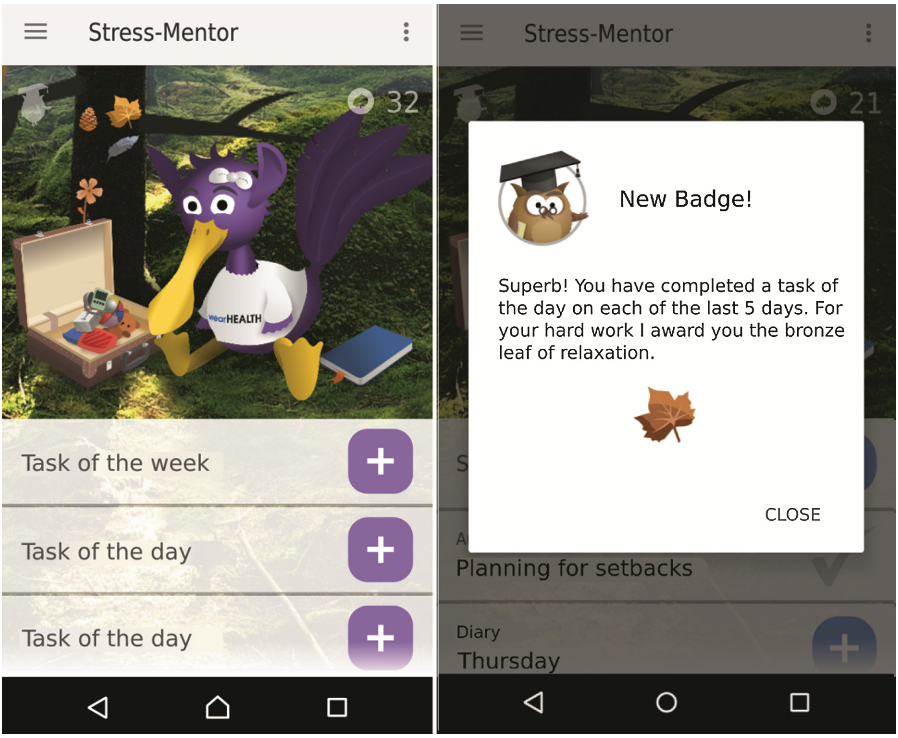

Fig. 3. Left: Screenshot of Stress-Mentor, showing the avatar and the suitcase, filled with virtual items. The badges are placed on the tree-trunk. The experience points are displayed on the right upper corner. Right: The wise owl hands a new badge to the user, who has completed the tasks of the day on a regular basis.

Besides progress bars, another visualization of progress and reward is implemented through badges. Badges can be earned by e.g., consistently keeping the diary and following the health recommendations (see Fig. 3, right).

The aspect of discovery is realized through several methods that are distributed throughout the app (e.g., after reaching a new level the avatar grows, discounts on items in the shop, opportunity for taking photos is not fully predictable). Generating unpredictability in this manner is expected to encourage the user to return.

After finishing the designated usage period, the avatar leaves, symbolizing freedom and autonomy. The user receives postcards from the avatar on a regular basis to "provide follow-up prompts".

3 Outlook

The presented gamification concept can be easily adapted for other applications to support mental and physical health. The behavior change techniques which are associated with the agent, the avatar, the photo book, the experience points, the acquisition of items for the avatar and the badges are not restricted to the stress management context and are therefore useful for a broad range of intervention technologies. The "task of the day" and "task of the week" features offer a universal tool to teach skills and knowledge in mobile health, as their content can be adapted to the respective context. In future studies, we will investigate the effects of this gamification concept on users' intention to use Stress-Mentor and actual usage behavior.

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Chat-Box: Proposing a Mood Analyzer for Individuals with Social Interaction Disabilities

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Abstract. Perception of social cues is a fundamental communicative skill that can be hampered by hearing and cognitive disorders. Understanding slang and sarcastic intent is often difficult in verbal communication, particularly for individuals who struggle with the perception of social cues. Misinterpretation of slang terms can cause discomfort or social isolation. Sarcasm is particularly difficult to recognize due to its inherently ambiguous and context-dependent nature. We have identified two problems of particular interest in social assistive technologies – slang word sentiment assessment and sarcasm detection. We propose combining a slang sentiment analysis model with a speech emotion analysis model to create an assistive tool, *Chat-Box*, which will detect social cues such as sarcasm, slang, and sentiment.

Keywords: Slang · Sarcasm · Speech · Word2Vec · Slang2Vector
Wire-frame · Assistive technology

1 Introduction

Difficulty in perceiving verbal emotional cues can arise from hearing impairments and cognitive disorders [1]. There are over 466 million people with disabling hearing-impairment worldwide, 34 million of whom are children [2], and an estimated 1 in 88 children in the United States has an autism spectrum disorder (ASD) [3]. Children with ASD in particular face difficulty with perceiving social cues [4]. Social anxiety can give rise to and be reinforced by social cue misinterpretation [5]. This ability to perceive verbal social cues is a central element of social competence [6], which is assessed by quality of social outcomes [7]. Intervention to promote the successful development of social competence can produce improvements in an individual's psychopathology later in life [8], alleviating potential depression and isolation. Thus, a tool that can aid in perception of social cues can produce positive developmental outcomes later in life.

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Informal words used in informal conversations, i.e. slang words, are not always included in the corpora which are used to train sentiment polarity models [9]. However, these slang words are an important part of everyday colloquial speech [10]. Models that neglect slang words can miss the meaning or even get the polarity completely wrong [9].

Sarcasm is a form of speech where speakers implicitly convey their messages to mean something different from the normal textual meaning [11]. The inherently ambiguous nature of sarcasm sometimes makes it hard for humans to decide whether an utterance is sarcastic or not, particularly in the case of individuals with social interaction disabilities or hearing impairments [12].

Addressing both of these challenges is necessary to create a useful assistive tool for emotional cue analysis. Thus we propose Chat-Box, a novel tool which monitors conversations in real-time and provides the user with auxiliary information, in particular sarcasm-aware sentiment analysis. We provide a brief survey of important previous work that informs the design of this tool and a description of our proposed approach.

2 Related Work

Multi-modal sentiment analysis approaches have been popular lately [13,14]. Both slang word analysis and sarcasm detection have great utility beyond assistive technologies, with the potential for better summarization, dialogue management, and review ranking systems [12].

2.1 Textual Sentiment Analysis

Textual sentiment analysis is valuable in a wide variety of disciplines [15]. Opinion mining, reliant on sentiment strength detection is a task of interest in business analytics [16,17]. Very large text posts and online conversation corpora have been mined from platforms such as Reddit, Facebook, and Twitter [18–20]. However, traditional sentiment analysis machine learning based models tend to rely on assumptions such as the use of formal English spelling, grammar, and register. This limits the effectiveness of these models in real-world use cases where user-generated content is short and informal, such as inclusion of "lol", "sup" and "ya". We refer to such informal words that are not present in the dictionary but are regularly used in informal conversations as slang words. More accurate sentiment analysis driven by better slang corpora has the potential to improve summarization, review ranking, sarcasm, and opinion extraction.

2.2 Slang Analysis

Baccianella et al. [21] proposed SENTIWORDNET3.0, a lexical resource explicitly devised for supporting sentiment classification and opinion mining applications. It was developed by classifying the sentiment strength of WordNet synsets according to the degree of neutrality, positivity, and negativity. Based on SENTIWORDNET3.0, Wu et al. [9] introduced SlangSD Dictionary, a look-up table for slang words and their sentiment polarities, using the existing lexicons such as SentiWordNet [21], LIWC [23], MPQA [22] and using the algorithms DeeplyMoving [24] and SentriStrength [21]. The SlangSD assigns sentiments to slang words in the following categories; strongly positive (+2), weakly positive (+1), neutral (0), weakly negative (−1) and strongly negative (−2).

2.3 Textual Sarcasm Detection

Researchers have worked on detecting textual sarcasm on corpora including information mined from Twitter [26,27] and Amazon reviews [28]. Significant progress has been made using methods including semi-supervised pattern extraction and hashtag-based supervision [29]. However, modeling sarcasm in text remains a challenging problem due to difficulties involved in modeling context [25,30], and for more general corpora hashtag analysis will not be viable. Hence, we are particularly interested in using verbal emotional cues supplemented with textual ones to drive better sarcastic sentiment interpretation.

2.4 Spoken Emotion Classification

Speech sentiment analysis also shows promise as a useful assistive communication technology for individuals with social disabilities. Current promising methods typically employ convolutional neural networks on spectra extracted from speech, using Fourier spectrograms or Mel-frequency cepstral coefficients (MFCCs).

Kim et al. [31] used a deep "3D Convolutional Neural Networks (3D-CNN)" architecture to capture spectro-temporal features across an entire spoken phrase's spectrogram. Trigeorgis et al. [32] used convolutional neural networks to learn instantaneous spectral features on spectrogram slices, using long short-term memory (LSTM) to learn the time dependencies between the features. Neumann and Vu [33] demonstrated cross-lingual spoken emotion labeling using time-convolving convolutional neural network with MFCCs as input.

Zadeh et al. [13] demonstrated multi-modal sentiment labeling using a "Multi-attention Recurrent Network", which runs LSTHM (Long Short-Term Hybrid Memory) blocks on instantaneous chunks of the raw speech, text, and video signals for emotion detection and then feeds them into a "Multi-Attention Block" that captures cross-view dynamics between the three modalities. This whole architecture is run recurrently to estimate the speaker's emotion.

3 Chat-Box: Slang Analysis

Slang sentiment polarity models require a sufficient amount of data featuring text and speech conversations containing natural slang words. Currently available tools for sentiment polarity analysis such as the Word2Vec model [34] are designed to remove and ignore "abnormal" phrases including typos and slang words. This is problematic because slang words can play a crucial role in determining the sentiment and meaning of the complete sentence. For example, someone says, “that ain’t cool, Bro”. A naïve sentiment analyzer would miss the slang meaning of “ain’t” as “is not” and mistakenly label the phrase as positive sentiment, based on the presence of “cool” and additionally not consider “Bro”, because slang words are typically dropped [9]. In this work, a wider range slang words receive sentiment polarity assignments, allowing the meaning of a sentence to be correctly parsed.

For slang word analysis, we used a crawler-parser to extend the SlangSD Dictionary provided by Wu et al. [9]. We used SentiWordNet, Micro-WNOp and WordNet to extend the extracted slang words. http://onlineslangdictionary.com and http://urbandictionary.com were used to collect slang words data. To efficiently assign sentiment polarity to new slang words, we propose a “Slang2Vector Model” which is an extension to the Word2Vec model [34] along the lines of SentiSD [9]. This model will consider the slang words for assigning sentiment polarity to them instead of filtering them out as stop words.

4 Chat-Box: Sarcasm Detection

Sarcasm is often included in both textual context and verbal intonation [11]. For example, the phrase “you did a fantastic job” can be certainly understood to be positive in the wake of an accomplishment. However, after a failure, the same phrase carries a very negative meaning. Using only text, context becomes important for determining the intended sentiment [29]. However, when the phrase is spoken aloud (as in “you did a *fantastic* job”) the sarcastic intent is easier to parse [35].

We propose using Chat-Box to detect and understand sarcasm to enhance social interactions for individuals with social interaction disabilities, in order to promote social inclusion and participation.

5 Chat-Box: Proposed Approaches for Designing Models

The architectures discussed in the related work section can be adapted for this task. The speech emotion analysis architectures focus on capturing spectro-temporal features, which can include intonation changes involved in spoken sarcasm [11].

A naïve approach separately computes textual sentiment using the proposed Slang2Vector model, and speech sentiment, relying on cases where the sentiment polarities reported by the models are in opposition to determine sarcasm.

A more advanced speaker interactive sarcasm detection system might fuse the speech signal spectro-temporal features with the word embedding within its recurrent structure, as suggested by Zadeh et al. [13]. This method would require a labeled dataset of “sarcastic speech” and ordinary speech, which presently does not exist. A dataset collected from a web-video service could serve this purpose, we are assessing acquiring permissions for this.

Another way to collect such a dataset could involve using sample slang word sentences from onlineslangdictionary.com and urbandictionary.com. A future user study can record these statements spoken by different people in their interpreted mood. This approach can yield a small dataset to design the above proposed model as a prototype. Due to a large number of users necessary to compose the dataset, this is a time-consuming task; however, when completed, it will vastly improve the potential of a sarcasm detection model which incorporates slang words. However, this dataset would not contain real, "in the wild" data, limiting its usefulness.

The CMU-MOSEI dataset contains video, speech, and text of speakers with emotion labels, which has been extracted from online video sources [36,37], but that would also be time consuming.

6 Chat-Box: Demonstration

The goal here is to depict the vision for a fully-developed Chat-Box guiding the person with social interaction disability in a crowded sports stadium.

Figure 1 depicts a person A, with a social interaction disability entering a sports stadium and another person, say B, attempting to speak with A. Speech can be difficult to understand for A due to the amount of noise in the stadium.

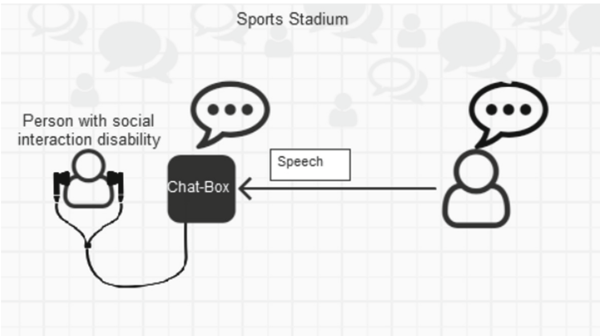

Fig. 1. Example of use case scenario

Figure 2 depicts the Chat-Box capturing B's speech, storing it as a WAV file and passing it through internal automatic speech recognition (ASR) system to get the textual content of B's speech.

