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Human Work Interaction Design

Designing Engaging Automation

5th IFIP WG 13.6 Working Conference, HWID 2018
Espoo, Finland, August 20–21, 2018
Revised Selected Papers

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Preface

Human Work Interaction Design (HWID) was established in September 2005 as the sixth working group (WG 13.6) of the IFIP Technical Committee 13 on Human–Computer Interaction (HCI). The scope of this group is the analysis and interaction design of a variety of complex work and life contexts found in different business and application domains. For this purpose, it is important to establish relationships between extensive empirical work domain studies and HCI design. WG 13.6 aims to provide the basis for an improved cross-disciplinary cooperation and mutual inspiration among researchers from the many disciplines that by nature are involved in the deep analysis of a work domain. Complexity is hence a key notion in the activities of this working group, but it is not a priori defined or limited to any particular domains. WG 13.6 initiates and fosters new research initiatives and developments, as well as an increased awareness of HWID in the HCI curriculum.

This volume presents chapters extending the papers presented at the 5th HWID working conference that was held at the University of Aalto (Espoo, Finland) during August 20–21, 2018. In continuation of the series of the Human Work Interaction Design working conferences, the fifth edition was aimed at investigating the theme "Designing Engaging Automation."

Interaction design for work engagement has recently started to gather more attention, especially in designing tools for employees. Work engagement takes usability of interactive systems to the next level by providing employees with pleasurable and meaningful experiences via the tools used at work. The theme of HWID 2018 emphasized the need for providing these experiences also when parts of the work are automated.

Examples of relevant questions we posed during the conference include: Is automation making work less interesting or more engaging? How can we improve work engagement by automation? How can we share work optimally between humans and automation? How can we maintain operator vigilance in highly automated environments? How can we support situation and/or automation awareness? How can we evaluate the impact of automation on work engagement?

The chapters in this book focus on answering these questions to support professionals, academics, national labs, and industry engaged in human work analysis and interaction design for the workplace. The first section of the book collects the chapters that present cases of HWID in practice, while the second is focused on the chapters that present methodological discussion.

October 2018

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Prototype Design of Android App for Mothers of Preterm Infants

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Abstract. The challenging family and work environments affect health of women as well as their pregnancies in developing countries like India. Some of these pregnancies occur too early and may lead to health complications at the time of child birth. A preterm birth of infants is a significant public health issue and there are several problems faced by mothers and their families. These problems include absence of messaging/calling service in emergency, lack of communication channel with physicians, no platform for experience sharing, poor understanding about infant growth tracking, induced mental stress and shattered confidence. This paper discusses about a paper prototype design of proposed app for mothers of preterm infants. A paper prototype for this app is designed based on correlated literature survey as well as peer Android app review. This prototype design include several facilities for 'Save Our Souls' (SOS), user guide, growth tracking, experience sharing and mother's health monitoring, improving their work engagement and communication with assigned physician(s). In future, this app will provide a user guide in local Indian languages along with experience sharing option for mothers.

Keywords: Mother · Preterm infant · Android app · Paper prototype Neonatal ICU

1 Introduction

The world human population has reached around 7.5 billion by end of 2017. The global population growth amounts to about 83 million or 1.1% per year [23]. India is the second-most populated country in the world and supports over 1.3 billion people, which is around 18% of the world's population. In 2017, a crude birth rate for India was 18.8 births per thousand population [4]. Since the total size of the population is already huge, there is urgency for speedy achievement of demographic transition from high birth rate to low birth rate, resulting in lower population growth. The effects of the high population growth in India include unemployment, malnutrition, high poverty level, inequitable distribution of income, over-strained infrastructure, over-stretched health and educational services [2] Such challenging environment affects health of women as well as their pregnancies. Some of the pregnancies occur too early, too late or too frequently and it may lead to illness and complications at the time of child birth.

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A preterm birth of infants is a significant public health problem across the globe because of the related neonatal mortality during first 28 days of life, as well as short-term and long-term morbidity or disability in later life. The term - 'Preterm' for babies is defined as the infants born alive before 37 completed weeks or fewer than 259 days of gestation period [9, 14]. Table 1 depicts the categories of infants based on the related gestational age (in weeks), which is a duration of conception to birth for an infant [20]. Generally, a full term human pregnancy lasts about 40 weeks and preterm infants have premature birth.

Table 1. Categories of infants based on gestational age

Category of infants	Gestational age (in Weeks)
Extreme **Preterm**	< 28 0/7
Very **Preterm**	28–32 6/7
Moderate **Preterm**	32–33 6/7
Late **Preterm**	34–36 6/7
Preterm	< 37 0/7
Early term	37–38 6/7

According to World Health Organization (WHO), every year about 15 million babies are born prematurely around the world and that is, more than 1 in 10 of all babies born globally. Almost 1 million children die each year due to complications of preterm birth [5]. The rate of preterm births ranges from 5% to 18% of babies born all over the world [18]. In India, out of 27 million babies born every year, 3.5 million (about 13%) babies born are preterm [12].

The mothers of preterm infants experience significant psychological distress, with elevated levels of depression or anxiety. The study of maternal-infant bonding reveals that contact with infant is fundamentally important for the development of self-confidence, security or sentimental emotional stability of the mother [9]. With improved infant care and related healthcare services in Neonatal Intensive Care Unit (NICU), the survival rate of preterm infants has been increased. The quality of early maternal-infant relation is an important factor with potential for long-term negative effects on the mother and her preterm infant. To reduce the gap between NICU and the parents, there is a need for an android application, which can track the growth of infant and can provide an information support to the mother of preterm infant.

This paper provides an overview about the **initial design process and a paper prototype developed for Android application** designed for mothers of preterm infants. Along with this research work, there is a plan of developing a user persona for Indian mothers of preterm infants. This mother's persona is being developed through field studies and interviews of selected mothers as well as physicians in local hospitals and NICUs. Such persona is based on philosophy of **Human Work Interaction Design (HWID)** and is expected to provide insights about mothers of preterm infants in the form of their attributes, work habits and challenges faced during patient care.

This mother's persona along with a paper prototype design for related Android app will provide a solid foundation for actual design of Android app for mothers of preterm infants.

2 Literature Survey

The literature surveys in healthcare domain and related with mobile apps are vast and varied. This section discusses few of these related research articles, which are helpful in prototype design of a proposed Android app for mothers of preterm infants.

The aim of the study by Mbwele et al. has been to assess mothers' experience, perception and satisfaction of neonatal care in the hospitals of Kilimanjaro region of Tanzania. This cross-sectional study has employed qualitative and quantitative approaches involving semi-structured interviews of 112 mothers from 14 healthcare facilities [14]. Several reasons such as shortage of food supply, cost of medical care, impoliteness of staff, care for husband and other children, domestic responsibilities, and lack of transportation facility have developed a reluctance of mothers to attend medical services. Other complaints from mothers included **foul language, irregular doctor examinations, nurses in a hurry, little opportunities in asking questions and delay of medical care.** This study has highlighted important aspect – need for communication between patient and a physician. Therefore, a physician is included as a vital medical user and a mother is provided with several **communication channels such as appointment booking option, messaging service for advice and messaging/calling facility in case of emergency**. The proposed app also provides growth tracking facility for infants and also the user guide, which can help in reducing stress level of mothers of preterm infants.

In an Iranian study, Heidari et al. have attempted to investigate about socio-cultural factors of Iranian parents with hospitalized preterm infants in NICU. This article has revealed that the parents of hospitalized infants in Iran experienced **stress-induced physical and emotional problems, shattered confidence in their parental role, challenges related with family dynamics, shame as a social stigma, and job or income loss** [8]. This study makes one aware about the mental state of the mothers of hospitalized preterm infants and several problems faced by parents in their social life. Thus, the study has pointed out the emotional problems of the mothers and their need for support. The proposed Android app provides several experience sharing options to support the mothers of preterm infants. These options include **forums, videos, reports and physician recommendations.** Such experience sharing options can help mothers understand the challenging situation better and effectively to deal with their traumatic experiences.

Hayes et al. have described the design process and principles used in the development of Estrellita, a mobile capture tool to support parents of preterm infants in homes to track health data [7]. This article has emphasized on two vital aspects in application design - healthcare and parenting concerns. It has highlighted several design principles for such apps - **supporting flexibility and clinical adherence in data collection, enabling parent empowerment through education and/or reflection, and supporting communication through data sharing.** The proposed app supports infant growth tracking facility based on infant data collected from or entered by mother and monitored by connected physician and/or a nurse. The mother is empowered by providing user guide and experience sharing facility. **The user guide has components such as Frequently Asked Questions (FAQs), medical terms and NICU equipment list, supporting flexibility through content in multiple languages**; at least few of European and Indian languages apart from English. A physician is included as a vital medical user and can use **data sharing or communication service for advice** and messaging/calling facility in case of emergency.

The objective of the study on **infant growth tracking** by Riddle et al. is to provide gender-specific preterm infant growth curves that can be incorporated with WHO growth standards to continuously track weight, head circumference and body length of infant from 22^{nd} week of gestation through 2 years of age [21]. Intrauterine growth charts are used to monitor the growth of preterm infants in the NICU. The case studies involving infants from United States of America (USA), Australia, Italy, Israel, Turkey, Sweden and United Kingdom (UK) are considered for comparison in this research article. During study of infant growth tracking, the gender-specific percentiles for **birth weight, head circumference and body length values** are also compared. The **age-adjustment calculator** for infants, **user-preferred measurement units** and **value ranges of growth tracking parameters** with Indian context will be provided in proposed app.

3 Android App Review

A systematic review has been conducted for currently available Android apps related with neonatology and pediatrics used mainly by mothers of infants and other medical users. **There are seven Android apps for mothers of infants available in 'English' language, mostly developed in USA.** Figure 1 depicts sample screenshots of four Android apps. The app review is focused on seven identified Android apps and aimed to provide interesting insights into functionalities and other design aspects. To examine such aspects of selected Android apps, an expert-based review is conducted by authors. The team of authors includes an active physician too. During the review process, the authors have put themselves in the role of potential users i.e. mainly mothers to assess the mobile apps in terms of their functionalities as well as other design aspects.

Table 2 depicts details of apps used by mothers based on design considerations and user acceptance parameters. Major design aspects considered in selected apps include **mother's health option, targeted users, 'Save Our Souls' (SOS) button, app downloads and user rating**. There are three calculators – adjusted age calculator, drug dose calculator and NICU calculator, apart from a major function of growth tracking. An adjusted age is preterm infant's chronological age minus the number of weeks infant is born early. An adjusted age calculator helps in calculating this age for the infant. Due to lack of proper brain development, preterm infants are often at elevated risk for health issues with learning, communication, emotional regulation, and social bonding [17]. Therefore, **physicians often consider adjusted age in assessment of infant's growth and development.** Drug doses are part of regulated administration in NICU and usually expressed as a quantity per unit of time. **A drug dose calculator**

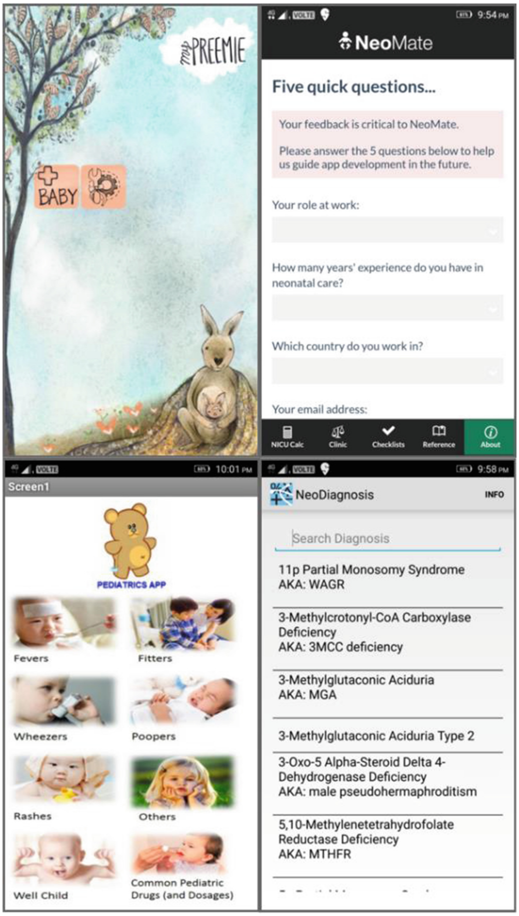


Fig. 1. Sample screenshots for selected Android apps

helps in normalizing the drug dose according to neonatal age and body weight. Such normalized drug dose is required for infant's safety and well-being [11]. The NICU calculator provides calculations for different types of drugs based on body weight of infant. It also provides calculations for **intubation tube, oxygenation index, intravenous fluids and central line size** along with information on when to start cooling treatment for infant [15]. The vital observations from entries in Table 2 are provided as follows:

- Most of the apps (6 out of 7 apps) are designed mainly for mothers of preterm infants; but these **apps don't provide much support for mother's health (1 out of 7 apps) directly.**

Table 2. Details of Android apps used by mothers based on design considerations and user acceptance parameters

App name	Major function	Mother's health option	Targeted users	SOS button	App downloads thousands	User rating Max. 5
Ovia Parenting	Growth tracking	No	Mother & caregiver	Yes	100	4.7
Neomate	NICU calculator	No	Mother	No	50	4.4
NeoDiagnosis	Diagnosis Search	No	Nurse	No	01	4.2
Pediatrics	Drug dose calculator	No	Mother & paediatrician	No	10	4.6
Mypreemie	Growth tracking	No	Mother	Yes	10	4.4
Preemie Adj. Age Tracker	Adj. age calculator	No	Mother & caregiver	No	01	3.8
Connect2NICU	Growth tracking	Yes	Mother	Yes	01	4.5

- **Most of the apps (4 out of 7 apps) have included caregivers such as physicians and/or nurses in patient care of mothers and their preterm infants.** One of the apps has included specialist physicians such as pediatricians to support these mothers.
- **Some of the apps (3 out of 7 apps) provide SOS button for making emergency contacts.**
- **All apps have at least one thousand downloads.** Few of these apps (2 out of 7 apps) have more than 50 thousand downloads.
- **Average user rating for the apps is 4.4/5.0** and most of the apps (6 out of 7 apps) have user rating of at least 4.2.
- **The single-functionality apps** such as NeoDiagnosis and Preemie Adjusted Age Tracker **have comparatively less number of downloads (just over one thousand).** The average user ratings for these apps are around 4.0/5.0 lesser than average user rating of all apps - 4.4.

Table 3 depicts details of apps used mainly by mothers based on major functionalities. All entries in the Table 3 are either 'Yes' or 'No', indicating presence or absence of that functionality in related app. Major functionalities observed in these selected apps include **growth tracking, adjusted age calculator, drug dose calculator, diagnosis search, user guide and term illustrations.**

The preterm infants are more vulnerable to infections than other term babies and therefore, their health as well as growth needs to be continuously monitored. **A growth tracking record helps physician as well as mother to keep infant development diary incorporating head size and body length, track a weight gain, log infant feeds and share growth progress with physician and parents.** An adjusted age

Table 3. Details of Android apps used by mothers based on major functionalities

App name	Growth tracking	Adj. age calculator	Drug dose calculator	Diagnosis search	User guide	Term illustrations
Ovia Parenting	Yes	No	Yes	No	Yes	No
Neomate	No	Yes	Yes	No	No	Yes
NeoDiagnosis	No	No	No	Yes	Yes	Yes
Pediatrics	Yes	No	No	Yes	Yes	Yes
Mypreemie	Yes	Yes	Yes	No	No	Yes
Preemie Adj. Age Tracker	No	No	Yes	No	No	No
Connect2NICU	Yes	Yes	No	No	Yes	Yes

calculator and drug dose calculator are also vital functions in infant care and they are explained in earlier part of this section. A diagnosis search is a facility allowing the detection of any subjective evidence of an ailment or medical condition. Such **diagnosis search may be run by the mother based on known symptoms, with the assistance of medical personnel if required.** The user guide is a technical communication document intended to give assistance to medical users using the mobile app. This **guide helps the user to know how to use the application functions and details along with the step-by-step guidance to perform specific tasks.** A function - Term illustrations is a facility provided to medical users, who want to refer or understand the medical terminologies related with neonatal care. It offers concise and easily accessible information searching for descriptions of the related medical terms. Important trends observed with entries in Table 3 are listed below:

- **Most of the apps (4 out of 7 apps) provide the infant growth tracking facility, which is vital functionality** in reducing the stress levels among mothers of preterm infants.
- **Most of the apps (5 out of 7 apps) have provided calculator facility for adjusted age and/or drug dose.**
- **User guide and Term illustrations** are important facilities for mothers as well as other medical users. **They are provided in most of the apps (6 out of 7 apps)**.
- **Diagnosis search is provided by only two apps**; mainly for physicians or pediatricians.
- **There are two single-functionality apps -** NeoDiagnosis and Preemie Adjusted Age Tracker - that **focus on only one particular function such as diagnosis search and adjusted age calculation** respectively.

4 Paper Prototype Design for Mobile App

A prototype is an experimental model of an idea. It can be considered as an attempt of a designer to present his/her idea in front of the world. A paper prototype is a low-fidelity option in mobile app design [19]. Such paper prototype is proposed for eye-free Android app for visually impaired users by Sagale et al. [22]. A similar paper prototype design is proposed in this paper for Android mobile app for mothers of preterm infants.

The proposed mobile app starts with user login process either using Facebook/ Google login or user registration option. If the user is a mother of preterm infant, she is redirected to SOS Setup in which she needs to provide the default contacts required in case of any emergency. A menu screen provides the user with three major options - **Growth Tracking, User Guide and Experience Sharing.** Each of these options has few more options, which are presented later in this section. A physician needs to track health of mother continuously and is connected to the mother via the option - **Mother's Health.** App Settings option is also provided to the user for control of settings related with **Font, Language and Security**. A physician performs two main functionalities in the app - to track infant's growth as well as mother's health, and validate the infant body parameters. Physicians may communicate with the mothers on weekly basis via any method of appointment, by calling or messaging mechanism. They can also recommend mothers with consolidated reports of other mothers and some informative articles for reference. This section presents the major screenshots in paper prototype along with related design considerations for proposed mother's app.

The screenshots for **User Login** and **SOS Setup** are depicted in Fig. 2. In User Login, user can complete login process either using **Facebook/Google login or User Registration option** as seen in Fig. 2(a). There is a User Registration option, through

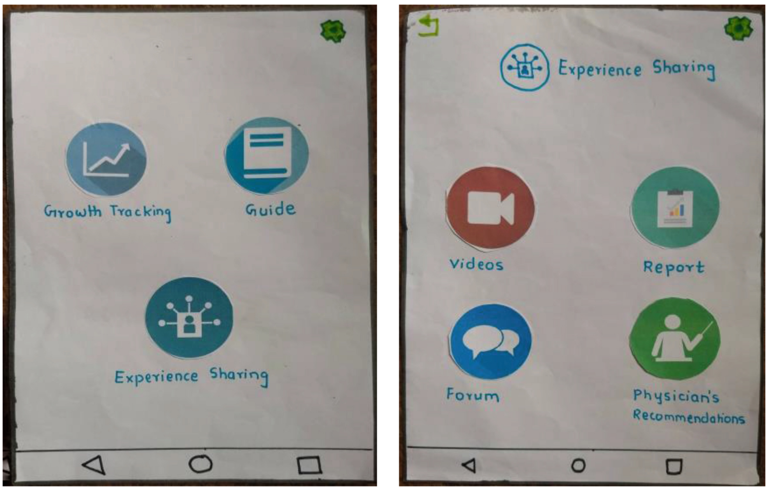
(a) (b)

Fig. 2. Screenshots for (a) User Login and (b) SOS Setup

which mother or medical users can complete user registration process and then, can proceed to use the app though own login. The user login process considers three major types of users - **mother, physician and even nurse**, observed in mobile app review in Sect. 3.

A screenshot for SOS Setup is depicted in Fig. 2(b). It has been included in app design since several mobile apps studied have **SOS button/option for signaling of extreme distress or an emergency condition** [7, 14] as depicted in Table 2. It can be used by mothers to contact the concerned **physician, husband or other family member.** The proposed app stores emergency contact numbers of the physician(s) or other family member(s) collected from the mother during SOS setup process. These contacts can be changed as per her preference. In case of any emergency, a mother needs to touch the SOS option, which notifies the related contact persons via different modes like vibration, blinking, notification, alarm and even a call. Such notification can even be supported with real-time safety information using the Google Maps to detect location of emergency and also, to provide a suitable map route of where to go and how to get to the location of emergency. Thus, **SOS button/option provides a useful messaging service in emergency to the mother.**

A screenshot for Menu option is depicted in Fig. 3(a). This main menu has three vital options which are **Growth Tracking, User Guide and Experience Sharing**. The growth tracking process involves monitoring of infant's growth through supervision of body measurements with due consideration to adjusted age of the infant. A user guide includes information about Medical Terms and Equipment used in NICU along with related FAQs for mothers, medical users and other family members with multilingual support. These options are also discussed in details later in this section.

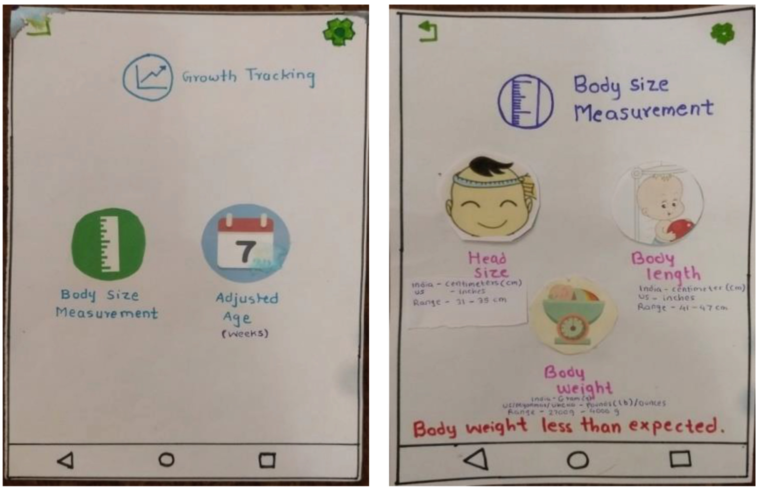


(a) (b)

Fig. 3. Screenshots for (a) Menu and (b) Experience Sharing option

An Experience Sharing option contains facilities for sharing especially the experiences of the mothers. These facilities include **Videos, Reports, Forums and Physician Recommendations.** A mother and family of a preterm infant are required to deal with mainly stress-induced emotional problems as revealed by literature survey. The parents' confidence may be shattered and few other challenges are created related with family dynamics [8]. In order to change their mindset and help them to deal with their emotional traumatic experience, a thoughtful learning strategy needs to be incorporated in proposed app design. Such experiences are personal, but there is a lot of social learning that can be derived from similar experiences of other members of society. The mothers and family members can learn through videos, reports and online community groups. **Forums targeting online community groups of mothers help them bounce ideas off each other, share care tips and get answers to their queries** [16]. Videos are also a powerful mode of experience sharing and learning. They should essentially relay on what the infant's family has done or accomplished, and how the mother talks about her own past experiences. **The physician often recommends the mother some consolidated information or reports from medical journals, articles, news, and blogs, which can help her resolve issues or concerns, to improve communication among physicians and patients.**

The screenshots for Growth Tracking and related Body Size Measurements of infant are depicted in Fig. 4(a) and (b) respectively. The Growth Tracking option focuses on **growth monitoring of infant through supervision of body measurements as well as adjusted age of the infant.** The literature survey also reiterates the need of growth tracking functionality in the app for improved communication with mother and also, for reducing their stress level [9].



(a) (b)

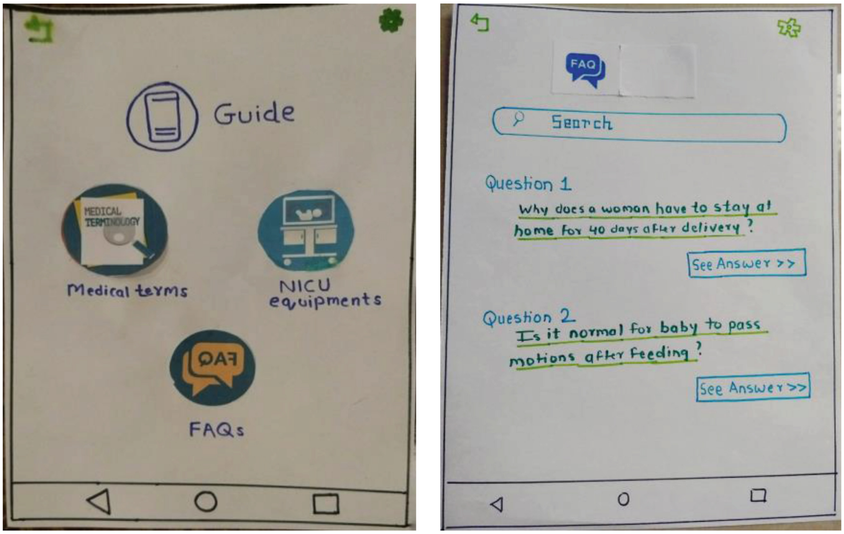
Fig. 4. Screenshots for (a) Growth Tracking and (b) Body Size Measurements

The body measurements of infant have three significant parameters such as **Head Size, Body Length and Body Weight.** It is essential to know the gestational age-adjusted measurements as there is a significant relationship of preterm birth with neonatal complications, mortality and developmental delay [10, 21]. These measurements can be entered periodically into the proposed app either by NICU nurse or mother of preterm infant and may be closely monitored and verified by the physician. The default value ranges for each of body parameters and user-preferred measurement units are also depicted in Fig. 4(b). For example, a head circumference normally measured in cm (in India) or inches (in USA). The amount of increase in head circumference helps in identification of high-risk infants [21].

A Fig. 5 depicts the screenshots for User Guide and related FAQs in Fig. 5(a) and (b) respectively. The User Guide is really crucial function as highlighted in both literature survey as well as app review. Generally, a User Guide/manual is a technical communication document intended to give assistance to intended app users. It may even include instructions and step-by-step guidance on how to perform related task [1, 3]. This guide is desired to be in users' language and with possible multilingual support. A proposed User Guide has options for **Medical Terms, NICU Equipment and FAQs** for helping mothers and her family members as suggested by Hayes et al. [7] and these options are depicted in Fig. 5(a). The definitions and explanations of Medical Terms assist especially the mothers to understand the medical context related to preterm births, pediatrics and NICU. These terms include the terminologies such as **preemie, neonatology, adjusted age, induced preterm infant** and others. The Equipment used in NICU for infant care include **incubator, lung ventilator, multi-parameter monitor, radiant warmer** and other devices. An introduction along with images of these devices under Equipment option help the mothers and other family members in accepting and even appreciating the infant care in NICU to reduce their stress. Mothers can take benefits from FAQs by exploration of related answers whenever required. The FAQs can be explored using a search bar where user can enter keywords and the app displays related FAQs in a list format as seen in Fig. 5(b). The FAQ's can be updated periodically as per physicians' recommendations and feedback from mothers.

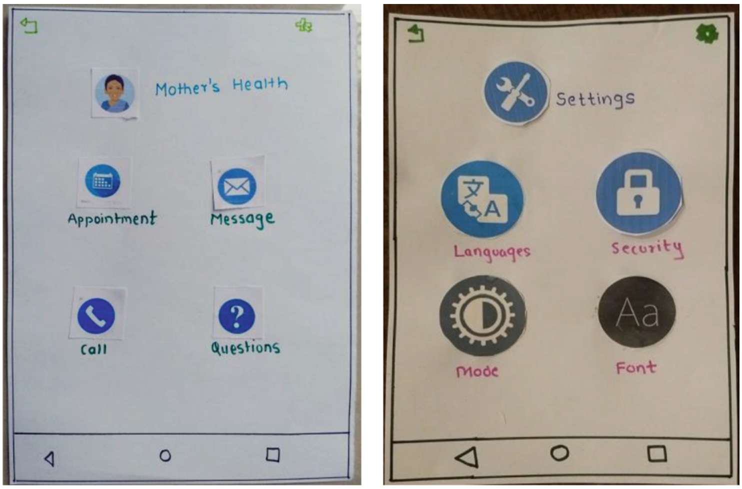
A screenshot for Mother's Health is depicted in Fig. 6(a). It has been included in proposed app since such option has not been provided in most of the related apps as seen in Table 2. A physician can track Mother's Health and can connect to the mother via this functionality. It includes **Appointment, Call, Message and Questions.** The option - **Questions**, provides a personal channel to the mother for asking specific queries to related physician as discussed in Mbwele et al. [14].