In Fig. 3, Chat-Box predicts the sentiment polarity of the speech into five classes: strongly negative, weakly negative, neutral, weakly positive and strongly positive. Existing neural network models can predict sentiment polarity of the stored WAV audio [31]. The SlangSD-based Slang2Vector model [9] can be used to predict the textual sentiment polarity. In this scenario, the models work separately and analyze the sentiment polarity of the same speech using different

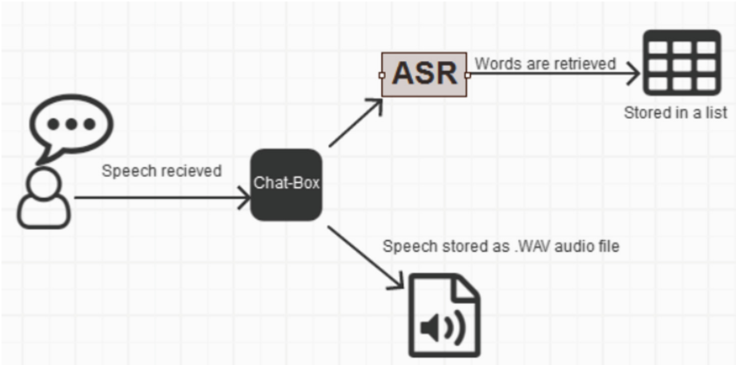

Fig. 2. Chat-Box's processing steps

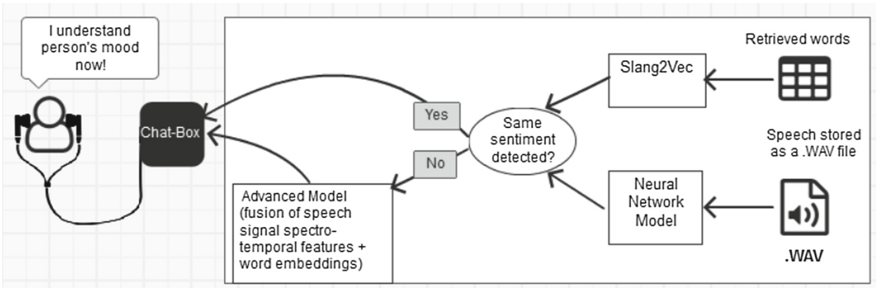

Fig. 3. Proposed models for sentiment prediction

models. If the sentiment polarities reported by the models are in opposition, Chat-Box concludes it as a sarcastic comment.

7 Conclusions

We propose designing a social interaction tool: Chat-Box, to assist individuals with social interaction disabilities by detecting sarcasm and emotion from speech. We outline the steps for creating a novel Slang2Vector along with a verbal emotion recognition engine that can be trained to identify sarcasm. Once the problem of identifying real colloquial spoken intent can be meaningfully solved, Chat-Box can be further developed for best sharing its insights with an individual. Social cues perception is very impactful to an individual's social development, including improvement in psychopathology. Chat-Box, when fully developed, will allow individuals who typically are challenged in this realm to flourish.

Acknowledgements. We would like to thank Meredith Moore, Dr. Hemanth Venkateswara, and Dr. Ramin Tadayon from the Center for Cognitive Ubiquitous Computing (CUbiC) of Arizona State University for providing valuable insights and constant support.

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Proposal for an Affective Skateboard Using Various Lighting Patterns

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Abstract. In recent years, ideas for more enjoyable playing through the use of emotional design concepts like affectivity and pleasurability factors are attracting attention. In this study, we focused on the effect of blinking and moving light patterns on users' enjoyment of skateboards. An evaluation experiment was conducted to clarify users' impressions of these light patterns using the following five evaluation items: (1) level of feeling of wanting to move your body, (2) level of feeling of wanting to get closer, (3) level of feeling of being in danger, (4) level of perception of beauty, and (5) level of preference. From the experiment, we found that there are some characteristics in impression of patterns of blinking and moving light and there is a common impression of the lighting pattern in 'level of feeling of wanting to move your body' and 'level of feeling of being in danger'. Moreover, it was clarified that there are some light patterns that users preferred and felt were more beautiful than others.

Based on these results, a glowing skateboard, named "Glowboard", was proposed using an Arduino system and a non-contact rotation speed sensor. "Glowboard" shows various blinking and moving patterns with different colors of light depending on the rotation speed of the skateboard's tire. From an evaluation experiment with "Glowboard", we found that using the various lighting patterns is effective not only developing performance through riding, but also for evaluating skaters' skill in skateboarding competition. The result is illustrates that "Glowboard" is effective for increasing users' enjoyment. In the future, it is necessary to clarify the impression and influences of different colors of lighting on enjoyment. "Glowboard" will be developed using a wider variety of light patterns based on the results of further study.

Keywords: Affective · Lighting pattern · Skateboard · *Kansei* engineering

1 Introduction

In recent years, the number of products and services to counter a lack of exercise have been increasing. In particular, there is a growing need for users to relieve mental stress and enjoy exercise more. In other words, ideas for more enjoyable play using emotional design concepts that address affective and pleasure factors are attracting attention.

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With this background, some interaction design focuses on the interaction between body movement and light. Good examples include “Orphe (Fig. 1 [1])” and “PRAMA (Fig. 2 [2]).” Orphe demonstrates shoes with a lighting function. This idea caters to dancers who want to make their dance more powerful and dynamic by adding light. PRAMA is an example of promoting exercise through the use of light at a sports gym. The concept of these designs is based on the idea of using light to increase motivation to move the body.

Fig. 1. Orphe

Fig. 2. PRAMA

Many services and products such as Orphe and PRAMA have been deployed based on this concept, but currently its application has not clarified the relationship between light and human feeling. It has been established that more effective results can be obtained in the future by using objective research results to develop services and products that use light. However, in many of the approaches, the prototypes incorporate light without consideration for a logical process, such as which element in the lighting pattern makes the strongest impression on users.

In recent years, there have been numerous studies on improving motivation through entertainment. According to Scott et al., there are two factors in entertainment that contribute to motivation, “Group Competition” and “Solo Competition” [3]. Akiyama et al. investigated the relationship between optical property parameters such as “contrast,” “gloss” and “surface gloss” of flooring materials and their visual impressions [4].

In this study, we focused on the effect of blinking and moving light patterns on users’ enjoyment of skateboards. The purpose of this research was to clarify the relationship between lighting patterns and users’ feelings, and to propose an interactive skateboard with changing light patterns based on the rotation speed of the skateboard tire, following experiment results.

2 Evaluation Experiment: The Relationship Between Lighting Patterns and Users’ Feelings

2.1 Purpose and Method of the Evaluation Experiments

Visual inductive self-motion perception (vection) [5] is an approach that involves observing self-body motion, which occurs in the direction opposite to a visual pattern where the regular movement of a large visual pattern occupies most of the field of vision. In this research, the glowing skateboard in the final proposal involves a user who is not only a skateboarder but also the viewer of the skateboarder as a subject, an experience that is judged to be different from the evaluation experiment of the skater affected by ‘vection.’ In this research, an evaluation experiment was conducted to visualize the impression made by various light patterns and to clarify the relationship of the different light patterns to the motivation to move the body.

In the evaluation experiment, each participant saw six types of light pattern. Figure 2 shows the six types of light pattern. These six types of light pattern were created with LED serial tape and the Arduino UNO system, which made it easy to control the lighting and movement of the patterns.

The evaluation experiment was divided into the following two groups: six patterns of light with the condition of moving in a horizontal direction. The experiment was conducted with 38 students of Future University Hakodate on July 7, 2016.

In the experiment involving six patterns of light with the condition of moving in a horizontal direction, the following occurred: (1) For condition A, the lights emerge from the left side and move toward the right (A pattern). (2) For condition B, the lights emerge from the right side, and move toward the left (B pattern). (3) For condition C, both lights emerge from the center, and each light group moves to the left and right (C pattern). (4) For condition D, both lights emerge from the left and right sides simultaneously and move into the center (D pattern). (5) For condition E, the lights emerge from the left side, and move toward the right in an irregular pattern that goes back and forth (E pattern). (6) For the last condition F, the lights emerge from the right side, and move toward the left in an irregular pattern that goes back and forth (F pattern).

Figure 3 shows the six lighting patterns.

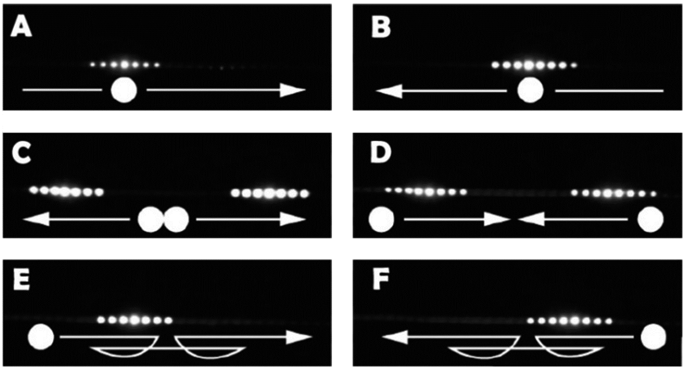

Fig. 3. Six patterns in which lights move in a horizontal direction

Initially, each participant observed the six different lighting patterns. Then, each participant evaluated the following five items related to "impression" and "motivation": (1) level of feeling of wanting to move your body, (2) level of feeling of wanting to get closer, (3) level of feeling of being in danger, (4) level of perception of beauty, and (5) level of preference. In the final step, each participant ranked each of the six different lighting patterns based on the five evaluation items.

2.2 Results of Evaluation Experiments

The results of the two experiments were analyzed using the Normalization Ranking Method (NRM), which is a method of ranking and comparing visual stimuli to each other. NRM is less difficult for the participant than the paired comparison method. Moreover, NRM is easy to use when conducting an experiment due to the small calculation amount for analysis [6].

Level of Feeling of Wanting to Move Your Body. From the results of the experiments, the F pattern, which involves very complex and random movements, was most highly evaluated for the 'level of feeling of wanting to move your body.' Conversely, A and B, which involve the simplest movements, were evaluated as the lowest in the same evaluation item. Figure 4 illustrates the results of the evaluation (Fig. 5).

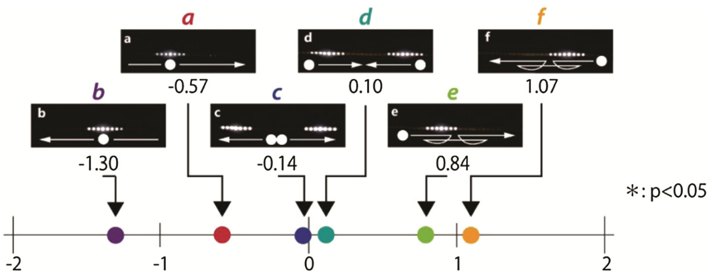

Fig. 4. Results of evaluation in the level of feeling of wanting to move your body

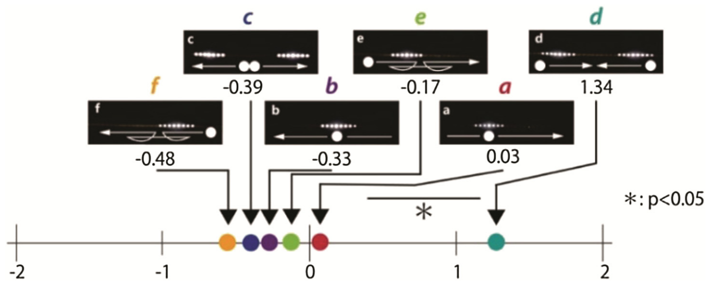

Fig. 5. Results of evaluation in the level of level of feeling of wanting to get closer

Level of Feeling of Wanting to Get Closer. In the evaluation item of 'level of feeling of wanting to get closer,' the D pattern, in which two lights emerge from the left and right sides simultaneously and move into the center, was most highly evaluated.

Level of Feeling of Being in Danger. In the evaluation item, 'level of feeling of being in danger,' the E pattern, which is a complicated movement contrary to the natural flow, was most highly evaluated. Conversely, A and B, which involve the simplest movements, were evaluated as the lowest in the same evaluation item. Especially, the lighting of the B pattern, which flows very simply and naturally, was lowest in the evaluation (Fig. 6).

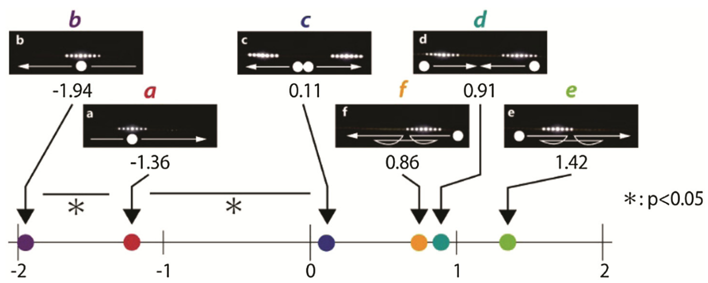

Fig. 6. Results of evaluation in the level of feeling of being in danger

Level of Perception of Beauty. In the evaluation item, 'level of perception of beauty,' the C pattern, in which two lights emerge from the center, and each light group moves to the left and right, was most highly evaluated. Conversely, E and F, with their complex and random movements, were evaluated as the lowest in the same evaluation item (Fig. 7).

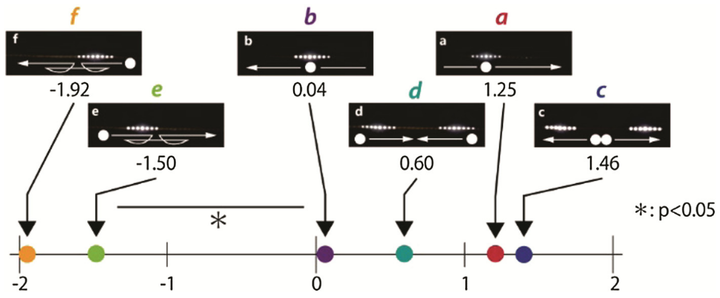

Fig. 7. Results of evaluation in the level of perception of beauty

Level of Preference. In the evaluation item, 'level of preference,' the D and C patterns were most highly evaluated. However, E and F, with their complex and random movements, were evaluated as the lowest in the same evaluation item (Fig. 8).