App Settings screenshot has options for settings related with **Languages, Security, Mode and Font** as seen in Fig. 6(b). These are commonly used setting options in most of the apps. A Language function can offer multi-lingual support to the mothers as well as other users. Selecting preferred language overcomes language barrier and helps mothers to get desired guidance and support effectively [6]. A **day-night mode and adjustable font size** helps to reduce the eyestrain of the users.



(a) (b)

Fig. 5. Screenshots for (a) User Guide and (b) FAQs



(a) (b)

Fig. 6. Screenshots for (a) Mother's Health and (b) App Settings options

5 Conclusions and Future Work

The proposed app for mothers of preterm infants is quite interesting and useful Android app. A paper prototype for this app is designed based on allied literature survey as well as mobile app review. This prototype design includes several functionalities to support mothers, family members as well as physicians. It has options for SOS, User Guide, Growth Tracking, Experience Sharing and Mother's Health. Thus, the proposed app is designed with main intention of helping mothers in getting answers to their queries along with improved communication with assigned physician(s). **The development of proposed Android app for mothers will improve the work engagement through automation and will also, in reducing the mental stress faced by mothers as well as by their families.**

In future, the proposed app will be developed with initial focus on user guide as well as growth tracking option, and its first version will be available on Google Play Store by later 2018. There is also a plan of providing a user guide in at least one Indian language along with English. **The availability of local language support in the app will impart health education to even more number of mothers of preterm infants and help them in taking care of infants more effectively.** This app will be tested through usability testing method with selected mothers and physicians in real-life work environment of hospitals and NICUs. The option of physician's recommendations along with experience sharing will also be incorporated in the app in subsequent versions.

Acknowledgments. We thank the physicians and medical staff at Bharati Hospital, Pune for their valuable inputs during prototype design of proposed mobile app for mothers of preterm infants. The research team has to face tough time as this paper has been completed during hospitalization and sad demise of Mr. Dattatray Bhutkar – father of one of the coauthors – Dr. Ganesh Bhutkar.

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Enhancing Your Mental Well-Being and Creativity While Writing: A Crowdsource-Based Approach

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Abstract. We describe a crowdsourcing platform for writing called Creative-Wall, where users can preserve their creative writings and share them with the community. By using images, moods and locations we create a more visual perspective of a moment that can bring creativity and mental well-being to the writer. We also present an evaluation of our crowdsourced platform. Our findings suggest that, from a mental well-being perspective, the participants felt more inspired, more focused, more creative and more immersed when using the CreativeWall add-in. Additionally, CreativeWall helps writers to trigger their creativity while writing. We highlight some results triangulating qualitative and quantitative data. Results show that users performing the tasks with Creative-Wall lost track of time more often than participants using our baseline. From user interviews, results suggest that the tasks performed with the CreativeWall add-in were more enjoyable and that the users had no issues kickstarting the writing process, which could mean that these tools can help in the initial phase of the creative writing process.

Keywords: Creative writing tools · Human computer interaction Creativity support tools · User interface design · User experience design Crowdsourcing · MSWord Add-In · Human work interaction design

1 Introduction

As we know, writing is one of the main artistic expressions of humans. In ancient times, images were used as a form of expression, and nowadays we use images as a way of recording a moment that we want to continue or "use" later on. Creative writing often displays imagination or invention. It goes outside the bounds of normal professional or technical forms of literature and can be found in journalism, science fiction, etc. and typically identified through different forms such as prose, poetry and many assorted ways [1]. Writers tend to write using different techniques and they take their creativity from anything. The creative writing process can be divided into six different stages: pre-writing, drafting, revising, editing, evaluating and publishing [2]. But in this process, writers often have one or more creative blocks, and they need creativity for finishing their work. Sometimes writing might not be as easy as it seems, as there are millions of subjects a writer can write about, thousands of ways to spread the same idea, hundreds of tools to use to help them write. Deciding what to write about can

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sometimes be surprisingly tricky. Writers often face a common problem known in this area as writer's block [2]. They refer to writer's block as the inability to write, despite the desire and ability to do so. There are different reasons for this situation to happen. Aspects such as stress, fear or simple problems with organization or prioritization can be the cause for it [3]. There are currently some possible solutions [4–8] to this issue and each writer seems to have its own way to deal with it. Writers need to look for ways to get creative and finish their work.

Search engines like Google can help you find ideas on what to write about but it takes a lot of time to analyze the thousands of results that are presented, even though they are shown in an optimized way. Social networks like Facebook or Pinterest can help you as well, with groups that are created with the objective of helping writers, but they lack categorization and can be really distracting. The best way to gather enough data for such a creativity tool is to take advantage of crowdsourcing. This way one can raise a community who is interested in writing and give them the opportunity to share their creative writings. These writings can then be used by the tool to help other writers with their own work.

In this paper, we present the crowdsource platform called CreativeWall and a Microsoft Word Add-In to enhance the mental well-being and creativity of users in the creative writing process. One of the problems that usually moves writers away from their goals is a condition called writer's block. Writer's block can last for entire days [9] and becomes a real source of frustration when people are anxious about deadlines and really need to get the writing done. One of the methods used to avoid writer's block is the use of writing prompts [7, 10], which consists of a small text that is supposed to help writers to have ideas on what to write. We decided to take this method further and refined it by adding some more components that can help the writer have the creativity he needs. By using images, moods and locations [4, 11] we create a more visual perspective of a moment that can bring creativity and mental well-being to the writer. The remaining of this paper is organized as follows: in the next section, we review related work about crowdsourcing, creative writing, flow theory and supporting creativity theories about mood, emotions and colors. We then present a section describing CreativeWall as well as the CreativeWall's Microsoft Word add-in. Afterwards, we detail the field study of CreativeWall by detailing the participants, methods, procedures, setting and results. Finally, we wrap up with a discussion as well as the overall conclusions and future work.

2 Background

2.1 Creativity Support Tools

New technological developments, such as those in the field of virtual reality, facilitate new forms of creative work. It is a two-way process, the interaction with technology provides fresh possibilities to use it in creative ways, while also leading to the evolution and sometimes transformation of technologies. Emerging computer-based tools can develop better and more creative solutions to the problems they face whether it's in decision support systems [12] or in simple software systems.

After decades of creativity research there is still no consensus on how to evaluate how well a Creativity Support Tool (CST) supports the creativity of its users [13]. Hedge et al. [14] considers that success during software development, depends on the creativity of software engineers, despite being a conceptually complex, knowledge-intensive activity. We can praise science and engineering, but there is still a paradox about technology that helps us to be more productive, perform our work more rapidly and effectively. Therefore, there is an effort for developing creativity support tools, which enable us to explore, discover, imagine, innovate, compose and collaborate [15]. Joy et al. [16] suggest that people who generate multiple possible solutions are more likely to produce solutions which are less common. Also, they argue that some people are more capable than others of breaking free from the mental set established by their initial ideas, therefore they are more flexible, from a cognitive point of view.

Selker [17] considers that creativity and motivation enhancement can easily be aligned with the design of high-quality human-computer interaction and also that creativity might be viewed as any process which results in a novel and useful product. Shneirderman [18] argues that it is a challenge to construct information technologies that support creativity and the goal of developing new CST can be obtained by building upon an adequate understanding of creative process.

The main goal of CST is to develop improved software and user interfaces that make users become more productive, and more innovative [18]. Search tools based on clustering, self-organizing maps, employing visual maps of semantic relationships are just one example of CSTs. Any user interface or software system that has a focus on improving creativity can be considered a CST: this naturally includes VR-based technology and tools, which show promising potential for effectively addressing the problem of improving creativity levels. Creativity and motivation enhancement can easily be aligned with the design of high-quality human-computer interaction and also creativity might be viewed as any process which results in a novel and useful product, as stated by [17]. Researchers have also targeted other stimuli to support creativity, such as the visual stimuli, images and text [6, 19], increase both originality and diversity of ideas during brainstorming [20, 21]. Other such as Gonçalves et al. studied UI Zen-based themes, composed of sound and images, foster inspiration, focus and immersion on creative writing tasks [7] and also with smell and sound [5].

2.2 Crowdsourcing

Crowdsourcing is a concept that, although very powerful and effective, is relatively recent and still doesn't have a solid theoretical knowledge base that allows it to have a clear definition [22]. According to Howe [23] crowdsourcing can be defined as "*the act of taking a task traditionally performed by a designated agent and outsourcing it by making an open call to an undefined but large group of people*". Another example of a definition comes from Brabham [24], who says it can be defined as "*a new web-based business model that harnesses the creative solutions of a distributed network of individuals through what amounts to an open call for proposals*". As for Kleemann et al., [25] crowdsourcing can simply be defined as "*the outsourcing of tasks to the general internet public*". These are all valid definitions but there is no consensus regarding what would be a definitive and complete definition. For the purpose of this work we will only focus on two types of crowdsourcing [25], product design and product rating by consumers and consumer profiling, which are the ones that better suit our needs.

2.3 Moods, Emotions and Colors

As Baas et al. [26] states, there are differences between moods and emotions. According to the reference, moods are long lasting while emotions are more related towards a specific stimulus, for example, an emotion would be a person feeling happy because he/she found some money on the ground. This situation forces an emotion onto the person, the emotion of happiness. On the other hand, a mood is something that is more general, for example, a person feeling happy because he/she just feels great. With this we can conclude that there really are differences in terms of intensity of feelings, being that emotion is generally stronger than a mood. Another definition of mood states that moods are the accumulation of emotions and other affective events [27]. Moods can have multiple dimensions, but only three of those dimensions have been proven to be related to creativity. They are hedonic tone, activation level and regulatory focus.

The hedonic tone, or valence, simply put, describes whether the mood is positive or negative [26, 28] (e.g. happiness has a positive tone while anger has a negative tone). This dimension is usually related to creativity as some studies refer [29]. The same studies state that moods with a positive tone help a subject produce more original word associations which means that there might be a boost in creativity.

Activation relates to whether or not the mood can generate active behaviors in the subject (e.g. calm is a deactivating mood while fear is activating). According to De Dreu et al. [28] activation is a necessary precondition for creativity to come by while hedonic tone determines the route through which creative fluency and originality is achieved. They also argue that activating moods are more likely to generate creativity than deactivating moods.

Regulatory focus refers to the motivation an individual has to complete a task. According to studies made in this area, regulatory focus plays an important role in triggering creativity [30]. There are two types of regulatory focus, the promotion focus and prevention focus. Promotion focus comes from the desire of accomplishing something, while prevention focus comes from the will of securing something [26]. A good example of this would be the attackers and goalkeepers in a football game. The objective of the attackers is to score goals and that's their motivation for playing (promotion focus). On the other hand, goalkeepers want to prevent goals, and that's their motivation for playing (prevention focus). Color can lead to feelings, and that have been proved by several studies in this area [31, 32]. An example of this statement is a cloudy day. A cloudy day has a predominant color, which is gray, and gray is related to sadness, so people usually feel sad on cloudy days. If you look outside through a yellow window you can see that a feeling of warmness comes to you and everything feels a bit happier, as states by Goethe [33]. It's curious to see that the relation between color and emotions (or feelings) was already object of research more than 100 years [33]. Kaya et al. [31, 32], performed user studies in order to be able to map colors to emotions and the result were somewhat similar to the statements made in the [33].

After considering the statements above, a list of moods and a mapping to colors was produced by us. Table 1 shows the mapping between color and emotion. Even though fearful and angry are not considered to be creativity enhancing moods, they were included in the list in order to give users some variety to choose from. As future work an increase to the number of moods should be granted in order to include other creativity enhancing moods.

Table 1. Moods mapped into colors

Happy	Yellow	
Hopeful	Green	
Excited	Orange	
Energetic	Light Blue	
Loved	Pink	
Fearful	Black	
Angry	Red	

3 CreativeWall Platform

CreativeWall is a crowdsourcing platform where its users can share their creative writings along with images, locations and moods, creating what we call a creative and mental well-being moment. This concept came to life from the idea that people sometimes have ideas for creative writings when they are, for example, walking on the street and see something that triggers their creativity and mental well-being. That is the essence of the creative moment. They have an image that triggers an idea that is described by the text. A certain mood is also associated to that moment and it happens in a certain location, date and time. When brought together, all these aspects generate our creative moment. Figure 1 illustrates how a Creative Moment is shown on the platform.

In this case the creative moment was captured in Portugal when the user was Happy. The moment has author, date and time information for a better knowledge about its details and the environment where it happened. With this kind of information, other users can recreate the moment mentally and maybe absorb some kind of creativity from it giving birth to their own ideas based on what they see and feel with the moment recreation.

With this kind of information, other users can recreate the moment mentally and maybe absorb some kind of creativity from it giving birth to their own ideas based on what they see and feel with the moment recreation.

Figure 2 shows the final prototype and how the section My Posts looks. There are two main sections on the platform, the Creative Wall and My Posts.

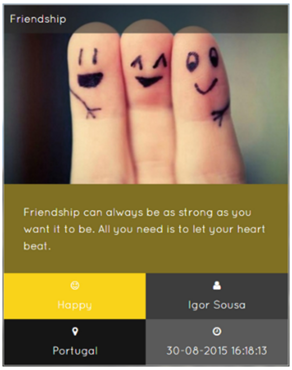

Fig. 1. Example of a creative moment

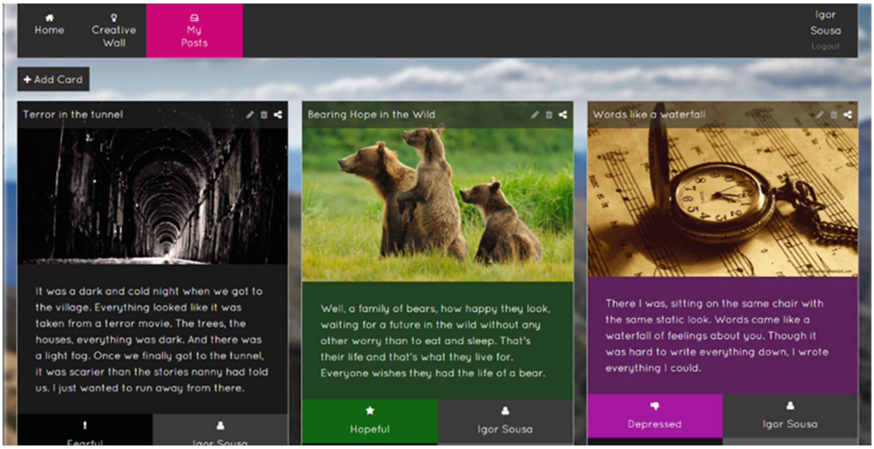

Fig. 2. Final prototype of CreativeWall

3.1 Creative Wall

In this section users can check out creative moments shared by other users. They can also report, flag the moments as well written, or rate them. The first option, the reporting of moments, allows users to report other user's moments for offensive content, copyright violation, etc. As for the second option, the well written flag, it allows users to flag the moments that have a correct syntax and semantics, and with this make them part of the moments that appear when a user selects the well written filter. The last option, the moment rating, allows users to rate a moment from 1 to 5 stars where 1 means very uncreative and 5 means very creative. By doing this users make shared moments more and more relevant. These three options are part of a very important component of a crowdsourcing platform, the quality control, and can only be accessed by users that are logged in the platform. Below we can see these three options and how the user interacts with it. Figure 3 shows the three options described above.

Fig. 3. Top bar of the moment showing the three options available

In this case the moment has already been rated, but is not checked as well written. Figure 4 shows how a user can interact with the system in order to rate a moment.

Fig. 4. Top bar of the moment showing the rating feature

We can see that the user rated the moment with two stars. This means that the moment was uncreative and should not appear on the top of the relevant moment's list.

Another important feature that was implemented is a filter system where users can insert the conditions that most suits them and the platform will look for the moments that match those conditions. There are three fields on the filters bar, mood, location and tag. These three fields help users categorize their searches for faster finding of the moments they want. Each moment can be associated to a group of tags that can then be used for search purposes. There is also an option for sorting the results for a variety of options. Figure 5 shows the list of options that are available for sorting.

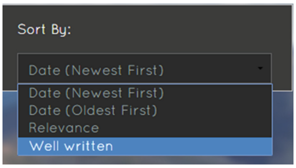

Fig. 5. Sort feature showing the options available

For the first two options, they are self-explanatory. On the relevance option, the moments that are presented first are the ones with a higher average rating. This average is calculated by dividing the sum of all the ratings by the number of ratings assigned to that moment. As for the well written, the first moments that are presented are the ones with a higher count of well written flags. With this feature, it is possible to make sure that only quality content is shown and that the user does not have to pay extra precious attention to error check on moments shared by other users.

3.2 My Posts

In this second section, users can see all the moments that they have already created, share them, add new ones and edit or remove the existing ones. Users can choose whether or not they want to share their moments. They can use the platform just for saving their moments without making them available for other users to see. To share a moment, users just have to press the share icon and the moment is made available for every user. To edit or delete a moment, users just have to press the according icon.

When a user deletes a moment a confirmation dialog box is presented to make sure that this is the desired action. As referred before, a user can also create a new moment in this section. When the user presses the button to add a new moment, a dialog box is presented with all the fields necessary to create the new moment. Figure 6 shows all the information the user can insert to create the new moment.

Fig. 6. Dialog box showing the possible fields for creating a new moment

The final prototype can be seen in Fig. 7 and how the section My Posts looks. The design chosen was achieved and we felt very happy with all the design choices that were made. No specific tests were performed for the crowdsourcing platform as it acts only as a tool to populate the database with data to be used in the MSWord Add-In.

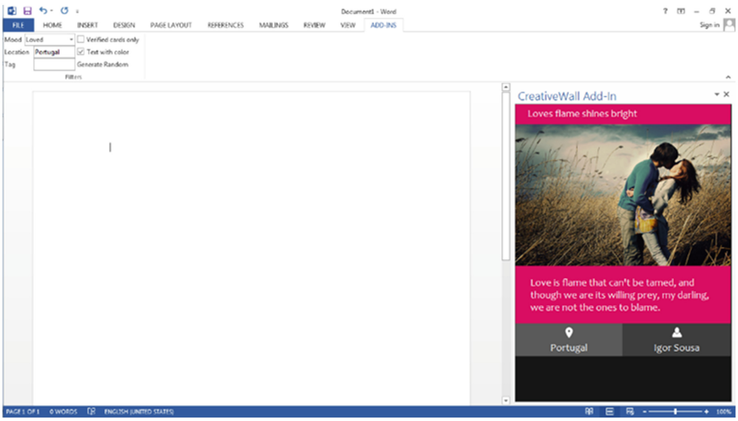

Fig. 7. Final prototype of the Microsoft Add-In.

3.3 CreativeWall Microsoft Add-In

CreativeWall MSWord Add-In is a plugin (called Add-In by Microsoft Office) for Microsoft Word that uses the data created in the CreativeWall platform in order to provide users with a way to trigger creativity while writing in the Microsoft Word application.

This plugin requests creative moments from the API according to some filters chosen by the user and then shows those creative moments in Microsoft Word. By doing this, the user can use the creative moments for triggering creativity in the word processor tool itself without having to change applications and search for creative moments in the online platform. The features that were implemented help the user getting what he wants as fast as possible, and that was the main goal of the interface implemented. The plugin has a ribbon that contains a set of buttons and inputs which the user can use to interact with the plugin. As described before, the ribbon contains a set of buttons and inputs that can be used to interact with the plugin. Figure 8 shows the ribbon and the elements available for interaction.

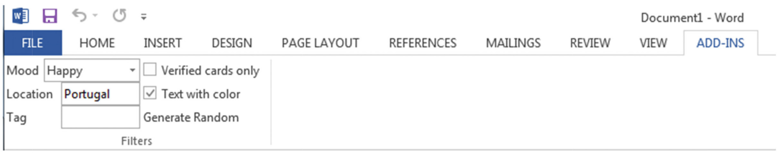

Fig. 8. CreativeWall Add-In ribbon with buttons and inputs available

The first three options, mood, location and tag are self-explainable, they apply filters to the results. The checkbox for “Verified cards only” will return cards that have average ratings over 4 stars and at least 5 well-written tags. This helps the user get data that has a minimum of quality and is not just random words with no meaning. This also helps the user getting creative moments that are written correctly. As for the option “Text with color”, it defines if the creative moment should be shown with a gray background or with a background according to the color associated with the mood of the creative moment. The button “Generate Random” generates a random creative moment according to all the filters selected on the other options. If the user inserts a set of filters to which there are no creative moments associated, an error message is displayed. The add-in creative moments interface is basically the same as the one in the CreativeWall web platform, it just has less fields. Each of the creative moments shown have a title, image, text, location and author. Figure 7 shows an example of a creative moment in the add-in.

After all the implementation was done a final prototype *(see* Fig. 7*),* that is to be used in the user study, was achieved. This prototype has all the features described above and they are all usable. It can be used by users after running a setup to install all the registry entries needed to use it on Microsoft Word as an Add-in. This prototype is just one example of an application using the add-in, since it may be used by any other word processor tool that wishes to implement our approach. All they need to do is register for usage of the API and after they set a client id and a client secret, they can start making requests to the API in order to receive the desired data.

In order to build a usable prototype a decision about the architecture of the software was needed. One requirement that was important was the scalability of the whole software structure. It is important, in the context of our approach, to be able to provide data to any word processor plugin or platform that wants to use the data created in our crowdsourcing platform, as long as they have previously applied for it. The solution is to build a client-server architecture. Having a centralized server (in our case the API works as both the server and an abstraction communication layer) it is possible to provide data to as many clients as we need. All connections should be made through HTTPS so the connection data (e.g. tokens or client credentials) is not exposed through package sniffing. For the purposes of this work we won't be making those HTTPS connections because this kind of features has high costs associated to it and it is not relevant for our user studies. This should be considered as future work. All the clients have read-only permissions, except for the crowdsourcing platform that sends data to the API for it to be inserted on the database. Before being able to request any data from the API the clients must be registered and define a client ID and a client secret so they can be authenticated before establishing a connection. This protects the data from being accessed by unauthorized clients.

4 Field Study - Pilot Evaluation

We addressed the following research question: *What is the influence of the Creative-Wall Add-In UI on the participants' mental well-being and creativity, when compared to the Microsoft Word Simple UI?* The experimental design was based on a within-subjects design in which each individual performed a creative task – writing in the three proposed conditions:

- **Condition A:** Baseline. Using Microsoft Office Word without any kind of add-in related to creativity to write a text based on a given context;
- **Condition B:** Using Microsoft Office Word with the CreativeWall Add-In with a gray background to write a text based on a given context;
- **Condition C:** Using Microsoft Office Word with the CreativeWall Add-In with a colorful background to write a text based on a given context.

To reduce a limitation such as order effect, we counterbalanced the order of each conditions for each participant. The individuals were assigned a random order of tasks in order to guarantee that no knowledge was passed from one task to the other as that would influence the results. As a prerequisite, participants had to have prior writing skills and had to be interested in writing.

4.1 Task

Participants were challenged to write a short text using the addressing tool. The time was limited to 10 min. Participants were free to finish the task whenever they wanted, under the 10-minute limit. Due to the use of a within-subject design, we defined three different writing tasks of a similar degree of complexity that participants were equally familiar with. The writing tasks were labeled as task A, B and C, respectively. All participants were presented with a context for each one of the tasks. For task A, the participants were given a context that was not produced by our crowdsourcing platform. This task was considered our baseline. Figure 9 shows the context given on the task A.

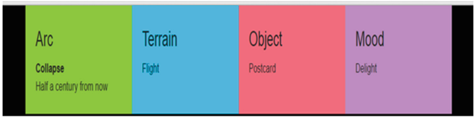

Fig. 9. Context given to the user on the first challenge

For task B, participants were given a context created on our crowdsourcing platform. This context is a creative moment that was created and shared by a user who was registered on the CreativeWall. Figure 10 shows the context that was presented for the task B. In order for this context to be presented in grey, the option "Text with color" on the MSWord Add-In has been turned off.

Fig. 10. Context given to the user on the second challenge

For task C, participants were given another context created on our crowdsourcing platform. Again, this context is a creative moment that was created by a registered user on the *CreativeWall* platform. Contrary to what happens on the second task, the option "Text with color" was turned on for this task. Figure 11 shows the context used for the task C.

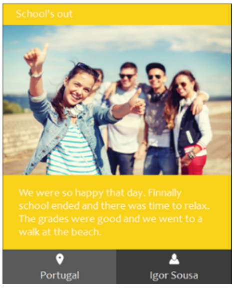

Fig. 11. Context given to the user on the third challenge

4.2 Participants

A total of 11 individuals (7 males and 4 females) aged between 20 and 32 years old ($M = 25.8$; $SD = 3.5$), took part of this study. Every participant was a Software Engineer, and they were recruited through the university mailing list. All participants reported having a normal or corrected visual acuity and none participant was color-blind. We conducted one session per subject.

4.3 Measures

Before they started the experiment, participants were asked to fill a very short survey in order to collect some demographic data and they also ranked their own creativity *("Do you consider yourself a creative person?")* in a Likert Scale (0–7 values) [34].

After completing each task, participants were asked to fill out self-reported survey. The survey contained some general questions like age, or gender and some Likert scale questions. Also a multiple choice question about how the user felt during the task was included. The Likert scale questions were ranked from 1 (totally disagree) to 7 (totally agree). The Likert scale questions were based on four dimensions of the Flow Theory [35]: 1. Intense and focused concentration on the present moment; 2. Sense of personal control or agency over the situation or activity; 3. Loss of reflective self-consciousness; 4. Distortion of temporal experience. For these dimensions questions such as "*I felt very concentrated during the challenge*" or "*I lost track of time during the challenge*" were included. Finally we collected qualitative data with a semi-structured interview with questions such as: "*Which condition did you enjoy using the most?*" or "*Is there any comment that you would like to add?*", *"Did time limit your creativity?"* in order to know the participant opinion about the whole experience.

4.4 Procedure

Participants were brought individually to a quiet room previously prepared for the experiment. For the examination, we used two laptops computers with a screen size of 13.3 inches and a display resolution of 1920 × 1080 pixels. When participants entered the room, they were asked to sit and before they started the experience, the experimenter ran the tool and asked them if they wanted to change little things in the environment, such as font size/type or something else. They had a few minutes to know each tool. We did this because we were using different conditions that they could be unfamiliar with as a way to reduce bias or any aversion to a given tool. After that, the writing task was explained. During the task, the participant was left alone in a room with the computer at his disposal. The time was monitored by the person responsible for guiding the participant through the tasks and after it reached the 10 min mark the participant was instructed to stop writing. When participants finished the writing task, they were asked to fill out the self-reported survey. Finally, participants were interviewed based on their experience using the tools. The total time per subject including questionnaires, experiment, breaks and semi-structured interviews took over one hour.

5 Findings

To inquire the impact of the CreativeWall Add-In UI on user's apparent and experienced creativity, we triangulated different data sources, such as behavioural data, users' verbal accounts during task execution, self-reports using psychometric scales of creativity and data from our exit interviews.

Is Our Sample Equally Creative?

Participants self-rated their creativity (M = 6.18; SD = 1.54) in a seven-point Likert Scale before starting the experience. 63.3% of participants considered themselves a creative persons in a seven-point Likert scale. 18.2% of participants considered themselves creative persons in a five-point values, 9.1% in a three-point values and 9.1% in a two-point values.

Did CreativeWall Add-In UI Lead to Increased Flow?

To assess the reliability of our survey, we used Cronbach's alpha as a measure. It was taken into account the polarity of the scale. Table 2 exhibits results of reliability (internal consistency) analyses for questions in each dimension of flow. Results show that the number of test items can be considered with an acceptable consistency in the scale used, from the survey, on seven-point Likert scales.

Table 2. Cronbach's alpha related to each of the dimensions

Flow dimensions	Cronbach's alpha
Concentration	.629
Sense of Control	.797
Lost Self-Consciousness	.672
Lost Track of Time	.633

We proceeded using repeated measures such as Friedman's ANOVA approach to testing differences between each condition. The Flow dimensions Concentration (Fr (2) = 5.20, p > .05) and Lost Self-Consciousness (Fr (2) = 1.90, p > .05) did not have statistical significance when compared with each condition. For the other dimensions Sense of Control (Fr (2) = 10.21, $p < .05$) and Lost Track of Time (Fr (2) = 17.43, $p < .05$) results were statically significant. Therefore the non-parametric Wilcoxon tests were used to display if there were any differences for each pair or conditions, using Condition A to compare as a baseline.