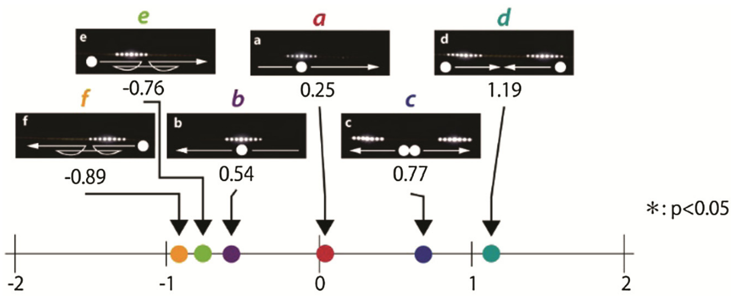

Fig. 8. Results of evaluation in the level of preference

3 Proposal for an Affective Skateboard Named "Glowboard"

Based on the above experimental results, we proposed a new skateboard named "Glowboard" (Fig. 9). The lower part of the skateboard is always in shadow despite daytime brightness. Especially, the light of the LED can be seen not only at night but also during the day or in a bright environment. Because the light of the LED on the lower part of the skateboard is conspicuous, LED serial tape was attached to the lower backside of the skateboard.

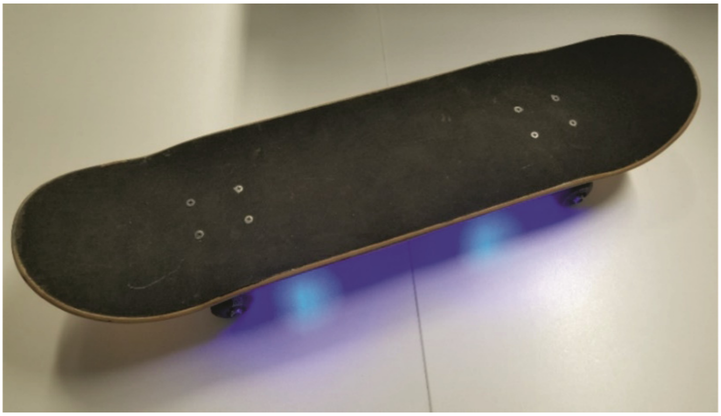

Fig. 9. “Glowboard”

For the “Glowboard” proposal, a skateboard, an Arduino UNO system, a non-contact rotation speed sensor (OH 182/E), LED serial tape, and a battery supply system were used (Fig. 10).

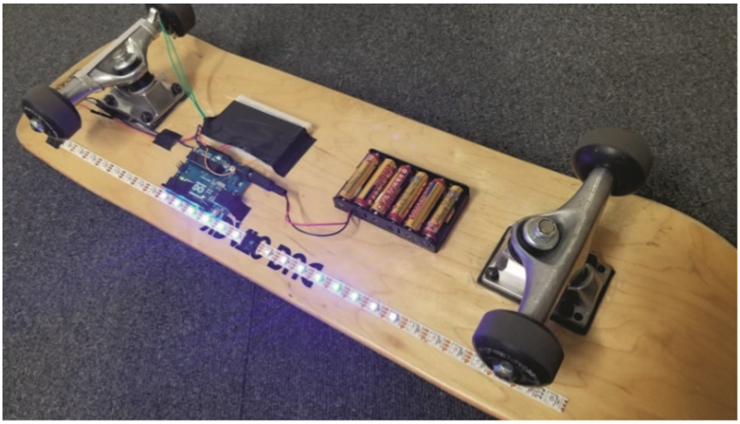

Fig. 10. Basic construction of the “Glowboard”

The mechanism of the “Glowboard” changes the light patterns according to speed changes of the user on the skateboard. The non-contact rotational speed sensor (Fig. 10) records the amount of change in the magnetic field in front of the sensor. A neodymium magnet is embedded in one front tire (Fig. 12); this sensor measures how many times the tire rotates based on the level of neodymium magnet. The programed Arduino Uno system acquires the measured amount of change in rotation as information on the speed of the skateboard per unit of time. The value obtained from the non-contact rotation speed sensor is converted to an easy-to-use value, and how much it changes in relation to a unit of time (in this case, the count exceeded 45 times) is measured (Fig. 11).

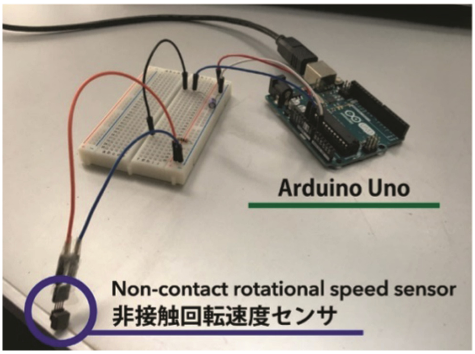

Fig. 11. Arduino Uno system and non-contact rotational speed sensor

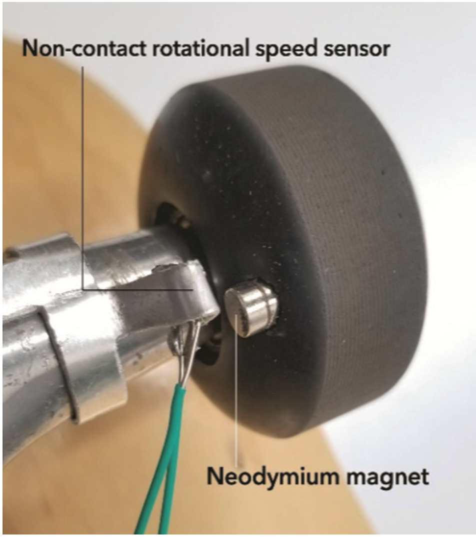

Fig. 12. Non-contact rotational speed sensor and neodymium magnet

In the next step, based on the obtained measured value, the programmed Arduino Uno system decides how to change the lighting pattern according to the evaluation experiments. In other words, the measured result is used as a value for switching the light conditions of the "Glowboard."

The "Glowboard" displays the following five blinking and moving patterns with different colors of light depending on the rotation speed of the skateboard's tire:

1. Stopped condition: D pattern with blue color. The D pattern was most highly ranked at the level of feeling of wanting to get closer.
2. Low speed condition: F pattern with green color. The F pattern was most highly ranked at the level of feeling of wanting to move your body.

3. Stable speed condition: B pattern with white color. The B pattern was evaluated as average in most evaluation levels. Furthermore, this pattern was the lowest at the level of feeling of being in danger.
4. High speed condition: C pattern with blue color. The C pattern was most highly ranked at the level of perception of beauty and ranked 2nd at the level of preference.
5. Too high-speed condition: E pattern with red color. The E pattern was most highly ranked in level of feeling of being in danger.

Figure 13 shows the five lighting patterns of the "Glowboard."

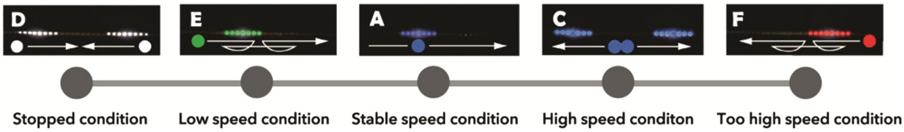

Fig. 13. Five lighting patterns of the "Glowboard"

4 Evaluation of the "Glowboard"

The evaluation experiment for the "Glowboard" was conducted with eight participants at Future University Hakodate on January 19, 2017. Eight participants watched a skater ride the "Glowboard" with its various lighting patterns, and a regular skateboard without any lighting pattern at random. They were allowed to touch the "Glowboard" directly. Afterward, each participant freely noted good points and bad points using a questionnaire. Table 1 shows some selected results of the questionnaire.

Table 1. Some opinions obtained from the questionnaire

Good points	"Glowboard" helps to develop skateboard performance
	"Glowboard" may become a new sport/exercise
	The colored light pattern helps to obtain rich information
	"Glowboard" can help to evaluate a skater's skill
	"Glowboard" may be useful at the show level also
	A parent can check their child's skills on the skateboard
	"Glowboard" prevents some accidents related to speeding
	It is easy for users to ride and check their skateboard purpose levels
	It is very fun to see the various light patterns
Bad points	There is no algorithm governing how the light colors change
	Sometimes the board movement direction and light movement direction were not linked
	The light color change time was too fast
	For the skater, it is difficult to see one's own light patterns

From the evaluation experiment with the "Glowboard," we found that the various light patterns are effective not only for developing skating performance but also for evaluating skaters' skills in skateboarding competitions. The results illustrate that the "Glowboard" is effective for increasing users' enjoyment. However, there are some points that must be developed in relation to the movement pattern and color variation through a logical research process.

In the future, it will be necessary to clarify the impression made and influence of the different light colors on enjoyment. The "Glowboard" will be developed using a wider variety of light patterns based on the results of further study.

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Intervention Effect of Color and Sound Cross-Modal Correspondence Between Interaction of Emotion and Ambient

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Abstract. Since the pressure of people's daily life and work, more and more people tend to be nervous and have negative emotions such as anxiety. In order to properly intervene in people's emotion, introduces a method of using electroencephalogram (EEG) to evaluate the intervention effect of color and sound cross modal on emotional state. The proposed method consists of three phases: emotion elicitation, emotion intervention, and EEG monitoring. The film clips are used to induce four target emotional states: joy, fear, sadness and relaxation, and a group of music clips and ambient lights were used as intervention factors. According to the two-dimensional model of emotion is described and take the valancing as the adjusting index, the ratio of the average power spectral of the left hemisphere to the right hemisphere are calculated to represent the valence change, thus evaluating the intervention effect. The results show that synesthetic combination of music and light has a more obvious effect on negative emotion intervention, the high-pitched and fast-paced music is in particular. And also Our findings highlighting the existence of cross-modal correspondence between sounds and colors in psychology.

Keywords: Cross-modal · Emotion · Ambient · Intervention

1 Introduction

Research on cross-modal correspondence between sound and color has a long history in the field of experimental psychology, dating back to the discovery of idiosyncratic sound-color mapping in synesthetes. And synesthetic correspondences between color and auditory stimuli in synesthetes were well-established in the literature [1–4]. Early cross-modal matching studies, as well as those studies involving the matching of sound with color, suggested that people make reliable associations between certain dimensions of color and sounds. Marks [5, 6] studied on the association of pitch, loudness and lightness, he confirmed that higher pitch and louder sound were associated with lighter color. Stevens [7] and Bonds [8] studied with grey color with sample waveform sounds and demonstrated that people matched brightness and loudness cross-modally, both of children and adults matched light grey color with louder sound and darker grey color

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with quieter sounds, and most of people consider that the combination of sound and color have a more significant effect on emotional intervention. For example, bright colors and fast rhythm music combinations are exciting and energetic.

Judging and shaping human emotions is not an easy task. Davidson et al. described the two-dimensional model of emotion [9]. From this model we can see that the emotions are determined by their position in the two-dimensional scale, and the two-dimensional scale is spanned by two axis that valence in horizontal axis and arousal in vertical axis. Valence expresses the quality of the unconscious emotion from unpleasant to pleasant. Arousal refers to the level of quantitative activation from calm to excited. The different emotional tags can be drawn on the 2D plane spanned by these two axis across each position, such as can be seen in Fig. 1.

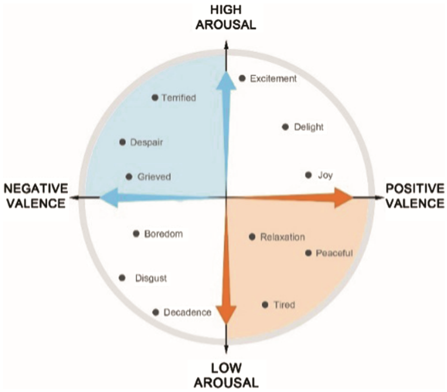

Fig. 1. Graphical representation of the emotion classification model. The emotions are determined by their position in the two-dimensional scale, and the two-dimensional scale is spanned by two axis that valence in horizontal axis and arousal in vertical axis.

Researchers usually use different approaches to simulate emotions, such as texts, music, and films, facial expressions, slides, photos, the characteristics of dynamic vision and auditory stimulation make the film seem to be one of the most effective ways to induce emotions [10–14]. Electroencephalogram is a non-stationary time series biomedical signal that provides information about human brain activities. Compare to the facial expression, human behavior, vocal expression and some physiological signals, EEG is a more reliable approach that could reduce masked emotions. A lot of studies have researched on the question of asymmetrical activation of the cerebral hemisphere. Davidson [15] detected that left frontal EEG activity is related to positive emotion, while right frontal is related to negative. In the EEG study on the reward and punishment of different brain functions, Henriques [16] found a pattern of relative right frontal EEG activity on depressed adults.

2 Materials and Methods

Aim to stimulate subject's emotions, a group of films clips were used as elicitors, the film clips set includes two clips for each of four target emotional states: joy, fear, sad and relaxation emotions. The selection criteria for film clips were as follows: (a) the length of the scene should be relatively short (3–5 min); (b) the scene is to be understood without explanation; and (c) the scene should induce single desired target emotion of subjects.

To intervene the emotional stimulation of the film, we used a group of music clips and ambient light as intervention factors. Music clips in accordance with the combination of the pitch level and rhythm of speed to get two different type of music including high-fast (HF), low-slow (LS), and select the typical music clips. Ambient light color selection of the most typical red, yellow, blue and green four colors. The selection criteria for music clips were as follows: (a) the length of the music should be relatively short (3–5 min); (b) the music is as unfamiliar as possible, such process as seen in Fig. 2.

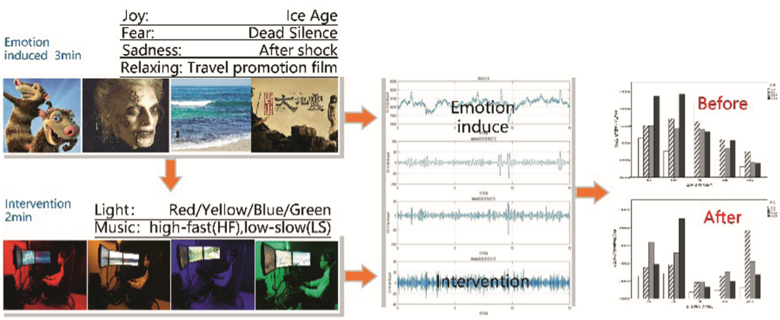

Fig. 2. Intervention experiment processing (Color figure online)

3 Experiment

3.1 Participants

We recruited a homogeneous population of 10 healthy subjects between 17 and 25 years of age (mean = 20.0 ± 1.7). Some subjects were students of Xi'an jiaotong University and others is Xi'an Gaoxin No.1 Hign School. All participants have normal vision and sound hearing.