Results showed that, participants in Condition A, when compared with participants in Condition B (T=0, $z = -2.06$, $p < .025$, $r = -.44$), for the dimension Sense of Control were not statistically significant. Also, participants in condition A when compared to participants in Condition C, for the levels of Sense of Control, even though the value is in the border line, it was not statistically significant as well ($T = 0$, $z = -2.23$, $p < .025$, $r = -.48$). We applied the effect size that gives us the magnitude of the effect investigated. For the dimension Lost Track of Time, the results showed a significant difference between the participants in Condition A when compared to participants in Condition B ($T = 0$, $z = -2.71$, $p < .025$, $r = -.58$). For the same dimension, the differences between participants in Condition A when compared to participants in Condition C were also statistically significant ($T = 0$, $z = -2.72$, $p < .025$, $r = -.58$). To assess the participants mental well-being we asked them to select up to three adjectives from the following list: animated, creative, distressed, fear, serious, angry, satisfied, frustrated, sad, astonished, depressed, bored, tired, happy, delighted, pacific and relaxed. Figure 12 shows the total count for each of the adjectives selected and presented on the above list. The words that were used the most were animated, creative, happy and pacific, being that creative was the most used for Condition B and Condition C, and serious was the most used for Condition A.

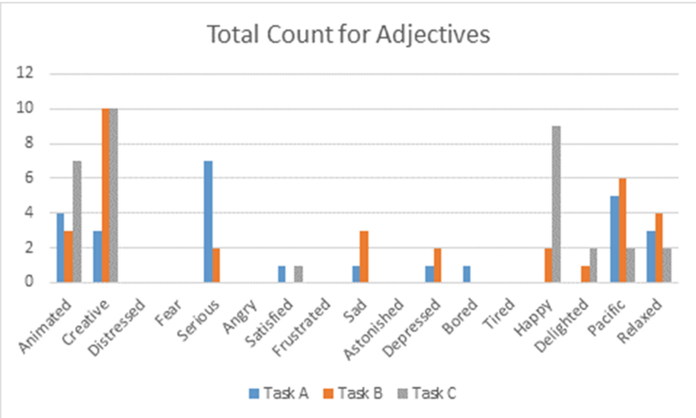

Fig. 12. Chart relating the tasks with the adjectives used in them

After analyzing the results, we are able to conclude that users who were in Condition B and Condition C report to feel more creative that users in Condition A. The most balanced word counts were relaxed and pacific, as they were selected at least twice for each condition. These aspects might indicate that users felt ease when writing.

Did CreativeWall Add-In UI Lead to Increased Output?
We used the Skeweness and Kurtosis and Kolmorov-Smirnov tests ($p > 0.05$) to analyze the data normality of the average number of words produced. Results showed that the sampling distribution was normal. T-tests were used to compare the statistical significance of the samples using a 95% level of confidence. Participants in Condition B wrote on average more words ($M = 186.1$, $SD = 49.3$) than in Condition A ($M = 156.2$, $SD = 54.5$). For the same condition the difference was statistically significant ($t\ (10) = -3.20$, $p < .05$). In Condition C, participants wrote on average more words ($M = 185.7$, $SE = 65.1$) than in Condition A ($M = 156.2$, $SD = 54.5$). The difference was statistically significant ($t\ (10) = -2.23$, $p < .05$) for the same condition. Table 3 shows statistics from the time and sequence in which the users completed their writing tasks.

Table 3. Statistics from time in minutes spent on each condition.

	Condition A	Condition B	Condition C
Mean	8.73	9.55	9.27
Median	9.00	10.00	9.00
St. Deviation	1.01	0.69	0.79

By statistically results reported in Table 3, we can see that most of the participants did not used the ten minutes for the writing task. When interviewed, 81.8% of participants did not considered the time limit a factor to restrict their creativity in the writing task. This might indicate that even though the conditions used for the experience helped the participants start writing, they are not as effective when it comes to keeping a constant creativity flux and therefore helping only on the first steps of the creative process. Triangulating the results with the semi-structured interviews conducted after the writing task apparently suggest that, by unanimity of the answers registered, Condition A was the less enjoyed condition. 63.6% of participants really liked the Condition C, and 36.4% liked to write in Condition B.

According to some participants (27.7%), the lack of image and texts is important for their creativity to flow, *"Condition A is very limited because it lacks the image, and the image is very important for creativity." (P6).* Another interesting fact is that, for the majority of participants, color helps but does not influence creativity when they don't find the text creative, *"Even though color is a very interesting component, the most important ones are the text and image. If the text is not creative then the color won't make a difference." (P4); "Color helps the user remember of something. For example, the yellow resembles the joy of the summer." (P6); "Color helped, but the most important thing was the text and the image." (P8).* Some other participants refer to the color as being a source of distraction or did not considered as an important factor, *"Color helps as well but is not as decisive as the text and image. Color can also be a motive for distraction. A less intense color might have been better." (P3); "The color is a little bit distractor." (P2).* With this we assume that our initial idea that color would help triggering creativity through the emotion it generates on people can't be applied to every participant. Even though some participants enjoyed having the color together with the image and the text, and stated that it helped their creativity to flow, they are still a minority. *"I think that in this case, color really helped, because the text was about summer and yellow resembles the summer. It did make me feel kind of happy." (P7); "The color and the image encourage creativity. In fact, I felt some ease on Condition C. The image and color helped me idealize some ideas." (P1).*

6 Discussion and Conclusions

The main goals of this work were to investigate if a creative writing support UI could enhance a user's mental well-being and creativity, and to check whether color could influence creativity in any way. Although the number of participants in the tests was limited, it was possible to develop some statistical results and take some conclusions from them. Even so, as future work, the idea of performing more studies for more solid results should be considered.

As for the results obtained through the user study, we were able to conclude, through statistical evidence that participants performing the tasks with the CreativeWall Add-In (Conditions B and C) lost track of time more often than participants using the simple Microsoft Word UI without any add-ins (Condition A). Another aspect that was statistically relevant was the fact that users using the CreativeWall Add-In were able to produce more words. It must be taken into account that efficiency can't be measured by the number of words alone as this can be misleading. Even so, having significant difference in number of words between different conditions might indicate that their efficiency was affected. Also, taking into account the answers that results from the semi-structured survey performed after each of the sessions, it was clear that the tasks performed with the CreativeWall Add-In were more enjoyable and participants had no problems starting to write, which could mean that these conditions help in the initial phase of the creative writing process. This could also mean, that, by consequence of the previous statements, this approach can be effective when trying to overcome writer's block. The writer's block is a source of frustration and weakness for authors [9] and has been acknowledged as a "*creativity killer*" [36]. It comes up when writers become too judgmental and apprehensive about their writing, resulting in a potential loss of productivity and feelings of self-doubt, which aggravate this state. Huston states that [37] as writers' anxiety levels increase, it becomes more and more difficult to write. About the color, the majority of participants stated that color does not influence their creativity, and can be somewhat distractive. With this kind of statements we can assume that color does not always influence the creativity of users.

One limitation of our study is that is does not consider the long-term usage of CreativeWall platform and add-in. Therefore, conclusions are limited to an incipient (11 participants) usage of the different creative writing tasks using the addressing conditions. However, it is still very useful to have this data. It is a challenge to construct information technologies that support creativity [18] and also to empower users to harness and embrace their creativity through the use of creativity support tools [13].

In summary, in this pilot evaluation of our crowdsourced platform, our findings suggest that, from a mental well-being perspective, it was clear that participants felt more inspired, more focused, more creative and more immersed when using the CreativeWall Add-In. Designing computer systems for people is especially difficult for a number of reasons, but the final goal is always a user interface that provides an intelligent and pleas-ant tool [38]. The author also suggests that design must be considered as a whole, and not an isolated piece. From a "productivity" perspective, our results suggest that the users using the CreativeWall Add-In were the most efficient. Taking into account, the conclusions made in previous the color feature should be reviewed in order to try and take the most out of it. This includes reviewing the concept and reviewing the color itself. Trying to make color less intense would be one of the solutions for some of the problems presented in the user study, namely the distraction caused by it.

We have addressed these somewhat sensitive issues and tried to empower participants with different user interfaces to help them overcome writer's block and to express themselves in a different way. The current prototype is only a first implementation of our ongoing work on the concept of creative writing user interfaces and new guidelines to creative support tools in writing. We would like to conduct a long term study, to obtain more results about creativity, and mental well-being of its users. Finally, we considered that it's important to increase the number of moods in order to include other creativity enhancing moods. We are also interested in the strong relationship between the user interfaces for supporting creative writing and the level of creativity of its users.

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Using Task Descriptions with Explicit Representation of Allocation of Functions, Authority and Responsibility to Design and Assess Automation

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Abstract. Automation can be considered as a design alternative that brings the benefits of reducing the potential for human error and of increasing performance. However, badly designed automations, of which some of them are called automation surprises, can have a very negative impact on the overall performance of the couple operator/system. Automation design requires the definition of three specific aspects defining the relationship between the user and the system: allocation of functions, authority and responsibility. While these abstract concepts are usually well understood at a high level of abstraction, their integration within a development process is cumbersome. This paper presents an approach based on task models to explicitly handle those concepts. We show how such concepts can be integrated in a task modeling notation and illustrate on a case study how this notation can be used to describe design alternatives with different allocation of functions, authority and responsibility between the user and the system. Exploiting the case study, we demonstrate that embedding explicitly these concepts in a notation supports analysis and assessment of automation designs.

Keywords: Automation design and assessment · Task modeling
Allocation of functions · Authority · Responsibility

1 Introduction

Currently, automation is one of the main means for supporting operators using systems that feature increasing complexity. Automation makes it possible for designers to transfer the burden from operators to a system by allocating to the system tasks that were previously performed by the operator. Automation is defined as "the technique, method or system of operating or controlling process by highly automatic means, as by electronic devices, reducing human intervention to a minimum" [9]. In this definition, the concept of

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control is highlighted in addition to the concept of allocating functions to the system. This concept of control is related to the authority the human or the system may have on the triggering of an operation or of a process. Another term used to define automated systems is "autonomy". This term refers to the independence from outside control of the human or system entity (i.e. self-directedness), whereas automation refers to an entity that will do only what it is programmed to do without having any choice [25]. This implies that the automated system may have a certain level of independence and thus be responsible for the outcome of the execution of the triggered functions. As both the operator and the automated system may have authority for triggering functions, then both the operator and the designer of the automated system may be responsible for the outcome of the triggering of a function. In addition to automation and autonomy, Bradshaw et al. [6] highlight another concept that is related to the self-sufficiency of the entity (defined as the French word for autonomous "autonome") and that is the ability to take care of itself. An entity with a high level of self-sufficiency should be given the authority on the functions that are related to the acquisition of its required resources. Allocation of functions is a pillar of automation design. Parasuraman et al. have defined a classification of different Levels of Automation (LoA) [22]. These LoA have been extensively used for assessing automation levels of command and control systems such as Air Traffic Management applications, aircraft cockpits or satellite ground segments. As none of these systems reach level 10 (full automation), they are usually called human in-the-loop command and control systems of partly autonomous systems [18]. Beyond that, these LoA were also used as a design driver for research and industry projects having as a target higher automation levels[1]. However, we argue that authority and responsibility should also be taken into account at design time.

The three main aspects of automation at design time thus lay in describing what functions/tasks are allocated to the system and the human (allocation of functions), who is allowed to perform what functions/tasks (authority), and who is responsible for the outcome of the execution of the functions/tasks (responsibility). Because increasing/decreasing automation can have a huge impact on human performance, workload, team size and human error, there is a need for methods and tools to support the assessment of the impact of automation design (including the positioning with respect to the LoAs) in early stages of the development process. In this article, we highlight the benefits of having a notation making it possible to describe (with models), in a complete and unambiguous way, allocation of functions, authority and responsibility. We argue that a dedicated notation provides support during various stages of the design and development of an autonomous or partly autonomous interactive system. The proposed notation makes these abstract concepts concrete enough to provide means for the independent analysis of each of them.

Next section (Sect. 2) identifies what information is needed, at design time, to take into account the allocation of functions, authority and responsibility and defines those concepts. Section 3 presents a qualitative analysis of the classification of the Levels of Automation according to the concepts of allocation of functions, authority and

[1] See page 5: 17 projects and 13 PhD funded by SESAR Joint Undertaking towards higher automation levels in aviation http://www.sesarju.eu/sites/default/files/documents/events/sesar2020-20150504/3_SESAR2020_ER_Info_Day_FV_David_Bowen.pdf.

responsibility. These two sections highlight the fact that there is no available technique for describing the allocation of functions, authority and responsibility during the design of partly-autonomous systems. Section 4 presents the elements of notation for task models to provide support for the identification and representation of allocation of functions, authority and responsibility. Section 5 illustrates these elements of notation with the example of the Game of 15.

2 The Concepts of Allocation of Functions, Authority and Responsibility and How to Use Them for Automation Design

This section presents the results of a literature review on approaches for designing automation that take into account allocation of functions, authority and responsibility (referred to as AFAR in the remainder of the paper). It first highlights the information that needs to be taken into account when dealing with the allocation of functions, authority and responsibility. It also highlights that most of the related work focusses on the techniques for dealing with the allocation of functions, and does not provide precise guidance for taking into account authority and responsibility.

2.1 Allocation of Functions

The concept of *Allocation of Functions* refers to "determining the distribution of work between humans and machines early in the design process" [26]. Human work is the set of perceptive, cognitive, motor and input interactive tasks that the user should perform to reach her/his goal. System work is the set of algorithmic, input and output functions that the system should perform to support user goal. The analysis of the allocation of functions is necessary to identify the optimal distribution of both functions and tasks between a partly-autonomous system and a user. The allocation of functions is also central to the design of automation because it provides support to migrate user activities to be performed by the system or to migrate system functions to be performed by the user. Indeed, according to [27], not enough functions allocated to user will lead to underload and boredom and thus decreased performance while too many functions will lead to cognitive, perceptive or motoric overload and increase stress and likelihood of user errors. The output of the allocation of functions is the description of the sets of tasks that the user should perform to reach her/his goal and the description of the sets of functions that the system should perform to support user goal. This implies that the system designer has to identify all the functions that have to be performed by the system together with all the tasks that have to be performed by the user.

2.2 Authority

The concept of *Authority* refers to "the power or right to give orders, make decisions, and enforce obedience" according to [21]. When dealing with the design of automation, Flemisch et al. [11] propose to refine this definition to "what the actor is *allowed* to do or not to do". Taking into account authority at design time requires analyzing how the authority can be shared between the user and the system, which possibly involves alternating between the user and the system over time. For instance, allowing the system to trigger a function on its own increases the overall system authority and decreases the one of the user. Thus, the goal of the design and analysis of the allocation of authority is to identify the optimal distribution of authority between an autonomous or partly-autonomous system and a user which heavily depends on the type of system considered (e.g. safety critical systems). The output of the authority distribution is the description of what the system and the user are allowed to do (and in particular, what functions the system will be authorized to perform and to trigger – also called *initiative*). This implies that the system designer has to identify and describe both the tasks that the user is allowed to perform and the functions that the system is allowed to perform.