3.2 Procedure

The experimental process is divided into two phases including emotional induction and emotional intervention. The emotional induction stage is mainly stimulated by the film segment in a white ambient light environment. The emotional intervention stage carries out emotional adjustment through four different types of music in an ambient light environment, such as seen in Fig. 3. The entire experimental process in a closed and opaque environment, the subjects must wear the EEG cap with EEG recording.

Fig. 3. Experimental environment. During the experiment, using four different films to induce four corresponding emotions. Then light and music work together on the subjects to intervene emotion.

3.3 Statistical Analysis Methods

In EEG recording, EPOC device developed by EMOTIV is used to measure EEG activity. The EPOC uses a dry-type sensor and covers 10ch electrodes, such as seen in Fig. 4. This device has high resolution, neuro-signal acquisition, and a processing wireless neuro-headset. The EEG data are sent to a computer through a serial port, and the sampling rate is 128 Hz.

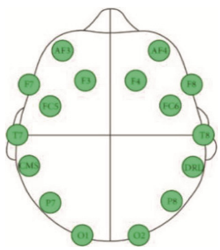

Fig. 4. Electrode position distribution

In EEG feature extraction, The EEG data we got from the experiments were analyzed through several procedures, including filtering, independent component analysis (ICA), fast fourier transform (FFT) and wavelet transform etc. Firstly we filtered to eliminate the presence of artifacts and linear trend items, and then carry out independent component analysis to eliminate the eye-electric artifact, and finally we use fast Fourier transform (FFT) to extract domain-frequency characteristics to get power spectra of EEG data of alpha, beta, theta .thus we use the average power spectra of EEG data and the ratio of the power spectral density of the symmetrical electrode in the left and right hemisphere as signal characteristics to represents the change of arousal and valence to evaluate the intervention effect of music and ambient light on the emotional state.

Therefore, we selected the electrodes of AF3, F3, F7, FC5 which in the left frontal area and AF4, F4, F8, FC6 which in the symmetric area to get the average power spectral of alpha band. The average power spectra and the ratio of average power spectra in the left and right hemisphere were calculated to confirm whether the emotion was to be elicited and intervened or not. When the subjects is in a high degree of valance, the ratio of average power spectral in alpha band of the symmetrical electrode decreases. While in a low degree, the ratio increases, such as formula 1.

$$x_{\text{valance}} = \frac{\alpha_{\text{average power spectra in left brain}}}{\alpha_{\text{average power spectra in right brain}}} \quad (1)$$

4 Results

4.1 Emotion Elicitation

Under the stimulus of the horror movie, the ratio of average power spectra in the left and right hemisphere significantly increases,as shown in Fig. 5(a). For the sadness film, the ratio of average power spectra in the left and right hemisphere significantly increase,as shown in Fig. 5(b). Stimulated by comedy, the ratio significantly decreases, as shown in Fig. 5(c). The ration significantly decreases as stimulated by relaxing film, which is shown in Fig. 5(d).

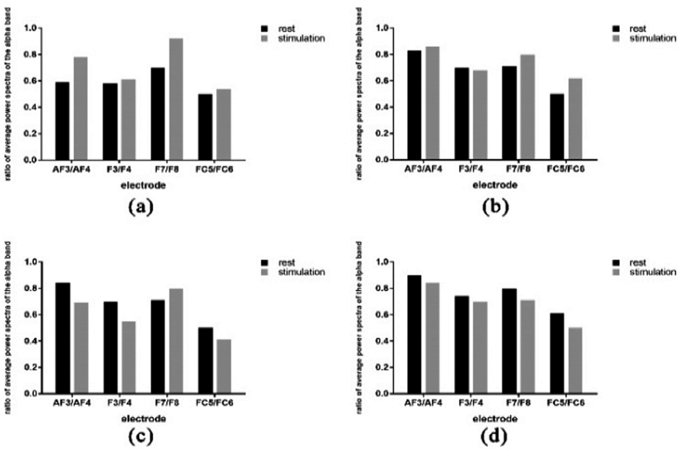

Fig. 5. The ratio of average power spectra in the left and right hemisphere. Four figures from (a) to (d) present the change of the ratio of average power spectra in the left and right hemisphere with fear, sadness, joy and relaxation emotions. The horizontal axis represents the electrodes, and the vertical axis represents the ratio of average power spectra of alpha band between relaxation state and simulation state.

According to the formula 1, subjects' emotional valence degrees decreased with the stimulation of horror and sadness movies. While stimulated by comedy or relaxing films, subjects' emotional valence degrees increased, which shows that emotions with fear and sadness need environmental intervention urgently. So, we're going to focus on the intervention effect of these two negative emotions.

4.2 Emotion Intervention

To intervene the fear and sadness emotions with sound and ambient light according to the cross-modal correspondence between color and auditory. A group of music clips and ambient lights were used as intervention factors. Music clips were divided into two groups in accordance with pitch and rhythm, namely, high-fast (HF), low-slow (LS). Red, yellow, blue and green were selected as the typical ambient light colors. The average power spectra of alpha band were collected from the right and left brain areas, and the ratio of average power spectra were calculated to evaluate the intervention effect of sound and light, as shown in Fig. 6.

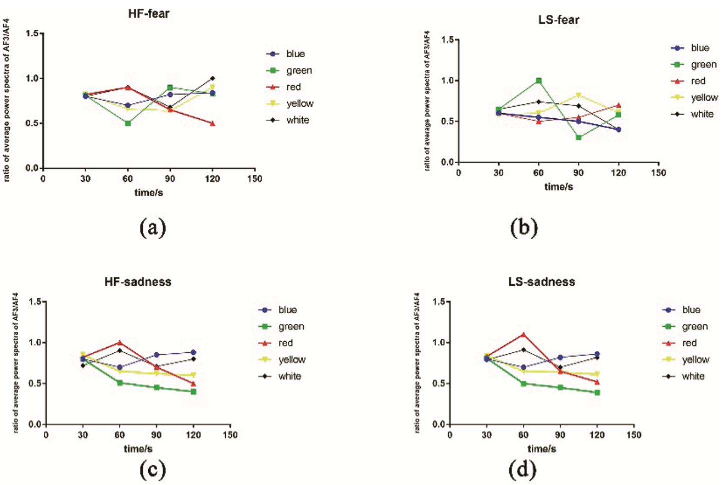

Fig. 6. The ratio of average power spectra of the alpha band in AF3/AF4 with different ambient light and music. Four figures from (a) to (d) present the average power spectra of the alpha band in AF3/AF4 under different ambient light and music stimuli. The horizontal axis represents the time, and the vertical axis represents the change of EEG data under different ambient light and music stimuli. Figure (a)–(b) indicate the EEG data collected in fear under HF and LS music, while Figure (c) and (d) indicate the EEG data in sadness under HF and LS music. (Color figure online)

Result from the figures, When the subject stayed in fear, red, green and white lights had a big fluctuation value, which indicated that the instantaneous interference effect was obvious, and with the passage of time, the intervention effects of music began to appear, such as HF music and red light combination could gradually make the ratio of average power spectra of the alpha band in AF3/AF4 initially raise then continue to decline, which suggested that HF music and red light combination had a positive intervention effect in valance. While under LS music, white, yellow, and blue light had a positive intervention effect in valance with the change of time.

In the emotion of sadness, subjects of HF group under green and yellow and red ambient lights showed a significant positive intervention effect in valance, the ratio of average power spectra of the alpha band in AF3/AF4 had a tend of decline generally, which indicated that the sadness was significantly relieved. The condition of LS group is similar to the HF group.

Emotional intervention study found that the effect of music on emotional intervention plays the dominant role, followed by color. For negative emotions, high-pitched and fast-paced music functions well in emotional soothing. Summarized the result of the experiment, we can draw on a typical soothing combination of music and colour for negative emotions. Shown as Table 1.

Table 1. Combination of music and light.

Emotion	Combination	Best combination
Fear	HF + green/red/blue LS + yellow/red/blue	HF + red LS + blue
Sad	HF + yellow/red/blue LS + yellow/red/blue	HF + green LS + green

5 Conclusion

In this study, experiments were carried out to investigate the effect of visual and audio stimuli on human emotions. For negative emotions, high-pitched and fast-paced music functions well in emotional soothing and synesthetic combination of music and color have a more significant effect on emotion intervention. In addition to the valance, there are more studies on arousal. In the fatigue state, the study on arousal is particularly important.

Cross-modal correspondence of music and color not only can be widely used in public environment, such as hospitals, where can calm patients by playing peaceful music, with harmony environment, also can be used in daily work to intervene people's negative emotions and to reduce adverse consequences or tragedies. Such as the concept design of car exhibited by Toyota in 2017 - Concept-i. which can perceive driver's emotions, then adjust the color of light and play soothing music. It makes the driving full of fun and reduce the chance of accidents, and truly realize intelligent human-computer interaction.

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A Study on Diversified Emotional Interaction Mode of Users

Research, Design and Realization of the Diversified Input Method Based on 3D-Touch Technology

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Abstract. The diversity of information interaction is constantly expanding, a variety of information interaction and cultural exchanges have changed people's behavior patterns. This paper based on the pressure sensitivity of the 3D touch technology, we made a real-time measurement of the pressure, time interval and other physical quantities of users when they press the screen to enter the information, and obtained the users'real-time emotion information combined with semantic recognition, then added it to the text by way of color, font and so on, which can solve the problem of semantic misunderstanding caused by the single expression of the information in text sequence communication, so that communication is more smooth and diversified. Therefore, This paper explores how to overcome the difference of cultural exchange by using the multiple ways of emotional interaction, aiming to build a more effective and effective way of information interaction mode.

Keywords: Emotional interaction · 3D-touch technology · Cultural difference

1 Introduction

1.1 Research Background

With the rapid development of the Internet and people's increased reliance on the Internet, the computer-mediated communication has become popular. Telecommunication represented by social tools and e-mails has gradually dominated the market. Internet-mediated communication becomes a model of modern social communication. In network communication, the keyboard-inputting text sequence is the main information carrier. However, a recent survey has revealed that more than three-fifths of people are not fully understood by the other party when chatting with emotions, and more than four-fifths of people have the experiences of being misunderstood. American psychologist Albert Mehrabian's research showed that in the expression of emotion and attitude, language only accounts for 7% of the communicative behavior, while tone and expression up to 93% of the information. In other words, there is a large distortion of the traditional text-based input method in the process of emotional transmission, which may results in unnecessary misunderstanding. In daily communication, people communicate

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mostly in a verbal way, at the same time, with gestures, tone, body language and other non-verbal means of expression to facilitate the communication and understanding. However, in the network communication, due to the lack of auxiliary communication of non-verbal means, information transmission becomes much less efficient.

1.2 Product Research

During the popularization of the Internet, a variety of information interaction and cultural exchanges have changed people's behavior patterns. Then non-verbal information expression occurs when text fails to carry the full meaning of the exchange. In 1982, an American Professor Scott Fahlman posted a string of ASCII characters: ":-)" on the campus electronic bulletin board, proposing it as a character sequence for joke markers. In the 1990s, Shigetaka Kurita of NTT docomo, Inc. created emoji, which is intended to provide richer emotional expression in the message dialogue, rather than the traditional plain text or simple expression, so that dialogue will not be misinterpreted. On January 26, 2016, with the update of Version 6.2.2, Mobile QQ launched the "LiMiXiu". It is a bound virtual image using spine2D animation technology, to exaggerate the interpretation of the action chosen by users in the process of chatting, which will add body language to the emotional interaction of network communication.

It can be seen from these products that a variety of non-verbal information expression has brought great convenience to people's network emotional interaction. Its working principle is to perceive the small changes in the distance in the process of finger pressing, through the capacitive sensors installed around the touch screen, which will convert the pressure to electrical signals, and then process the electrical signals through the pressure sensor, to ultimately perform the user intention. Except for the information-coding tool, finger's tactile and force input also have huge application potential, while the application of 3D-touch technology symbols a breakthrough of non-verbal information expression. 3D-touch technology, also known as force touch technology, its working principle is to convert the perceived pressure into electrical signals through the capacitive sensor installed around the corners of the touch screen. The sensor then carries on the processing of the electrical signals, and finally realizes the representation of the user intention.

2 Design and Realization

2.1 Design

2.1.1 Conceptual Design

Aristotle calls people "social animals." Indeed, we have a need for belonging, that is, to establish a continuing and intimate relationship with others. When we have a sense of belonging, that is, when we feel supported by an intimate relationship, we will be more healthy and happy. It's been pointed out in the "China Social Psychology Research Report (2016)" issued by the Institute of Psychology of the Chinese Academy of Sciences and Social Sciences Academic Press on December 12, 2016, that only 34.3% of the residents hold positive evaluation of social equity; price, income, children's education and others have become the largest sources of life pressure. In case of this complex and changing social situation, emotional communication is urgently needed in large amount.

The emergence of the Internet has great influence on the way people establish and maintain close relationships. Online communication is the most prevalent in network interpersonal communication, where people tend to talk through text without being seen instead. Although the network communication broke through the time and space constraints, but it also filtered a lot of non-verbal information in face-to-face communication, so that people online seem more indifferent than the actual personality of their own. Therefore, emotional expression is in urgent need, to promote the exchange of information in the network interpersonal communication.

We've done a large number of product researches and brainstorming of the design of diversified input method based on the 3D-touch technology, the final main technical line is as follows:

(1) Measure the real-time pressure, time interval and other physical quantities of information deliverers through 3D-touch technology when pressing the screen to enter the text;
(2) Analyze the text sequence information through semantic recognition, and obtain the users' subjective wishes and real-time emotional information combined with the real-time pressure results;
(3) Attach additional emotional information in form of color, font, etc. to the original text, so that the exchanges become more vivid and livelier.

2.1.2 Interface Design

The main interfaces of the input method include the input interface and setting interface. Others include the style instruction of the input method, keyboard selection and the tutorials interface.

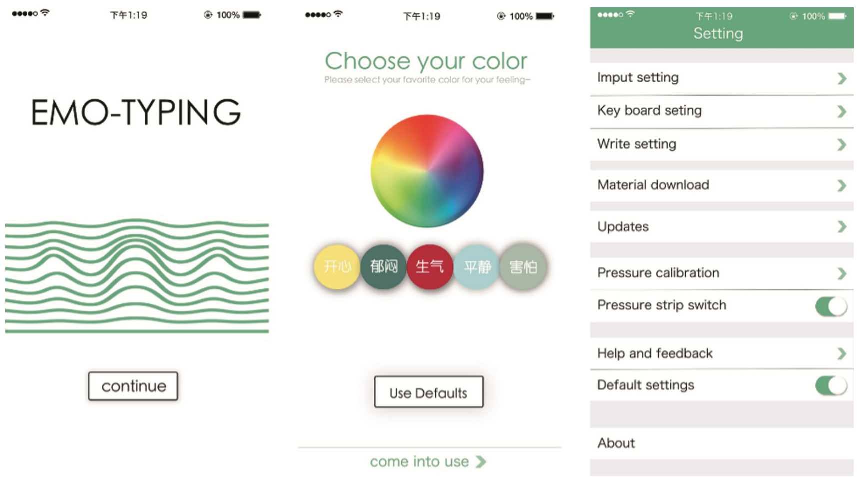

Fig. 1. User interface design

In order to account for the user's click pressure in real time, the input method has a pressure display bar on the right side of the selection bar. The pressure bar displays the user's real-time click pressure of inputting (as for styles selection of the pressure bar, see Input Method User Experience Study - Eye Movement Analysis).

In addition, a preview box provides a preview of the output in the upper right corner out of the inputting box, more details see the interactive design section.

The overall setting interface is designed Button Vertical Alignment, with one button in each line to lead to any other specific setting interface. It realizes the personalized interface of the emotion-relevant color in the prototype, and an interface for calibrating the reference pressure of inputting according to different click pressure of different users.

2.1.3 Interaction Design

The main interactive function of this input method is to implement the input by users. In this input method prototype, we provide an example of user's inputting. The sample shows the complete inputting process, which contains the following interaction factors:

(1) The button turned gray once pressed by users, and the cursor of pressure display bar moves, where the distance traveled corresponds to the pressure on keyboard.
(2) Click the word in the word selection box, then the selected word turns gray.
(3) The text in the output box is text without special effect; the preview box in the upper right corner outside the input method will synchronize the rendering result of these texts according to the identified emotions.
(4) Click the preview box to send the special effect text and click to send a text-only message.

2.2 Realization

2.2.1 3D-Touch Technology

Pressure tactile technology, through the generation of a certain induction pressure, and to change the shape of the screen, causing changes in electrical data. Finally, the command is generated.

In this process, the pressure generation, pressure identification, identification system after the feedback to the user is the pressure of the three elements of the touch system. Because of different pressure values will correspond to different response effects, so the user can realize the image of the corresponding sense of expression.

2.2.2 Semantic Recognition

Through the semantic analysis of user input text information, We can understand the user's intention and emotional state, And help the information presented results. The main technology is as follows:

(1) Application of Topic Recognition Technology. It is one of the key technologies of semantic recognition that how to distinguish and identify relevant information in various kinds of information and to predict the event through information reasonably.

(2) The Construction of Corpus and Emotion Lexicon. The corpus and the emotional dictionary are important resources in the process of text emotion analysis. Corpora are usually constructed by manual calibration, and there are also automatic labeling methods. Such as through the evaluation website, online shopping site reviews to collect corpus. The cummon corpus is: Cornell movie-review datasets, Multiple-Perspective Question Answering, NTCIR multilingual corpus. The common emotion lexicon is: General Inquirer Lexicon, Sentiment Lexicon, MPQA subjectivity Lexicon.

3 Iteration and Evaluation

3.1 Interview and Questionnaire

We introduced the product to eight interview users and 46 survey users in the demand analysis, and asked them about their feelings about some of the design details and other opinions and suggestions. According to the results, improvement has been made mainly in the following two aspects of the product.

3.1.1 Font Color Setting

As can be seen from the demand analysis, most users expect different font colors to express different emotions. Therefore, we made a questionnaire asking 46 users to evaluate which of the following colors can better convey their emotions (multiple choices), the results are shown in Table 1.

Table 1. Color preference of subjects in different moods (unit: person)

	Red	Yellow	Blue	Green	Purple	Gray	Black
Happy	10	18	4	11	3	1	2
Calm	0	3	25	14	5	2	5
Angry	27	4	2	1	3	2	5
Sad	0	2	7	2	6	24	5
Fearful	7	2	1	1	6	7	22

The results in Table 1 clearly show that subjects have different color preferences in different emotional states: yellow when happy (18), blue in calm (24), red in anger (27), gray when sad (24), and black in fear (22). Therefore, this product is also improved in the default color settings to satisfy a majority of the users, taking full account of the user experience.

3.2 Eye Movement Test

Designers designed three pressure bars of different shapes and colors, and tested the eye movement technology, with the results of which the most appropriate option is finally adopted.

3.2.1 Process

All subjects are on the eye movement cloud test platform for testing, using the same computer (resolution ratio 1366 × 768) with The Eye Tribe eye tracker.

Each subject needs to browse 3 WeChat interfaces using the new input method, as shown in Fig. 1. All the pictures are the same as all parts except the pressure bar at the right side of the input method. After understanding of the function of the new input method, subjects are asked to imagine that they are chatting using this product, and naturally browse each of the pictures without time limit, then an isometric white screen is shown to them for the purpose of interference, and then the next picture.

3.2.2 Test Result

In Fig. 2(a), it shows that the main areas of concern for the subjects are near the chat content, preview box, input box and pressure bar; while in Fig. 2(b), the keyboard and pressure bar in priority, then the chat content, preview box; and in Fig. 2(c) the hot spots concentrated in the nearby areas of input box, keyboard and preview box.

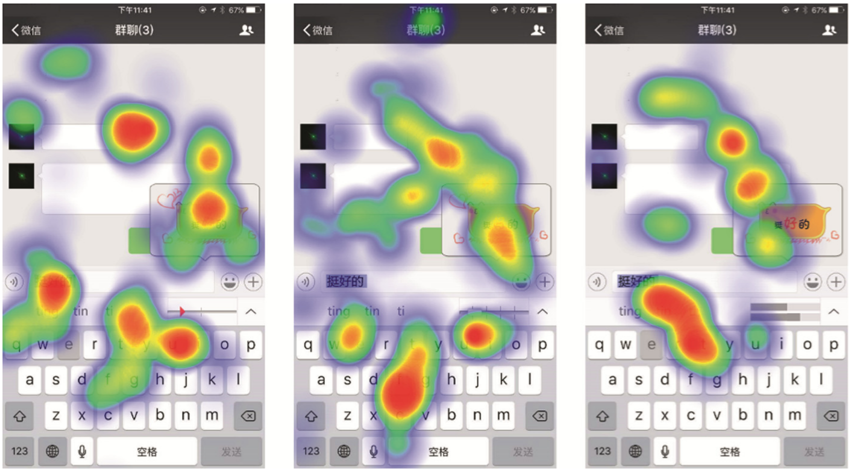

Fig. 2. Test result

The new input method determines the current mood of the user based on the input pressure and semantic recognition, and adjusts the text style according to the emoticon. Input box displays semantics, pressure bar reflects the pressure, dialogue contents provides the context, and the preview box shows the results of comprehensive analysis. These four parts should be the user's most concern. Therefore, in general, the pressure bar in (a) is the most appropriate choice.

3.3 Style Guide

The Style Guide documents the control standards for various design elements in the sensory design. The style guide for this application is based on three main criteria:

(1) Control of font elements. Emotions are mainly composed of there categories of positive emotions, neutral emotions, and negative emotions. Among them, positive emotions use cute fonts, such as the Marker felt Font; neutral emotions the sans-serif fonts, such as Microsoft YaHei; Negative emotions the more angular fonts, such as the Silom Font (Fig. 3).

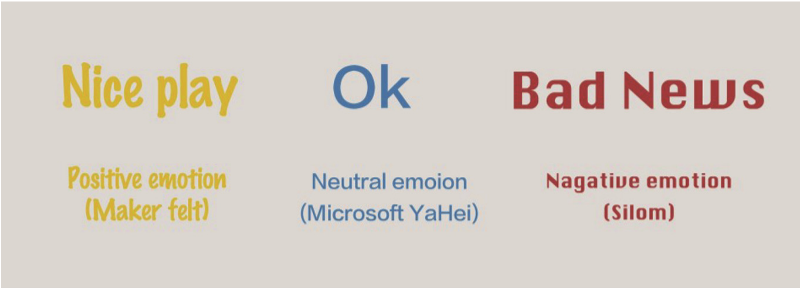

Fig. 3. Control of font elements

(2) Control of emoticon elements. Since the core target users of this application are women according to the questionnaire and interviews,. The overall emoticon element chooses the cute style with quasi-physical or animal images, using different colors to strengthen the representation.

4 Reflection and Extension

4.1 Reflection

Through investigation and analysis, it's found that the biggest problem in product promotion is that users worry about the emotional expression can not be true and objective, or whether it'll bring additional cognitive burden since it's not as convenient as the emoticons and others. At the same time, in terms of textual presentation, the perceptions and preferences of each person are inconsistent, thus the complete presentation database fails to be set based on large data. In practice, manual adjustments and daily calibration are required to ensure the accuracy of perceived pressure, which may lead to the loss of users.

On the other hand, with a diversity of expressions at present, the pictographic meaning of all kinds of emoticons and other non-verbal information representation gradually fades, while the symbolic significance becomes increasingly prominent, even with entertainment-oriented emotions. In some cases, the excessive use of emoticons will affect the effectiveness of information exchange, and even becomes a noise.

Of course, our product as a whole, is of great research potential and value. Based on 3D-Touch technology, emotions are identified by sensing the size of the pressure when typing, and expressed in the form of text, which to a certain extent, saves unnecessary time costs, and delivers the personal emotional information accurately and quickly, injecting vitality to the network communication.

4.2 Extension

4.2.1 Affective Computing

The affective competence of human beings plays important role similar with the rational thinking in their daily work and social contact. It was rare to connect emotions with machine. In the book "The Society of Mind" written by Professor Minsky (one of the founders of artificial intelligence) from Massachusetts Institute of Technology in 1985, it was put forward for the first time that computers should have affective competence. Professor Picard from MIT Media Lab gave a definition to affective computing in his book "Affective Computing" published in 1997, which related to, arose from, or deliberately influenced emotion or other affective phenomena.

According to the emotional communication process of human beings, affective computing can be divided into the following four parts: obtaining the affective information of users through sensors, analyzing and recognizing affective information by establishing models, deducting the results and developing perceptual awareness, then expressing the results in corresponding ways. Major technologies are as follows.

(1) Obtain affective information. Affective information is obtained through various sensors or measure tools, which measure the physiological characteristics or behaviors based on emotions, thereby obtaining related affective information.
(2) Model affective signals. When obtaining the affective information of users, the next step is to model and recognize obtained affective information, and combine affective information with emotional mechanism. The hidden Markov model was first put forward in MIT Media Lab, which can predict the emotional direction based on changes in affective probability of users.

However, as a large-scale affective data resource is insufficient and most research be restricted to speech sounds and body language, affective computing meets some obstacles to its development. Against this background, the application of diversified input methods based on 3DTouch brings huge convenience for affective computing research. According to statistics, daily active users of WeChat reach to 768 million in total, with 50% of them using WeChat for over 90 min per day. Therefore, the application of diversified input methods based on 3DTouch will not only bring more various affectively interactive experience for users in their online communication, but also help obtain numerous affective data resources, laying a solid foundation for research and development of affective computing as well as establishment of a friendly intelligent Human-Computer Interaction system.

5 Discussion

Social applications are known as smart city killers. More and more social networks appear in our lives, both the online and offline, with interest and hobbies as a clue to help with people's face-to-face communication, constituting the numerous distributed community network system. As Geoffrey Lynch, a materialist who studies urban development, puts it, "Cities are the results of the converging social network." Internet and large data connect tens of millions of complex communities together. It is concerned by researchers of smart cities how to create a valid and effective mode of information transmission in this huge system.

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Recording Your Stress, Can it Help to Prevent Job Stress?

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Abstract. Job stress has been regarded as an important issue in the workplace. Hoboubi et al. (2017) proposed that job satisfaction and job stress are important factors that affect workforce productivity. Employees' job stress not only influences their mind but also leads to poor performance at work. This research has been initiated with the assumption that the stress employees experience is similar to the stress they experience in the workplace. In addition, similar types of stress occur at the workplace and may be caused from meeting the same persons, same contents meetings, same location or same timings. We designed a web based calendar system called "My Stress Calendar" which provides various functions to subjectively record stressful events, relevant memos, and emotions. To evaluate it, we performed a within-subject research. Twenty subjects who are employees were recruited and evaluated for their perceived stress levels using a modified perceived stress scale, before and after using the system (Cohen et al. 1983). The results indicated that there was a significant difference in subjects' perceived stress score between the experiments. It turned out that recording stressful events is helpful in preventing stressful events and leads the subjects to stable and positive emotions.