Going back to the definition of authority presented above, "the right to give orders" and "the right to enforce obedience" are already taken into account (for instance in a task description) when describing the functions and tasks that the system and the human are allowed to perform. However, in conformance with [14], we consider that the identification of "the right to make decisions" has to be done explicitly because there are complex relationships between decision-making authority and the allocation of functions and tasks between the system and the human.

2.3 Responsibility

The concept of *Responsibility* refers to the fact that an actor should be accountable for the result of an action [11]. The allocation of responsibilities (between the user and the system) must make explicit the outcomes that are relevant and who (the user or the system) influences these outcomes. The purpose of making responsibilities explicit is to be able to support the identification of the actor who has been at the root cause of an unwanted or unexpected outcome. The output of the allocation of responsibilities consists in a list of both all expected and all actual outcomes when an activity is performed. The comparison between actual outcomes and expected outcomes makes it possible to identify deviations (that could be errors on the user side or failures on the system side).

2.4 Related Work Addressing Allocation of Functions, Authority and Responsibility

Existing approaches dealing with automation design usually focus on identifying functions that should be allocated to either the operator or the system. These approaches provide support for the identification of which tasks are good candidate for automation and which ones should remain performed by the operator [4, 8, 10, 23, 26]. All of these approaches use task description techniques and provide support for describing the possible workflows between user tasks and system functions. In addition to the description of the possible workflows between user tasks and system functions, the concept of orchestration, as defined in the software engineering and business process modeling (BPM) literature [20], provides supports to describe the control over the possible workflows between user tasks and system functions. Orchestration models, usually represented with UML diagrams or BPM models, thus provide support to describe the initialization, the changes and the finalization between the workflows of the user and the system. Rovatsos et al. [24] highlighted the benefits of having an "orchestration workflow layer" in addition to descriptions of user tasks and system functions when developing systems that are able to adapt to different user behaviors.

Beyond analyzing allocation of functions and possible workflows at design time, Loer et al. [16] propose a model-checking technique to verify the relevance of all possible temporal scheduling (workflows) of adaptive automation.

We have found limited related work dealing with design approaches that provide support for taking into account authority sharing and responsibility issues. Gombolay et al. [14] discusses the observations they have made about decision-making authority and responsibility sharing between human and robots from the point of view of reaching a global human-robot optimized performance. Flemisch et al. [11] as well as Miller and Parasuraman [19] proposed a conceptual framework that highlight the importance of taking into account authority and responsibility at design time. Boy [5] proposed a conceptual model to support the analysis of authority sharing amongst several humans and systems. Cummings and Bruni [7] proposed to extend Parasuraman information processing model by adding a decision making component. However, none of this work provide precise techniques or even guidance to apply to describe or design the allocation of authority and/or responsibility between a system and its user.

3 Levels of Automation and Allocation of Functions, Authority and Responsibility (AFAR)

This section aims at discussing how the classification of the Levels of Automation, as defined by Parasuraman et al. [22], provides support for the design of the allocation of functions, authority when developing partly-autonomous systems. Table 1 presents the qualitative analysis of the Levels of Automation according to the allocation of functions, authority and responsibility (AFAR). The first column presents the Levels of Automation (LoA) as defined in [22], ranging from the highest automation (Level 10), where the "computer decides everything, acts autonomously, ignoring the human", to the lowest automation (Level 1), where "computer offers no assistance: human must take all decisions and actions". The second column presents the allocation of functions, authority and responsibility according to the description of the LoA.

Table 1 shows that going higher in automation levels affects Authority, sometimes Responsibility, or Allocation of Functions but that it is not done in a consistent way. Indeed, one could have expected that going from bottom to top AF, A and R would move progressively from user to computer. However, at LoA 7, the authority is already all to the computer, while it is shared with the human at LoA 8, and is again all to the computer at LoA 9. The same holds for the allocation of functions as, for instance, the user has to perform more actions at LoA 8 (perceive and ask for information) than at LoA 7 (where the user can only perceive information). In addition, even though most of the levels of automation concern partly-autonomous systems where both user and

Table 1. Levels of Automation (LoA) from [22] and its interpretation using AFAR

Description of LoA as in [22]	Interpretation in terms of allocation of functions, authority and responsibility
10. The computer decides everything, acts autonomously, ignoring the human	AF: All to computer A: All to computer R: All to computer
9. Informs the human only if it, the computer, decides to	AF: All to computer but human might perceive the information presented A: All to computer R: All to computer
8. Informs the human only if asked, or	AF: All to computer but human might ask and perceive the information presented A: All to computer but human can ask to be informed R: All to computer
7. Executes automatically, then necessarily informs the human, and	AF: All to computer but human can perceive the information presented A: All to computer R: All to computer
6. Allows the human a restricted time to veto before automatic execution, or	AF: All to computer but human can perceive how to veto and trigger veto A: Mostly to computer but human can take authority over computer using veto R: To computer if no veto and to human if veto
5. Executes that suggestion if the human approves, or	AF: All to computer but human can perceive suggestion as well as how to approve and to trigger approval/denial A: Mostly to computer but human can take authority by rejecting suggestion R: Shared if approval and to human if not approved
4. Suggests one alternative	AF: All to human but computer must compute and present one alternative A: Mostly to human, computer can only provide suggestion R: Shared if human selects one element of the options presented
3. Narrows the selection down to a few, or	AF: All to human but computer must filter out and present options A: Mostly to human, computer can only filter out options R: Shared if human selects one element of the options presented
2. The computer offers a complete set of decision/action alternatives, or	AF: All to human but computer must present the complete set of options A: All to human R: All to human
1. The computer offers no assistance: human must take all decisions and actions	AF: All to human but computer might allow human to provide input A: All to human R: All to human

system are involved, they do not provide any information about the user interface and its associated interaction techniques. This is an important limitation of that LoA framework as partly-autonomous systems may embed complex UIs and that the tasks of interacting with this type of systems should be part of the description of the allocation of functions. Finally, this classification represents only abstract information about the allocation of functions and tasks. It is not sufficient when designing a partly-autonomous system, because quantitative data about user tasks and system functions, meaning precise descriptions of tasks and functions, is required to specify the behavior of the system, its UI and the operations that are allowed with it.

We choose the Parasuraman LoA [22] as an example because these LoA are widely used in the industry. Nonetheless, the same qualitative analysis can be done on other existing classifications of LoA. The interested reader can find more information in the Vagia et al. [25] literature review of proposed LoA. The Table 2 presents the results of the qualitative analysis of the levels of driving automation according to the allocation of functions, authority and responsibility (AFAR). This example focuses on the level 2 of the 6 levels of driving automation proposed by the standard SAE J3016 [15] for the design of automated cars.

Table 2. Levels of driving automation from [15] and its interpretation using AFAR

Description of level of driving automation as in [15]	Interpretation in terms of allocation of functions, authority and responsibility
2. Partial Driving Automation Human Driver (at all times): • Performs the remainder of the Dynamic Driving Task not performed by the driving automation system • Supervises the driving automation system and intervenes as necessary to maintain safe operation of the vehicle • Determines whether/when engagement and disengagement of the driving automation system is appropriate • Immediately performs the entire Dynamic Driving Task whenever required or desired Driving Automation System (while engaged): • Performs part of the Dynamic Driving Task by executing both the lateral and the longitudinal vehicle motion control subtasks • Disengages immediately upon driver request	AF: Mostly to the human driver, the human driver can delegate the dynamic driving function to the driving automation system A: Mostly to the human driver, the driving automation system can trigger both the lateral and the longitudinal vehicle motion control subtasks if the human driver engaged the driving automation system R: All to the human driver, except for the lateral and longitudinal movements if the human driver engaged the driving automation system

At this level of driving automation, all the functions are allocated to the human driver. However, the human driver can decide to delegate lateral and longitudinal motion control subtasks to the driving automation system. Then, the human driver has all the authority and responsibility except if the human driver decides to engage the driving automation system. In the end, this classification represents only abstract information about the responsibility and authority distribution between both entities.

Next section presents the elements of notation that aim at fulfilling the need of precise description of tasks and functions for the specification of the system.

4 Representing Authority, Responsibility and Allocation of Functions in Task Models

This section presents the task modeling elements of notation that aim at providing support for the explicit representation of allocation of functions, authority and responsibility. These elements of notations are demonstrated on the HAMSTERS notation but they could be added to other procedural descriptions of user tasks.

4.1 The Tool Supported Notation HAMSTERS

HAMSTERS (Human – centered Assessment and Modeling to Support Task Engineering for Resilient Systems) is a tool-supported task modeling notation for representing human activities in a hierarchical and structured way. The HAMSTERS notation and its eponym tool have initially been developed to provide support for ensuring consistency, coherence and conformity between user tasks and interactive systems at model level [1]. HAMSTERS embeds the common ground of task modelling such as hierarchical description of tasks, temporal ordering, refinement of tasks per types, manipulated data and structuring mechanisms [17]. This common ground is used to describe user tasks and system functions, and is thus used to describe the task and function allocation between user and system.

4.2 Allocation of Functions

The analysis of allocation of functions, authority, and responsibility requires at least one task model per role. The concept of role in HAMSTERS refers to a set of goals and tasks (described in one or several task models) that can be attributed to one actor. An actor is defined by an entity that is capable of performing a set of tasks and that has several characteristics such as physical properties, level of knowledge, experience…. Examples of actor can be a player (user playing a game) or a software application on a computer (as shown in Fig. 1(b)). In order to show the allocation of functions between the user and the autonomous part of the system, we propose to describe autonomous system functions in HAMSTERS as well. To distinguish user tasks from autonomous system functions in tasks models, we propose to describe autonomous system functions associated to corresponding dedicated roles in HAMSTERS. Figure 1(a) shows a typical example of project for studying automation in a mono-user computer game. The role called "Player as challenger" and the role called "Player as leader" contain respectively all the task models describing how the user can play as a challenger and as a leader. The role called "Player as game configuration manager" contain the task models describing how the user may configure the game if s/he is in charge of it. The role called "Software application as challenger" and the role called "Software application as leader" contain respectively all the task models describing how the software application can play as a challenger and as a leader. The role called "Software application as game configuration manager" contains the task models describing how the software application can perform tasks to configure the game (such as choosing the leader). The role "Software application as configuration maker" contains tasks models

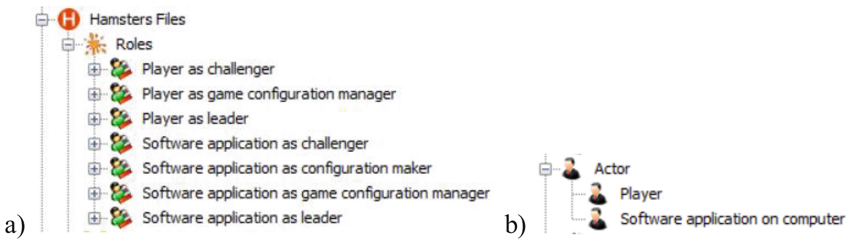


Fig. 1. (a) The six mandatory roles for describing automation and (b) example of two actors

describing how the software application can provide support to the user to configure the game (as for example its tasks to record the winner for each game).

It is important to note the difference with standard task modeling practices where a user task model integrates in a single model an interleaving of user behavior and system's response to user behavior. In our case, in order to describe explicitly user tasks and autonomous system functions, we require the creation of several roles and at least one associated task models for each role. This means that an autonomous system model (belongs to the one of the roles that can be attributed to the software application) is only made of tasks belonging to the system task category, while the user model (here belongs to one the roles that can be attributed to the player) can embed any type of task type but system tasks. However, due to this separation of concerns, it is impossible to describe interleaving of actions between user and system inside those models (as it is usually done in task modelling notations). For this reason, we have added a new event-based mechanism dedicated to the explicit description of interleaving of actions between the user and the system. Figure 2 (resp. Fig. 3) presents an example of software application task model (resp. player task model). These task models contain description of the events (grey boxes) that are produced (an outgoing arrow from a task to an event) in one task model and that trigger tasks (an incoming arrow from an event to a task) in the other task model.

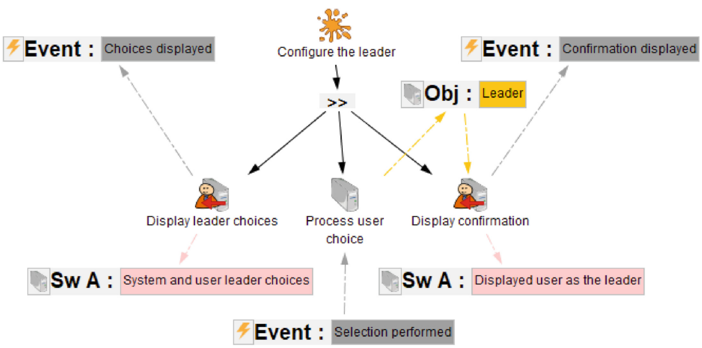


Fig. 2. Task model describing the software application behavior related to the task model of the player (see Fig. 3) for choosing the leader

For example, in the software application task model depicted in Fig. 2, the output interactive system task "Display leader choices" produces the event "Event: Choices displayed". This event triggers the execution of the visual perception task "See possible choices" in the player task model depicted in Fig. 3. Still in the player task model in Fig. 3, once the player has chosen who will be the leader (cognitive tasks under the temporal ordering operator choice "[]"), the player performs the selection (interactive input task "Select the leader"). This interactive input task produces an event "Event: Selection performed"), which is described in the software application task model (depicted in Fig. 2) as triggering the system task "Process selection".