Keywords: Job stress · Recording stress · Calendar

1 Introduction

Job stress has been regarded as one of the important issues at the workplace. Hoboubi et al. [1] proposed that job satisfaction and job stress are important factors that affect workforce productivity [1]. In Korea, adults who have a job spend at least 9 h at their workplace. This indicates that social, psychological and physical factors on the job may have a strong influence on employees' health. Caplan et al. [2] stated that stress refers to "any characteristics of the job environment which pose a threat to the individual." [2] Margolis and Kroes [3] suggested that job stress is a condition at work which interacts with worker characteristics to negatively influence psychological or physiological homeostasis [3]. Margolis and Kroes [3] proposed that there are five dimensions of job related strain: short-term subjective state (e.g., anxiety, tension, and anger), long-term and more chronic psychological responses (e.g., depression, general malaise, and alienation), transient physiological changes (e.g., levels of catecholamine, blood pressure, etc.), physical health (e.g., gastro-intestinal disorder, coronary heart disease, and

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asthmatic attacks), and work performance decrement [3]. Employees' job stress not only influences their minds but also leads to poor work performance by adversely affecting an employee's motivation. According to Beehr and Newman [4], job stress can be divided into six facets of the working context: environmental, personal, process, human consequences, organisational consequences, and time [4]. Similar to Beehr and Neman's [4] study, this research has been initiated with the assumption that employees experience stress which is similar to the stress acquired at their workplace. In addition, similar types of stress at workplace may be caused from meeting the same persons, same contents of meetings, same location or same timings. This means that employees should perform regular work and contact other persons regularly. That is the main reason why we focused on the concept of stress at the workplace. We hypothesised that people receive similar types of stress from the similar job events. In addition, we also hypothesised that recording the level of feeling regarding each event is helpful in tracking the past emotion corresponding to each event. Additionally, people can be careful to avoid the unpleasantness related to a specific event by recording the levels of their feelings that correspond to such events.

The purpose of this project is to arrive at a new type of solution to reduce job-related stress at the workplace. We developed a new type of calendar which allows the employees to record their feelings concerning each event in their schedule. The contribution of this project is to provide a stress calendar system to avoid stress by recording work-related stress. Additionally, the system will be evaluated to analyse whether using the system is helpful to effectively reduce stress or not.

1.1 My Stress Calendar

We conducted an online survey to find out how to reduce stress at the workplace where similar events happen. Based on a survey of 156 participants, it was found that 77.5% of participants normally experienced various types of stress caused by heavy workload or duties which were too difficult to complete. Thus, we designed a web- based calendar system called "My Stress Calendar" which provides various functions, such as subjectively recording stressful events, relevant memos, and emotions (Fig. 1). Furthermore, the system provides an emotional feedback depending on the stress index entered by the users.

Figure 2 describes the user interface of the My Stress Calendar system. In general, its basic function is similar to a normal calendar application. It shows dates in a monthly view. The user can input his/her events into the schedule. After the event, the user can edit the schedule to add one's emotional feelings about the event. The user can choose one of five stress levels (−2, −1, 0, 1, 2). Negative scores mean negative feelings about the event, such as frustration and anger. Positive scores mean positive feelings about the event, such as satisfaction and happiness. Zero means that the user felt neither positive nor negative feeling about the event. Thus, the user can track one's feeling about a past event.

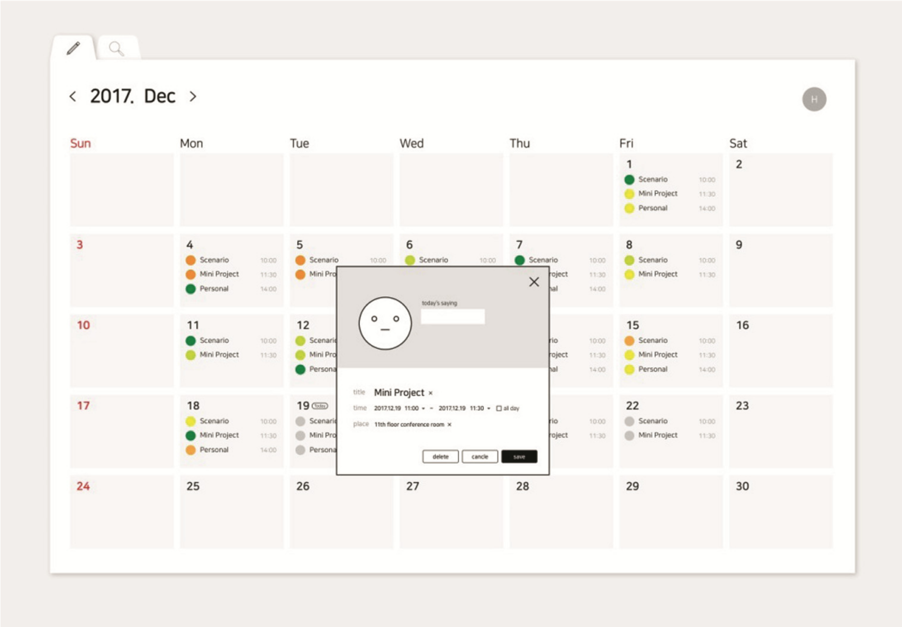

Fig. 1. My Stress Calendar sample image

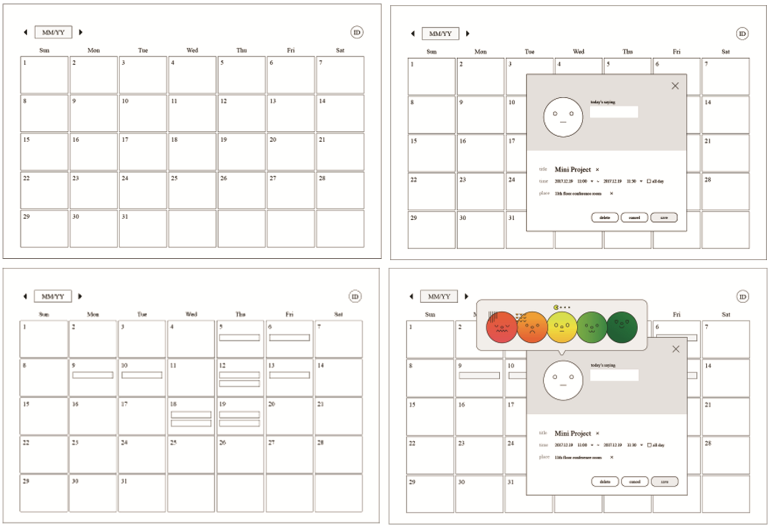

Fig. 2. The user interface

2 Related Works

Tomitsch et al. [5] stated that calendars have been regarded as a personal supportive artefact for a long time [5]. They conducted a research to find out the types of emotional values that occur when using a personal calendar. Tomitsch et al. [5] suggested that a calendar can play a variety of roles, as a temporal map, an emotional awareness artefact, a personal information management tool, a handheld tool and a diary [5]. Their study proposed that calendars have an emotional value for their users, recording states of relations and emotional expressions like diaries. Thus, a calendar is used not only to manage a schedule, to do list, and information but is also used to share emotional events with family or friends. By using a calendar as an emotional tool, the users can record their emotional expression on the schedule and remember it. Our study focuses on recording the level of stress corresponding to a schedule. Such a recording activity is regarded as a way of expressing emotion related to a schedule. Expressing emotion about the schedule may help people address similar events because they can remember why they experience a particular emotion that corresponds to an event in the schedule.

3 Methods

3.1 Experimental Design

Twenty subjects were recruited to evaluate the "My Stress Calendar" system. The independent variable for the experiment comprised using "My Stress Calendar". The "My Stress Calendar" was used by the subjects to evaluate the efficacy of this calendar system in reducing stress at the workplace. The dependent variable is the score of perceived stress scale [6]. Thus, before using the "My Stress Calendar", the participants were asked to record their stress level according to the perceived stress scale. There are seven positive and seven negative questions. Negative questions were used to find out the level of stress the participants perceived regarding an event. Positive questions were used to find out the level of positive feeling the participants experienced when they effectively dealt with a challenging event. The scale consists of five points; from 0 to 4. 0 is never, 1 is almost never, 2 is sometimes, 3 is fairly often and 4 is very often. The participants used the "My Stress Calendar" for three days. When using the "My Stress Calendar", they were asked to fill up their schedule on the "My Stress Calendar" and were also asked to record their feeling about the schedule. After that, they were asked to express their stress level according to perceived stress scale. Figure 3 illustrates the research process in detail.

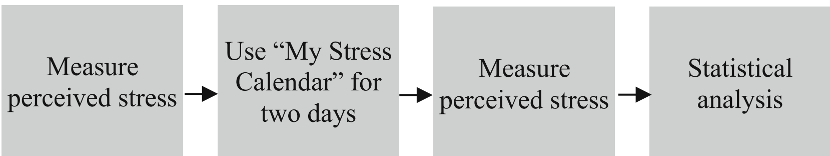

Fig. 3. Research design

3.2 Apparatus

A desktop computer which consists of an Intel core™ i7-6700 CPU @ 3.40 GHz and 16.0 GB of RAM was used. The monitor's resolution was 1920 × 1080. Windows 10 Enterprise was installed on the desktop computer and Microsoft explorer 11.0 was used to access the "My Stress Calendar" on the Web. The "My Stress Calendar" prototype, which is a web-based system, has been developed using PHP as a server-side script language running on an Apache Web Server; this application serves various dynamic web pages and works on a MySQL database. On the client-side, Javascript (pure Javascript, JQuery) was used to build various static functions and visual interfaces. Statistical analysis was conducted using Microsoft Excel 2010.

4 Results

Table 1 gives basic information about the subjects (participants). The mean age was 30.85; gender wise, there were 13 men and 7 women participants. Amongst the participants, 9 were designers and 12 were developers.

Table 1. Basic information

Age	Gender	Job role
Mean: 30.85	Male: 13 Female: 7	Designer: 9 Developer: 12

According to Table 2, the mean value of perceived stress score from the survey before using the "My Stress Calendar" was 26.85. However, the mean value of perceived stress score obtained after using the "My Stress Calendar" was 22.80. This indicates that the participants' stress levels decreased after using the "My Stress Calendar." The result of the one-way ANOVA indicates that there was a significant difference between before using "My Stress Calendar" and after using "My Stress Calendar" on the perceived stress score; the F-value was 4.12 and the P-value 0.04 (Table 3).

Table 2. Summary of ANOVA: single factor

Groups	Count	Sum	Average	Variance
Before using "My Stress Calendar"	20	537	26.85	48.87195
After using "My Stress Calendar"	20	456	22.8	30.58947

Table 3. Result of ANOVA: single factor

Source of variation	SS	Df	MS	F	P-value	F crit
Between groups	164.025	1	164.025	4.128465	0.049202	4.098172
Within groups	1509.75	38	39.73026			
Total	1673.775	39				

5 Discussion

It can be assumed that the subjects experienced less stress at their workplace after using the “My Stress Calendar”. There was a significant difference observed in the stress levels based on whether or not individuals used the “My Stress Calendar”; however, the difference was not significant as expected. To explain this result, several reasons have been identified and discussed in this section. Firstly, the users could not use the “My Stress Calendar” for a sufficiently long period. This project was carried out over three weeks, which included the development time for the “My Stress Calendar” web-based system. Thus, the subjects were given only two days to use the system due to limited project time. If more time had been given to the subjects, the difference would be considerable. Secondly, even though more emotional functions were designed, these could not be developed due to limited project time. We initially designed the system according to the comfort level of the users, depending on their feeling about the schedule. However, we could not develop “Comfort” functions; the system was only developed to the record the feelings about the events. Thirdly, if the subject felt bad suddenly from an unexpected event, then his/her stress score measurement may have influenced the result, without reference to using the system.

In order to find out how the subjects were influenced emotionally by recording their feeling about an event, we need qualitative data through in-depth interviews. In future, we will develop more system functions such as “Comfort”; then we will conduct an in-depth interview to find out how the subjects’ feelings may change by recording one’s feelings about the events. It is necessary to clarify the change of subject’s behaviours or feelings through qualitative data. This means that recording the stress level corresponding to each event may lead to cognitive behavioural change, such as avoiding the stressful event recorded in the system. In addition, the system may comfort the users when he/she records many stressful events. This indicates that the feelings of the users may change whereby their mental health improves. According to Beck [7], emotions, thoughts and behaviours are all connected and influence each other [7]. Hence, it can be assumed that the future study will investigate the relationship between recording stressful events, the change of behaviours, and the change of feelings.

6 Conclusion

We developed the “My Stress Calendar” which is a web-based system to record users’ feelings about their schedule. Twenty subjects were recruited and their stress score were measured based on a perceived stress scale. The results indicated that there was a significant difference in stress score between before using “My Stress Calendar” and after using “My Stress Calendar.” It turns out that recording how one feels about an event may be an effective behaviour to control one’s feelings and improve one’s mental health. However, this project has some limitations due to limited resources. In future study, we need to focus more on how human emotions, thoughts, and behaviours influence each other by recording feelings about events in one’s every day live.

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Generation "Always On" Turned Off. Effects of Smartphone Separation on Anxiety Mediated by the Fear of Missing Out

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Abstract. The present study was designed to analyze psychological effects of separating users from their smartphones regarding anxiety and "Fear of Missing Out" (FoMO). In a laboratory experiment, participants (n = 85) went through a seven-minute waiting session. They sat alone in a room - either with or without their phone. Results revealed that participants who waited without their phones reported significantly higher levels of anxiety, afterwards. Further, partial mediation was revealed with FoMO significantly mediating the impact of phone separation on anxiety. The findings suggest a psychological relevance of smartphones which reaches beyond the mere functionalities and applications. It is the entity of the phone itself which seems to be psychologically relevant offering a promising approach for analyzing psychological aspects of humans interacting with technological devices.

Keywords: Smartphones · Smartphone separation · FoMO · Anxiety

1 Introduction

Over the past 10 years, smartphones have evolved to be one of the most popular devices ubiquitous in everyday life, having overtaken in terms of distribution and frequency of usage (Kantar TNS 2017). Smartphones offer multiple applications and functions which refer to multiple motives of usage, e.g. communication, entertainment, organization of data or search for information. Accordingly, statistics reveal an intense daily usage of about 2.5 h a day, with rising tendency (comScore 2017). Users aged between 18 and 32 years even report to use their phone about four hours a day (Statista 2018) resulting in an ascription of being the generation "always on" (Knop et al. 2015). The smartphone accompanies its owner throughout the day, supporting him regarding various daily challenges. In sum, this leads us to the conceptualization of the smartphone acting more like a "digital companion" than mere technical equipment (Carolus et al. 2017). Consequently, we ask for the psychological effects of a sudden interruption of this close companionship: Will users be emotionally affected if they are separated from their "digital companion" for a short period of time?

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2 Theoretical Framework

2.1 A Psychological Perspective on Smartphone Separation

In a globalized world with families and friends dispersed among different places, mobile communication technologies allow their users to overcome communication barriers and exchange messages, e.g. texts, pictures or voices messages, independent of time and place. Hence, mobile communication allows us to in touch with families, friends and acquaintances which increases social connectedness and contributes to the gratification of fundamental human needs such as the need for affiliation or the need to belong (Deci and Ryan 2012; Wei and Lo 2006). The concept of "Fear of Missing Out" (FoMO) refers to this need. FoMO is defined as "the desire to stay continually connected with what others are doing" (Przybylski et at. 2013, p. 1841). Basically, the possibility of missing out social experiences results in an emotional state of anxiety. Originally, the concept referred to the usage of social media platforms. Research revealed that FoMO is positively correlated with users' "Social media Engagement" (Alt 2015; Blackwell et al. 2017). Further, FoMO was found to mediate the effects of users' satisfaction of the needs for competence, autonomy and relatedness, general mood and overall life satisfaction on Social Media Engagement (Przybylski et al. 2013). As smartphones offer continuous access to social media, FoMO should also affect general phone usage. Accordingly, research reveals FoMO to influence problematic smartphone usage, especially for social purposes, e.g. communication and social networking (Wolniewicz et al. 2017). Research also showed that intense or compulsive smartphone use (Smartphone Addiction; Kwon et al. 2013) was strongly related to both FoMO and anxiety (Elhai et al. 2016) as well as negative affects (Wolniewicz et al. 2017).

While FoMO focuses on the function of the phone in terms of access to social media or instant messengers, the concept of nomophobia focuses on the phone itself, specifically how users depend on the device and not on certain applications (King et al. 2013). Rosenberger (2015) discusses a phenomenon known as "phantom vibration": the misperception of a silent phones to vibrate shows that the device is constantly salient to its owner. Considering the phone as the point of reference results in the "fear" of being out of touch with the phone. In this context, Cheever et al. (2014) analyzed the effect of smartphone separation on anxiety levels. In their experiment, students were told to wait in a room for 65 min. Their only task was to answer an anxiety questionnaire three times (after 10, 35 and 60 min). Half of the participants were separated from their smartphones, half of them were not. Results revealed that anxiety would increase over time (t1 to t3) if participants waited without their phones. However, effects were only significant for students with average to high smartphone usage. Similarly, Clayton et at. (2015) separated iPhone users from their phones. While engaging in the experimental task participants heard their phone ring but were not able to answer. Results showed that these participants exhibited higher levels of blood pressure, increased heart rate as well as anxiety levels. Additionally, their task performance decreased.

2.2 Hypotheses

In sum, research so far focussed either on the psychological effects of smartphone separation without considering FoMO or on correlations of FoMO and the use of certain social media applications disregarding the mobile phone itself. Consequently, our study combines the vacancies of these two approaches by focussing on both smartphone separation and anxiety on the one hand and FoMO on the other hand. Following our idea of the smartphone acting the part of a "digital companion", we focus on the device itself. Because the phone provides access to social media and because social media has been shown to be associated with FoMO we ask for the impact of phone separation regarding bot anxiety and FoMO.

Hypothesis 1 refers to research which showed that users who were separated from their smartphone reported higher levels of anxiety than users who were not separated from their smartphone (Cheever et al. 2014; Clayton et al. 2015). In contrast to FoMO which is conceptualized as a trait, the emotional state of anxiety seems to be affected by phone deprivation. Thus, we hypothesize:

H1: Users who are separated from their smartphones experience significantly higher levels of anxiety than users who are not separated from their phones.

Further, FoMO has been shown to be a significant predictor of social media usage and smartphone usage (Wolniewicz et al. 2017). Accordingly, hypothesis 2 integrates FoMO which is postulated to mediate the effect of phone separation on anxiety:

H2: The effect of smartphone separation on users' anxiety levels is significantly mediated by FoMO.

3 Method

3.1 Participants

A total of 85 students (60 females, 25 males) voluntarily participated in a laboratory study at the university of Wuerzburg, Germany. Ranging in age from 19 to 35 with ($M = 22.26$ years; $SD = 2.56$), participants represented the so-called generation "always-on" which is referred to as being especially vulnerable to phone separation. On average, participants reported to use their smartphones 4.45 h per day ($SD = 2.39$), 1.15 h for work ($SD = 1.06$) and 3.30 h ($SD = 1.84$) during spare time.

3.2 Procedure

A single factor experimental design was conducted with participants randomly assigned to either the experimental (phone separation) or the control condition (no phone separation).

After being welcomed and introduced into the experimental setting by the researcher, participants agreed to the ethical guidelines of the German Psychological Association (DGPs). Afterwards, they were instructed to activate silent or vibration mode to avoid disturbances during the study. To allegedly further minimize disruptive factors, half of the participants (experimental group) were instructed to hand over their phone to the experimenter. The other half kept their phones (control group). Then, they were told to wait in the room until the researcher would have prepared the next part of the study. During a seven-minute waiting session a sound of a vibrating phone was played twice, after three and after 6 min causing salience of the phone. In contrast to Clayton et al. (2015) we implemented vibration instead of ringtones because vibration sounds are more universal than individualized ringtones resulting in a consistent manipulation. Afterwards, participants turned to a computer to answer a questionnaire.

3.3 Measures

Anxiety and FoMO were assessed using self-report measures with items to be answered on likert scales.

Anxiety
The State-Trait Anxiety Inventory (STAI) measures anxiety on both, state and trait level (Laux et al. 1981). Our study focussed on the portion referring to state level only. Hence, participants answered 10 positive items (e.g. "I'm satisfied.") and 10 negative items (e.g. "I feel very tense.") using 4-point Likert scale (1 = not all to 4 = very much so). Item scores are added to obtain total scores (range: 20 to 80) with higher scores indicating greater anxiety.

Fear of Missing Out
FoMO was measured using the scale developed by Przybylski et al. (2013) consisting of 10 items (e.g. "I fear others have more rewarding experiences than me.") which were answered on a 5-point Likert scale (1 = not true at all; 5 = extremely true).

Smartphone Usage and Demography
Participants reported daily smartphone usage (hours a day), distinguishing between work-related and spare-time-related use. Further, sex and age were reported.

4 Results

The descriptive statistics are displayed in Table 1. The internal validity of the anxiety and the FoMO scale was good to excellent with Cronbach's Alpha of .92 and .80.

Table 1. Anxiety ranged from 20 to 80, FoMO ranged from 1 to 5.

	Experimental group (phone separation)	Control group (no phone separation)	Total
Anxiety	40.26 (11.73)	34.57 (5.13)	37.45 (9.48)
FoMO	3.21 (.77)	2.86 (.56)	3.04 (.69)

To test hypothesis 1, an independent-samples t-test was conducted to compare experimental group and control group regarding anxiety levels. Results revealed a significant difference (t (83) = −2.88, p = .01), with the experimental group reporting higher levels of anxiety (M = 2.01, SD = .59) than the control group (M = 1.73, SD = .26). Thus, hypothesis 1 was confirmed.

To test hypothesis 2, a mediation analyses was conducted, with phone separation as the independent, anxiety as the dependent and FoMO as the mediator variable (see Fig. 1). To calculate, PROCESS version 3.0 was used (Hayes 2017). In step 1 of the mediation model, the regression of phone separation on anxiety scores, ignoring the mediator, was significant, $b = -5.68$, t (83) = −2.88, p = .01. Step 2 showed that the regression of phone separation on the mediator, FoMO, was also significant, $b = -.35$, t (83) = −2.39, p = .02. Step 3 revealed the mediator, FoMO to significantly predict anxiety while controlling for phone separation, b = 5.21, t (83) = 3.79, $p < .001$. Controlling for the mediator FoMO, step 4 indicates a decrease of the regression coefficient between phone separation and anxiety. However, the coefficient was still significant, $b = -3.86$, t (83) = −2.04, p = .04. The partially indirect effect of the mediation was tested using a bootstrap estimation approach with results indicating the indirect coefficient to be significant, $b = -.19$, 95% BCa CI [−.40, −.03].

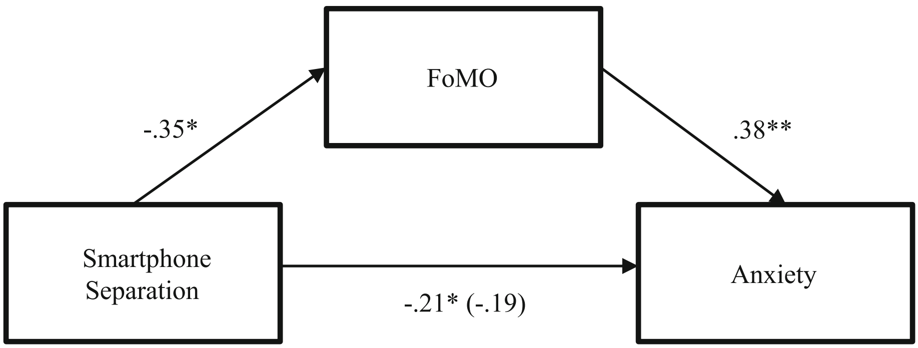

Fig. 1. Mediation analysis of smartphone separation, FoMO and anxiety. Effects are reported as standardized coefficients; $^*p < .05$; $^{**}p < .01$. The partially indirect effect between smartphone separation and anxiety is put in parentheses.

This study focuses on psychological aspects of smartphone usage, thus focusing on anxiety and FoMO as a mediator. However, research revealed duration of usage to be relevant, too. Regarding users who had been separated from their phones, Cheever et al. (2014) showed that smartphone usage frequency significantly predicted anxiety and Elhai et al. (2016) reported significant correlation of usage and FoMO. To account for these results, we exploratively analyzed the impact of smartphone usage resulting in positive correlations between usage and FoMO (r = .41, n = 85, $p < .01$) as well as usage and anxiety (r = .31, n = 85, $p < .01$). However, regression analysis did not reveal phone usage to significantly mediate anxiety.

5 Discussion and Conclusion

Smartphones are ubiquitous in our digitalized world. Today’s smartphone owners - and especially younger users representing the so-called generation “always on” - seem to be permanently in touch with their phones. Intensive usage can be explained by the multiple functionalities of modern phones which contribute to the gratifications of fundamental psychological needs such as the need to belong. By allowing communication and interaction with family, friends and acquaintances the use of the phone results in social connectedness and prevents FoMO. Consequently, we argue that the phone itself constitutes a relevant entity (“digital companion”). The present study confirms this idea by revealing that the deprivation of the phone emotionally affects the owner. Confirming hypothesis 1, participants waiting without their phone reported to be significantly more anxious than those who kept their phones. In line with Cheever et al. (2014), this result supports the psychological relevance of the smartphone as the seven-minute waiting session without the phone constitutes a rather minimal intervention. Confirming hypothesis 2, FoMO significantly mediated the effect of phone separation on anxiety with higher levels of FoMO resulting in higher levels of anxiety. This result indicates the importance of considering the individual’s psychological characteristics when analyzing human-computer-interaction. The deprivation of the phone does have an effect. However, this effect is mediated: As higher FoMO indicates higher social media usage (Przybylski et al. 2013), the deprivation of the phone which offers just the access to social media seems to be especially problematic for users who fear to be cut off from their social network. Explorative analysis has shown phone usage to relate to users’ anxiety and FoMO, however, the mere focus on duration of usage rather simplifies the underlying effects. The integration of psychological aspects, e.g. regarding the motivation to use the phone, increases explanatory value.

The current findings need to be considered in the light of possible limitations. First, our study concentrates solely on a student sample. To gain first insights, we focused on representatives of the so-called generation “always on” who appears to be especially susceptible to effects of phone separation. To generalize the results, future research needs to widen the perspective considering further user groups. Second, anxiety was measured using self-reports which are prone to (unconscious) manipulation. Physiological measures (e.g. heart rate, skin conductance) offer further development (Clayton et al. 2015). Third, during the waiting session, the same vibration sound was played for every participant to ensure comparability of the sessions. However, participants owned different phones and were used to different notification settings. The sound played during the experiment might therefore trigger different associations we did not controlled for. Future research should adapt to interindividual differences. Fourth, the control group needs to be analyzed more in-depth: Did they use their phone during waiting? Did usage type (e.g. application, duration) has an effect? Finally, regarding psychological variables the current study only considered anxiety and FoMO. The variety of gratifications smartphones offer (e.g. distraction, entertainment, self-presentation, self-assurance) refer to multiple psychological variables (personality, needs, motivation of usage) which refer to research questions of further research.

The spite these limitations, the present study contributes to the growing body of research focusing on the psychological effects of technological devices. In contrast to common approaches focusing on certain ways of usage (e.g. certain social media applications) our study suggests the entity of the device itself to be psychologically relevant. Understanding the psychological relevance of the device itself offers a novel avenue for psychological insights into the individual smartphone owner and the relationship to his device.

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A Study on Organization Simulator as a Means to Prevent Workplace Depression

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Abstract. We have investigated the organization simulator as a means to prevent workplace depression. The simulator and its communication model show the behaviors of human relationships based on the idea of 'Message Theory'. In this report, we investigate the effects of the message sending/receiving characteristics, and position of the person in the case of an organization where 9 persons belong. The conditions of simulation are (1) average persons, (2) a positive receiving person, (3) a positive sending person, (4) positive/negative person in the center, (5) positive/negative person in the marginal. As a result, the personal and organizational statuses (positions of the persons, mean distance, and mean mental health index) are varied according to the initial condition. Moreover, usage environment of the simulator based on the communication model were discussed.

Keywords: Workplace depression · Mental health · Simulation Organization assessment · Social isolation

1 Introduction

The treatment of mental disorders among employees can be a long-term economic, mental, and physical burden for the employees. The treatment can also result in socio-economic losses for the organization. In 2015, 1515 workers' compensation claims for mental disorders were recorded in Japan. Therefore, a predictive approach is required to protect employees and minimize losses due to workplace depression.

In the field of social psychology, various models of human relations and mental activity have been devised. Lewin [1] proposed that if the individual P and the environment E are included in the field and life space is denoted as $L\ sp$, and behavior is defined as $B = F\ (P,\ E) = F\ (L\ Sp)$, the field (area) vector affect the personal behavior [1]. Moreno developed a sociogram that expresses human relationships as a table and a figure [2]. Bales and Cohen developed SYMLOG (SYstem for the Multiple Level Observation of Group) based on the three-dimensional space that is designed to assess the characteristic behaviors [3].