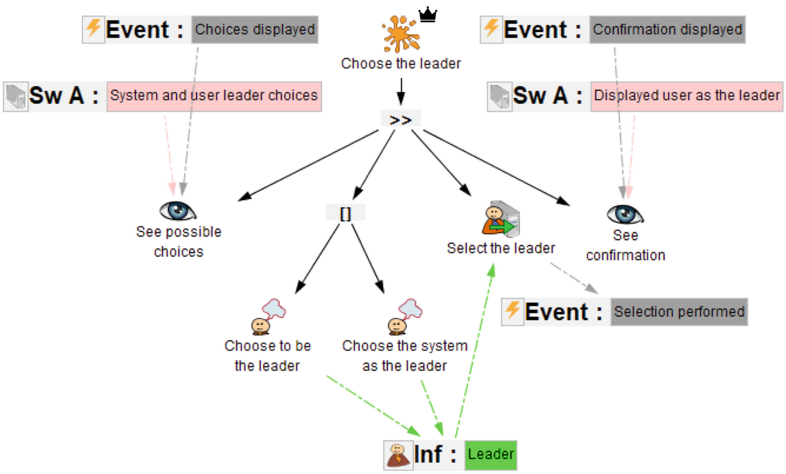


Fig. 3. Task model describing the behavior of the player to choose who (between software application and player) is the leader – this model is triggered by the model in Fig. 2

The description of the orchestration of the workflows of the user tasks and system functions is described in an orchestration model. The elements of notation used to describe the orchestration are the same than the HAMSTERS elements of notation with adding two icons. The first one is the icon "conductor" (depicted in Fig. 4(a)).

Fig. 4. (a) Symbol of the root node of a model describing how a set of task models is orchestrated, and (b) Representation of an entire task model that is used inside an orchestration model

The second one, is the icon "Model" (depicted in Fig. 4(b)), that is to be used in an orchestration model to represent a task model that can be started. In the orchestration model the temporal ordering of task models is represented using the standard operators in HAMSTERS. Comparing to swim lines with one possible sequence in BPM notations, the temporal ordering operators provide support for describing several distinct possible orchestrations. The orchestration model is used to describe the initialization of the workflows (which tasks and functions are started on the user side and on the system side), the possible dynamic changes (for example to represent that a function that is delegated to the system but that it could be re-assigned to the user) and the final completion of the workflows of the user and the system (what are the last user tasks and system functions).

4.3 Authority

The description of Authority can be either procedural or declarative. The procedural description of tasks aims at making what the system is allowed to do and what the user is allowed to do. It provides support to describe how authority goes from one role to the other one. In HAMSTERS this is represented using the event-based description of the triggering of tasks in another model. This view describes the switching of authority between the user and the system while the tasks are executing.

The declarative description aims at explicitly highlighting which tasks represent the right to make decisions, in order to facilitate the sharing of the decision-making. The icon "crown" (depicted in Fig. 5(a)) provides support to describe a task for which the user or the system has the decision-making authority. Only the tasks of type "abstract" may be represented with the symbol "authority" (depicted in Fig. 5(b)). This is because the user or the system can have the authority on a decision-making task. The refinement of the task and its associated set of actions is independent from the fact of having decision-making authority on it.

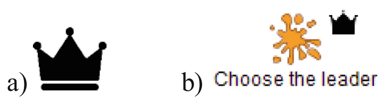


Fig. 5. (a) Symbol representing the authority (b) authority symbol associated to a task. The symbol is displayed when the property "authority" of a task is set to true.

Within this context of sharing authority, it is important to note that operators can perform actions by mistake or intentionally by violation. In the context of task descriptions, only nominal actions are represented as errors and deviations should be made explicit in other description [13]. Each task described in a task model means that the operator in charge of it is allowed to perform it.

4.4 Responsibility

The description of Responsibility can be either procedural or declarative. The procedural view is the description of the flow between the task and the outcome of the task. This description consists in a flow (arrow) between a task and information or objects describing the expected and actual results. The declarative view is the explicit representation of the symbol of "responsibility" in the relevant tasks, information and objects. The expected and actual results produced by a task can be represented with the data types "Information" (depicted in Fig. 6(a)) when the result is produced by the user, or with the data type "Object (depicted in Fig. 6(b)) when the result is produced by the system.

Fig. 6. Elements of the notation for representing responsibilities.

The tasks that set the expected results and/or have an impact on the actual results are tagged with the icon "scale". The icon "scale" (depicted in Fig. 7(a)) is displayed next to the user or system task (depicted in Fig. 7(b)). This icon represents that the user or the system is responsible for setting the expected results and/or for having an impact on the actual result.

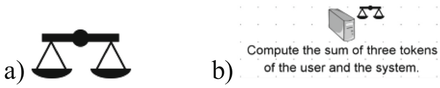


Fig. 7. (a) Symbol representing the responsibility (b) responsibility symbol associated to a task.

During the task modeling process, the task that produces the expected result has to be tagged with the symbol «responsibility». This symbol is displayed when the property "responsibility" of a task is set to true. These tasks have also to be connected to the information or object that describes the expected result, thanks to an arrow going from the task to the information or object describing the expected result. In addition, all the tasks that have an impact on the actual result have to be tagged with the symbol «responsibility». These tasks have also to be connected to the information or object that describes the actual result, thanks to an arrow going from the task to the information or object describing the actual result.

5 Illustrative Example: The Game of Fifteen

This section presents how the HAMSTERS notation supports the description of the allocation of functions, authority and responsibility through a simple case study.

5.1 Game of Fifteen: Main Principles and Rules

The Game of Fifteen is a two players game in which each player chooses and selects, in turn, a number (graphically represented as a token) ranging from 1 to 9. The first player who gets a combination of three numbers (amongst the set of tokens that s/he has selected) for which the sum is exactly 15 wins the game. No explicit rule defines who plays first, thus requiring players to reach an agreement. In the computerized version of the game, the software application on computer may act as a referee. In that case, it could declare the winner as soon as one of the players' set of tokens matches the winning condition. An example of a user interface for a computerized version of this game is shown in Fig. 8.

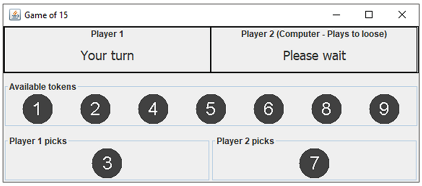
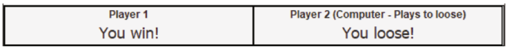
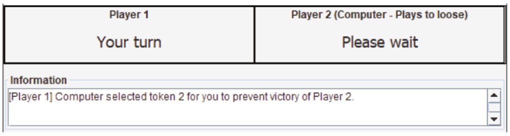
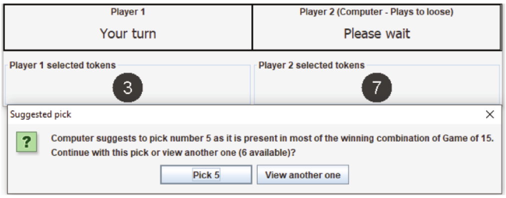


Fig. 8. An example of User Interface for the Game of Fifteen.

5.2 User Interfaces for the Game of 15 and Their Associated Levels of Automation

Table 3 presents several examples of user interface matching the definitions of levels of automation for the player task of selecting a token (number). We observe that at level 1 (LoA 1, Table 3), there is no information displayed regarding available or selected tokens. The player must memorize the already selected tokens before picking up an available one. Thus, at LoA 1, AFAR are all to human but the computer allows the human to provide inputs. At the highest level of automation (LoA 10, Table 3), there is no information displayed regarding available tokens either since the computer ignores the human for the fully automated task. Thus, AFAR are all to computer. From LoA 2 to LoA 6 (UI for LoA 2 and 5 are presented in Table 3) the player remains active in the decision process and is explicitly informed of what is going on via the User Interface. However, this UI evolves from "offering complete freedom" (at LoA 1) to "choose one token" (LoA 2). In those cases AFAR are all to human and the computer must present the entire set of options. At LoA 5, AFAR moves towards computer as the user must consider a suggestion made by the system. At this level (LoA 5), we observe the Allocation of Functions is all to computer but the human can perceive the computer's suggestion using the dialog window containing trigger for approval ("Pick 5") and denial ("View another one"). Authority is mostly to computer since it makes the suggestion, even though the human can take it back by denying the suggestion. Thus, responsibility is shared between human (if case of denial) and computer (if approval is granted).

Table 3. User interfaces matching the definition of Level of Automation for the game of 15.

LoA	Definition [19]	Example of GUI supporting the LoA
10	The computer decides everything, acts autonomously, ignoring the human.	
9	[The computer] informs the human only if it, the computer, decides to.	
6,7, 8	Not presented due to space constraints	
5	[The computer] executes that suggestion [from LoA 4] if the human approves.	
3, 4	Not presented due to space constraints	
2	The computer offers a complete set of decision/action alternatives.	See Fig. 8
1	The computer offers no assistance: human must take all decisions and actions.	

5.3 Modeling of Allocation of Functions, Authority, and Responsibility and with HAMSTERS

This section presents the description of the player tasks and of the software application tasks corresponding to different versions of the Game of 15. It aims at illustrating how the proposed notation provides support for the description and the analysis of the aspects related to AFAR during the design phases of a partly autonomous system. Due to space constraint, we have selected a set of representative models to illustrate all the proposed elements of notation.

The **allocation of functions** between the player and the software application is described in player task models (one of them is depicted in Fig. 10) and software application task models (one of them is depicted in Fig. 11). The **orchestration model** (depicted in Fig. 9) describes the possible orderings between the workflows of the software application tasks models and player tasks models. In this orchestration model, the player is in charge to choose the leader (represented by the model “Player as game configuration manager – Choose the leader” task model under the concurrent “|||” operator). Figure 3 depicts the user tasks of this model. Concurrently, the system provides a mean to configure the player choice of the leader (represented by the model "Software application as configuration maker – Configure the leader" task model with concurrent operator). Figure 2 depicts the player tasks of this model. The model "Software application as configuration maker – Configure the leader" produces the object "Leader" (system side) and the model "Player as game configuration manager - Choose the leader" produces the information "Leader" (user side). Both elements of data contain the reference to the name of leader of the game. Then, if the user is the leader (left branch under the choice "[]" operator in Fig. 9), s/he starts to play as the leader (condition on the information "leader") and the software application on computer starts to play as the challenger (condition on the object "leader"). Alternatively, if the player is the challenger (right branch under the choice "[]" operator in Fig. 9), s/he starts to play as the challenger (condition on the information "leader") and the software application on computer starts to play as the leader (condition on the object "leader"). Finally, the software application is in charge to store the winner at the end of the game (last model "Software application as configuration maker – Store the winner" on the right under the sequence "≫" operator).

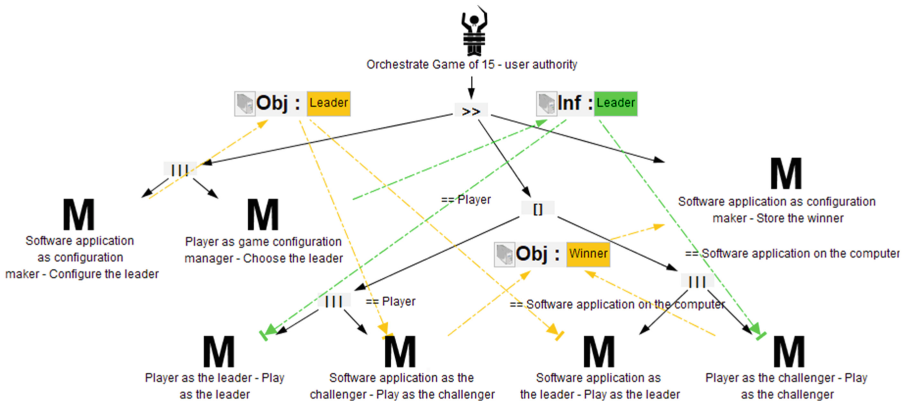


Fig. 9. Orchestration model of the computerized version of the Game of Fifteen.

Figure 10 depicts the **software application task model** of the software application tasks that have to be performed to play a turn of the version of the Game of 15 for the LoA 5. In order to process user turn (abstract task "Process user turn (level 5)" in Fig. 10), the system sequentially (sequence "≫" operator): displays tokens played by both the players and a suggested token for the user (interactive output tasks "Display tokens played by user" and "Display tokens played by system"). Then, the system suggests and displays a token iteratively (abstract iterative task "Suggest tokens") on user demand until the user confirms one of the suggested token (system task "Process user confirmation" under disable "[>" operator). The abstract iterative task "Suggest tokens" consists in the following actions. The system has to suggest a token that have to help the user to win (system task "Suggest a token" that accesses to the declarative knowledge "The token suggested have to help the user to win"). Then, the system displays the suggested token through a pop-up window (software application information "Suggested pick pop-up") and triggers an event ("Suggested token is displayed" event). The system cannot execute its following tasks ("Suggest a token" and "Process user confirmation" system tasks have an input event) until one of the two user events are triggered: user clicks on "View another one" button (interactive input task "User clicks on "View another one" button" in Fig. 11) or user clicks on "Pick [number] button" (interactive input task "User clicks on "Pick [number]" button" in Fig. 11).

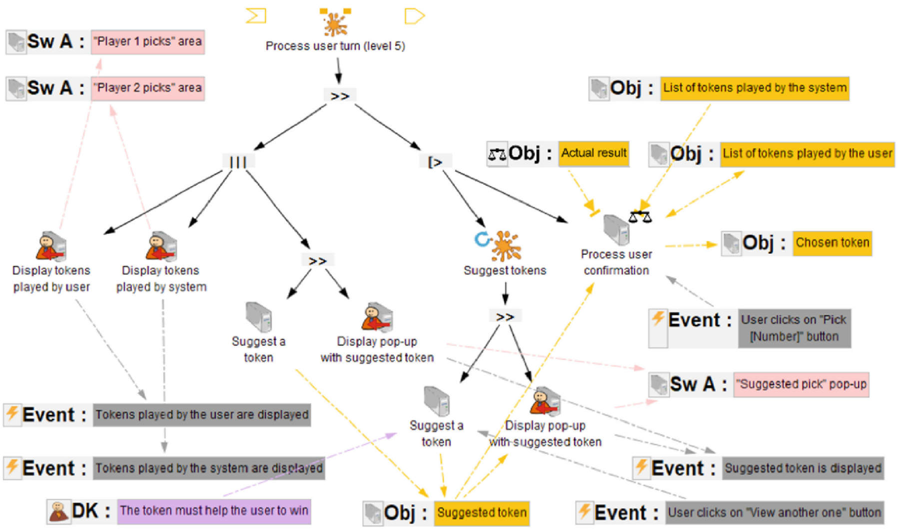


Fig. 10. Task model of the software application task "Process user turn" (for LoA 5).