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In this study, we focus on individual behavior in the workplace, including positive and negative message sending/receiving characteristics and investigate changes in human relations.

2 Mental Health and Stress Factors in the Workplace

Social isolation in the organization, causing symptoms similar to depression and anxiety disorders, can be strong stress factors [4].

Stress has harmful effects on the brain. It impairs cognitive and emotional functioning as compared to a healthy state of mind. In addition, it is believed that an individual's perception of a message given from others decides his/her emotional, physical reaction based on the interpretation, and influences the action [5,6].

Therefore, it is important to recognize the impact of the quality of communication in the organization on the employees' personal mental health. The organization simulator is useful for observing isolated individuals and proactively preventing workplace depression.

3 Communication Model and Simulator

In this communication model (Fig. 1), the *World* includes *Organizations*, and the *Organizations* include *Persons*. *Persons* display various message sending/receiving characteristics (*Influence(a, b)* for sending, *Sensitivity(a, b)* for receiving). Based on a message exchange, a persons' positional relations may vary, limited within the frame of the organization.

On the simulator, every person sends a message to others or themselves once in one turn. The persons' source message *MSG* is generated as random numbers following standard normal distribution *N(0,1)*. The *sendMSG* is generated by senders' *Influence* as shown in (1). The *sendMSG* is transmitted to the recipient selected depending on the proximity or Euclidean distance. The *rcvMSG* is generated by the receivers' *Sensitivity* as shown in (2). The recipient selection probability *sendP* (rank of closeness: rank of oneself = 1) is calculated with (3) (e.g. $n = 3$; $sendP(1) = 0.5$, $sendP(2) = 0.33$, $sendP(3) = 0.16$).

$$sendMSG = a_i * MSG + b_i \tag{1}$$

$$rcvMSG = a_j * sendMSG + b_j \tag{2}$$

$$sendP(rank) = \frac{n + 1 - rank}{n(n + 1)/2} \tag{3}$$

When the message is received positively, the simulator display a circle around the recipient with line, and the message is received negatively, display the circle with dot line. Such appearances show the relationship between the *sendMSG* and the *rcvMSG* (Fig. 2).

Based on the results of message exchange, the senders' and receivers' positions follow four patterns as follows, (1) both sender and receiver approach,

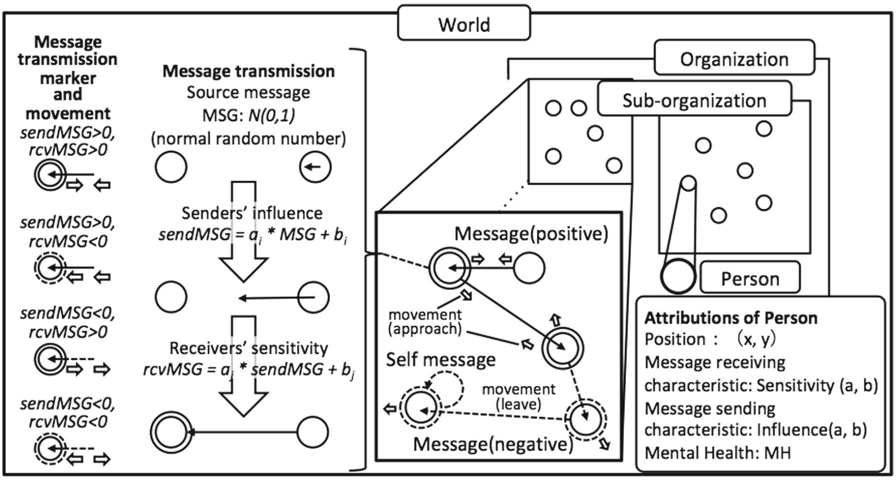


Fig. 1. Communication model for the organization simulator

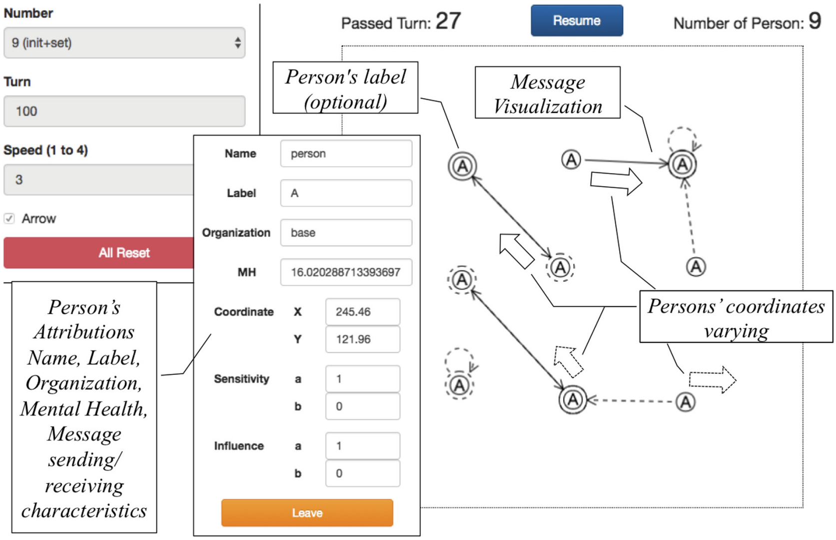


Fig. 2. Prototype of simulator

(2) sender approaches and receiver leaves, (3) sender leaves and receiver approaches, and (4) both sender and receiver leave. After all message exchanges in a turn, the persons' coordinates are varying (except in case of self-message).

The user can input persons' attributes (*x, y, Influence. Sensitivity, Mental Health*) and number of finish turn, then observe the simulation. The examples of behaviors of the simulator in the case of 9 persons organization are following.

In condition 1, all the persons are average message sending/receiving characteristics. They send/receive a message directly (Fig. 3). In condition 2 and 3, a person has positive message receiving and sending characteristics, respectively (Figs. 4 and 5). In condition 4 and 5, a person has positive message sending/receiving characteristics, and locates the center or the middle right (Fig. 6). In condition 6 and 7, a person has negative message sending/receiving characteristics, and locates the center or the middle right (Fig. 7). In the condition 7, a negative person has a tendency toward socially isolated. As just described, persons' positional relationship changes according to persons' attribution.

4 Usage of the Simulator

The industrial counselors, human resources personnel, and clients are the target users of the simulator. The users can set a person's attributes optionally to reflect the organizational environment and inter-personal relations.

A. Use with industry counselor: The simulator will make it possible to share information for client and industry counselor.
B. Human resource personnel use: The simulator works as a means of monitoring the coping behavior not only for personnel managers, but also for people experiencing a mental health crisis in the workplace.
C. Self-consultation: A person who is troubled with human relations in the workplace inputs his/her own situation (e.g., psychological distance from others and personal characteristics) into a simulator and observes the movement. The user can obtain an overview of the situation objectively, and can accordingly adjust his/her behavior and characteristics.

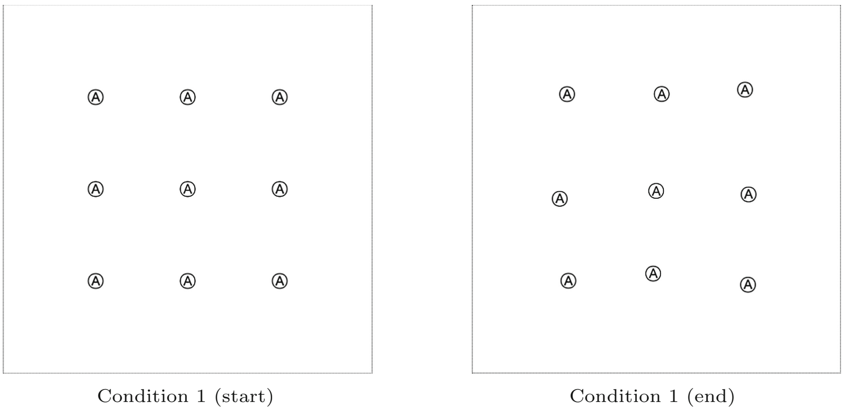
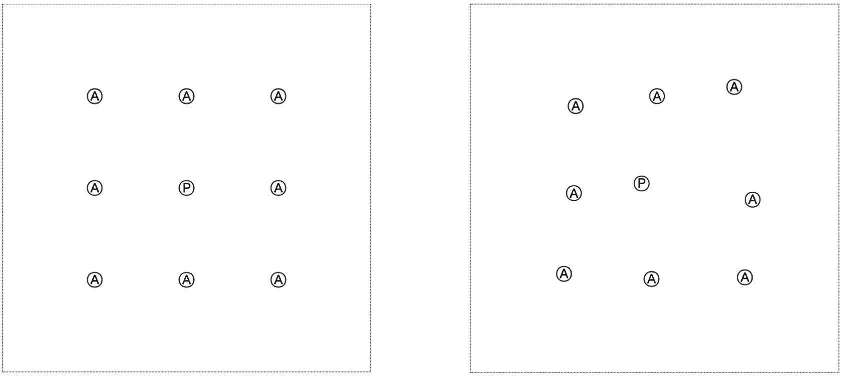
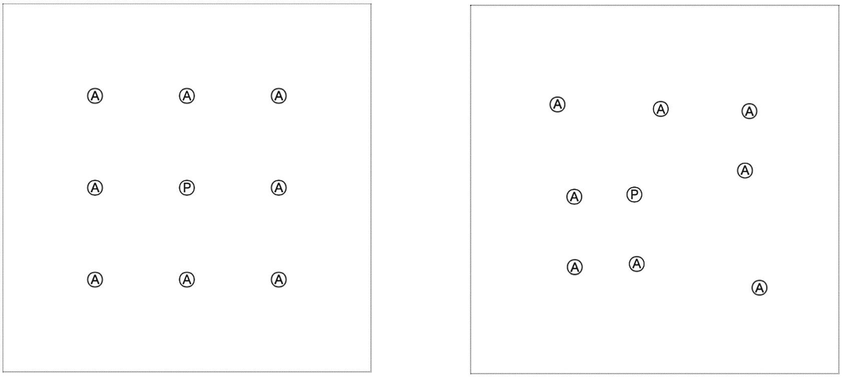


Fig. 3. All persons have average message sending/receiving characteristics (*Influence* $a = 1$, $b = 0$, *Sensitivity* $a = 1$, $b = 0$). Distances of each persons nearly unchanged.



Condition 2 (start) Condition 2 (end)

Fig. 4. A person have positive message receiving characteristics (*Influence* $a = 1,\ b = 0$, *Sensitivity* $a = 1,\ b = 0.5$). A part of distances slightly changed.



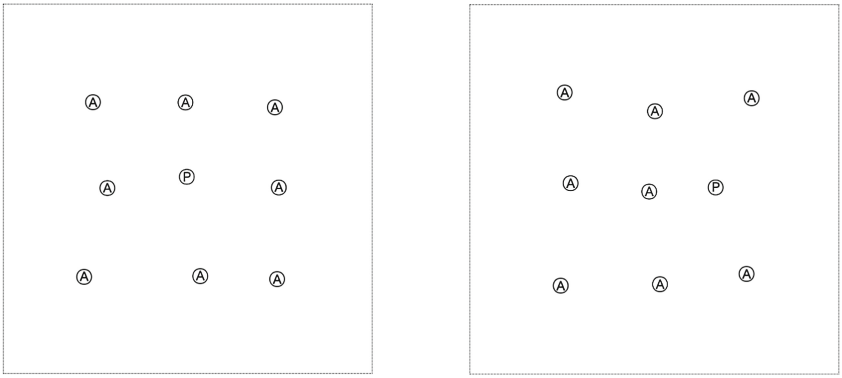
Condition 3 (start) Condition 3 (end)

Fig. 5. A person have positive message sending characteristics (*Influence* $a = 1,\ b = 0.5$, *Sensitivity* $a = 1,\ b = 0$). A part of distances slightly changed.

5 Discussion

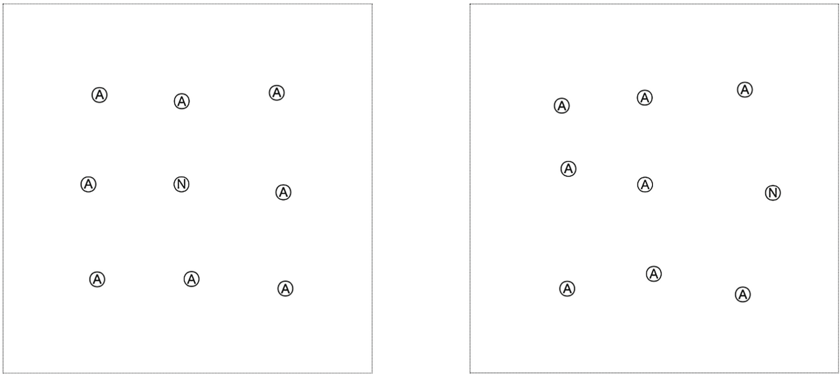
The prototype of simulator has the functional limits as follows.

(1) How can users input their message sending/receiving characteristics to the simulator?: It's not always true that users know his/her characteristics. So we would need some method to adjust parameters automatically (e.g. extract parameters from e-mail messages or voice call).



Condition 4 (end) Condition 5 (end)

Fig. 6. A person have positive message sending/receiving characteristics (*Influence* $a=1,\ b=0.5$, *Sensitivity* $a=1,\ b=0.5$). A positive person of condition 5 have a tendency toward to approach inside of the group.



Condition 6 (end) Condition 7(end)

Fig. 7. A person have negative message sending/receiving characteristics (*Influence* $a=1,\ b=-0.5$, *Sensitivity* $a=1,\ b=-0.5$). A person in the middle right have a tendency to move outside.

(2) Implementation of more than one or more organization and sub-organization: In most situation, the organization doesn't exist alone but has the sub-organizations and the other organizations. Persons in the organization must be able to send/receive message beyond the frame of the organization.
(3) Influence of message to the workplace environment: It seems message affects not only a target (receiver) person but also surrounding persons indirectly.

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