Figure 11 depicts the **player task model** of the tasks that have to be performed by the player to play a turn of the version of the Game of 15 for the LoA 5. For this LoA, the player supervises the choice of token (abstract task "Supervise token choice" task in Fig. 11). In that figure, the player analyzes and reads the token suggested by the system until s/he confirm one (iterative abstract "Analyze and read suggestion" under a disable "[>" operator with abstract task "Confirm suggested token"). At any time, the player can think about the token to play during the supervision (iterative and optional cognitive task "Think about the token to play" under the concurrent "|||" operator). More precisely, the event "Suggested token is displayed" that is triggered by the system allows the user to see the suggested token (motoric sight task "See suggested token") and to memorize it (cognitive task "Memorize the suggested token"). In the same way, the player can read the tokens played by the system and by her or him in an independent order (order independent "|=|" operator between user tasks "Know suggested tokens" and "Know tokens played by the system"). Then, the player analyses the suggested token and she or he decides to select the suggested token or to ask for another one (sequence of cognitive decision task, motor task and user input task).

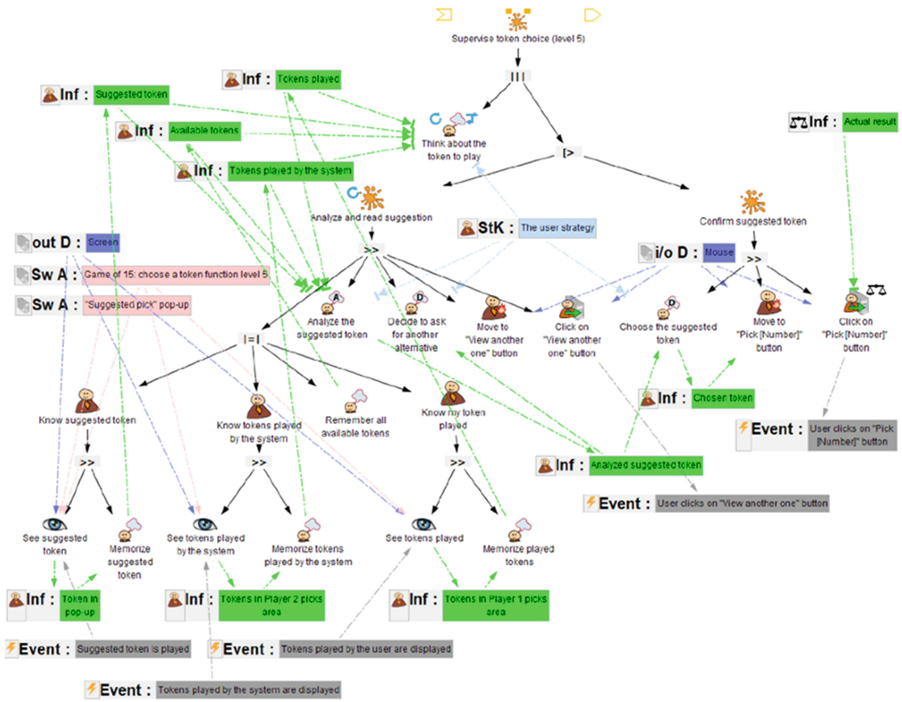


Fig. 11. Task model of the player task "Supervise the token choice" (LoA 5).

The input and output events between user tasks and system tasks describe the procedural change of **authority** between the player and the software application. An output event from a system task in conjunction with an input of this event to a user task describes a switch of authority from the system to the user. An output event from an interactive input task in conjunction with and input of this event to a system task describes a switch of authority from the player to the software application. However, even if one of the roles has the authority on the other for a task, the other can execute other concurrent task over which s/he has the authority like thinking about the token to play (cognitive task "Thinking about the token to play" in Fig. 11). In this version of the Game of 15, there is one task related to **decision-making authority**, it is the task "Choose a leader" and the player has the authority on it (as depicted in Fig. 2). The explicit representation of the authority on this decision task provides support for discussing about what would be the impact if assigned to the software application, or if transferred from the player to the software application at runtime. When the player confirms a suggested token, the software application has the **responsibility** to process correctly the suggested token confirmed by the player (system task "Process user confirmation" in Fig. 10) and the player has the responsibility to confirm the correct suggested token according to his or her expected result ("Click on "Pick [number] button" input task in Fig. 11). Both tasks have an impact on the outcome of the game (connection between these tasks and the corresponding objects and information in

Figs. 10 and 11). The explicit representation of responsibility by the description of the expected and actual outcome of these tasks provide support for arguing about the actions that should be taken if the user or the system tasks fail in reaching the expected outcome (e.g. modifying the display size of the tokens and or buttons if the user do not "Click on "Pick [number] button").

6 Future Work

We have presented extensions to a task-modelling notation and tool in order to provide support to the explicit description of allocation of functions, authority and responsibility. As a future work, we plan to propose an approach for the qualitative analysis of allocation of functions, authority and responsibility based on task models. For example, the systematic analysis of the required cognitive tasks described in the task models as well as the information manipulated by the human for different allocation of functions, authority and responsibility distributions will aim at providing insights on the impact of these choices of allocation on the cognitive workload. Another example of analysis that would be part of the approach is the analysis of motor tasks described in in the task models to determine the impact on the effort for example. Furthermore, the analysis of the number of tasks and the types of tasks allocated to the human can provide a model-based analysis of some user experience aspects. This type of analysis can help to prevent design solutions where the human can be bored or complacent in case of high-level of automation. This approach will aim at providing a comparison between different distributions of allocations of functions, authority and responsibility.

Another possible future work is to introduce the description of possible errors in the task models (this technique is already supported by HAMSTERS notation and tool [13]) to provide support to analyse how to give back the authority to the human in case of automation failure.

7 Conclusion

Automation has been studied for many years and even though metaphors [12] or frameworks [22] have been proposed, the description of the allocation of functions, authority and responsibility between the user and the system is not supported by notations and tools. However, when designing automation, a precise description of those elements are required in order to:

(1) identify and specify the partly-autonomous system functions and the user tasks,
(2) identify and reason about the actions the system is allowed to trigger and the decisions the system is allowed to take, (the similar holds on the user side),
(3) understand mutual responsibility (and liability) in case the cooperation between the user and the partly-autonomous system does not produce the expected outcomes.

Existing approaches for the design of automation mainly focus on the allocation of functions and deal with authority and responsibility only at a high abstraction level.

This does not provide support for reasoning about the quality of a given allocation of authority and responsibility and makes the task of engineering of partly-autonomous system cumbersome, leaving design decisions in the hands of the programmers. This article has argued that the analysis of the allocation of functions must go beyond the analysis of the sharing of the tasks of high-level types (decision, suggestions, commands as proposed in [22]) and that fine-grain descriptions of user and system actions are required. This article also argued that the allocation of authority and responsibility has to be taken into account at the same fine-grain level as the allocation of functions and tasks.

We have proposed several extensions to an existing notation for describing user tasks in order to make it possible to represent in an explicit manner these three elements. We have demonstrated on a case study that the extended notation makes it possible to describe these three elements on a concrete example and that these descriptions provide complementary information with respect to the Levels of Automation classical approach for automation design. Future work will be dedicated to the use of this notation at design time to design function allocation between the system and the user in order to avoid the pitfalls exhibited by [27] and build systems that support best operators in their tasks.

However, in a similar way as human can make errors, automation can fail and asking user to take over is not a viable option [1]. In order to ensure continuity of service, the automation should degrade in a graceful way, reconfiguring itself as this can be done with interactive or classical systems [3]. Such dynamic reconfigurations raise interesting and challenging issues that are not covered by the presented approach but will be addressed in future work. Finally, system behavior description might require more powerful notations (for instance making explicit large number of states) than the one of HAMSTERS. In order to address this, the use of complementary and compatible notations will be required as proposed in [2].

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Improving the Tourists' Experience

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Abstract. The Internet of Things (IoT) is part of a new paradigm where it is possible to integrate every sensor to the Internet, allowing it to be even more immersive and pervasive. Mastering these technologies, such as pervasive and smart places, is a challenge, especially when the goal is to achieve a closer interaction between citizens and applications. The rapid development and exciting innovation create an opportunity to stimulate a variety of new tools for tourists. Taking into account the versatility of IoT sensors for different applications, in this position paper we outline our perspective of ambient intelligence in smart tourism.

Keywords: BLE · Beacon · Mobile device · Personalization Ambient intelligence · Internet of Things · Big data · Tourism Text retrieval · Social network

1 Introduction

Today, people are surrounded by intelligent and intuitive interfaces embedded in all kinds of objects. It is a true challenge to design applications that support users of technology in complex and emergent organisational and work contexts [1]. Information and communication technologies (ICT) and all artefacts would fade into the background while people are immersed in a digital environment [2].

As stated by Cook et al. [2], Ambient Intelligence (AmI) is an emerging discipline that brings intelligence to our everyday environments and makes those environments sensitive to us. It is a multidisciplinary paradigm that draws a new kind of relationship between humans, their environment and the technology [3]. Friedewald et al. [4] state that it is a vision of the future information society stemming from the convergence of ubiquitous computing, ubiquitous communication and intelligent, user-friendly interfaces. Also, Aarts et al. [5] state that their ubiquity, transparency and intelligence will characterize ambient intelligence environments. In another way, Weiser [6] states that the computer of the 21st century should be invisible to its users. Also, it would be embedded in the environment. Such invisibility is related to the capacity of the technology to help users to reach their goals in a less obtrusive way. Others, such as Hopper [7], stated that

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applications could be made more responsive and useful by observing and reacting to the physical world and this is particularly attractive in a world of mobile devices and ubiquitous computers. The development of technologies including facial expression [8], emotion [9], speech [10], or gesture recognition, motion tracking [11], facilitate normal interactions with intelligent environments. Essentially, AmI systems should know when it is convenient to interrupt a user when to make a suggestion but also when it is more convenient to refrain from making a suggestion [2].

Smart destinations enable a city to achieve a unique selling proposition and to make the overall experience of tourists visiting the destination more fun-filled and convenient [12].

As stated by Gubbi et al. [13], the evolution and convergence of several technologies, such as wireless communications, machine learning, real-time computer decision–making, sensors, cameras, and embedded computing are promoting the fast growth of the Internet of Things (IoT). Talari et al. [14] considered that these technologies, supported by a network of embedded sensors and applications, contribute to enhance the citizen's comfort and to simplify the work-life. In this context, concerning a close interaction between citizens and applications, explosive growth is expected in the number of the embedded sensor devices connected to the Internet in the next years. Around the world, the potential market of the IoT is expected to reach $724.2 billion by 2023 [15].

The IoT is part of a new paradigm where it is possible to integrate every sensor to the Internet, allowing it to be even more immersive and pervasive. Most of the IoT sensors devices require significantly low–power consumption, given that these devices are expected to operate using a battery for months or years without resorting to external power sources.

In this position paper, we outline the emerging opportunity to use pervasive technology among other technologies to improve the tourist experience. Using BLE (Bluetooth Low Energy) as a new approach, we outline our approach for providing useful contextual services to the tourist in our scenario "Old part of the Town in Madeira Island".

2 Background

2.1 Merging the Ubiquity

The Internet of Things is part of a new paradigm where it is possible to integrate every sensor to the Internet, allowing it to be even more immersive and pervasive. Most of the IoT sensors are expected to operate using a battery for months or years without resorting to external power sources. To satisfy this expectation, suitable wireless sensor network technologies are required [16] including low power WPAN (Wireless Personal Area Network) standards such as Bluetooth Low Energy (BLE) [17].

BLE is a new approach to wireless communication with a large potential mainly due to its low power requirement and inexpensive characteristics compared with classic Bluetooth [18]. These BLE small transmitters can act as beacons and are used to interact with mobile devices once they enter into their transmission range.

Using beacons, retailers can send customers notifications about product specifications, videos of how to use products, coupons, and deals. Retailers can also use the technology to monitor movements and patterns of costumes within the store to improve product placements and personalise notifications based on past purchases [19]. Starwood Hotels & Resorts is running beacons in 30 of its hotels and resorts. The beacons are helping the concierges in greeting guests by name and accelerating the check-in process for frequent guests. It has also implemented a pilot program that will allow Starwood guests at two of their U.S. hotels to skip the check-in process and along with a partner application unlock their room door using their smartphones [19]. After being popularised by Apple and big brands, local businesses and institutions have also started using iBeacon technology to aid in their services.

In the famous Antwerp museum in Belgium, visitors are directed towards exhibits and notified about stories behind the exhibits. The beacons also stimulate interaction with visitors through interactive trivia questions [17].

2.2 Smart Tourism and Big Data

Smart tourism is a new buzzword applied to describe the increasing reliance of tourism destinations, their industries and their tourists on emerging forms of ICT that allow for massive amounts of data to be transformed into value propositions [20].

Smart tourism initiatives around the world are seeking to build viable smart tourism ecosystems [21] but the complexity of the sector makes it extremely difficult to go beyond the very specific platform, technology or service specific innovations.

Improving touristic experiences was in the scope of Human-Computer Interactions researchers in the past [22]. Poon [23] refers in his study the importance of technology as a strategic tool to tourism. Research on information technology and tourism has reflected the general understanding of how technology changes our society and economy [24]. There are now possibilities to access a variety of data, in massive quantities, in different formats and potentially real-time [24]. Fuchs et al. [25], presents a knowledge infrastructure which has recently been implemented as a genuine novelty at the leading Swedish mountain tourism destination by applying a business intelligence. Their study highlights how this type of approach can be used by tourism management to gain new knowledge about customer-based destination processes focused on pre - and post-travel phases. It is clear that big data can provide better, targeted, and profitable services and products to consumers [26]. For instance, big data analytics can capture information of consumer interest from social networks [27].

Ballagas et al. [28] designed a mobile game - REXplorer for tourists in Germany. The game uses locations sensing to create player encounters with historical figures that are associated with historical buildings in an urban setting. The game is designed to make learning history fun for young tourists and influence their path through the city. Others such as Schöning et al. [29] evaluated how information generated on-the-fly about a point of interest (POI) can be presented interactively using an augmented reality approach. In another way, Marshall et al. [30] analyses how tangible multi-touch surfaces could be adapted to multi-user interactions between users in a touristic centre in the planning phase of a trip. More recent Zhang et al. [31] investigate how generating touristic trips differs when performed by a group of people, including inter-group communication, labour & information search division, and cultural difference between the tourists.

Potter et al. [32] explored the application of the virtual reality in tourism and found the great potential for the use of this technology in nature-based tourism for the provision of both information and education. Khan et al. [33] refer in their work that smart tourism has emerged over the past few years as a subset of the smart city concept, aiming to provide tourists with solutions that address specific travel related needs.

3 Proposed System for Passive Tracking

Main components are: beacons, offline tracking, Mobile App, Mobile tourist survey, count tourist, tourism big data, data analytics and a dashboard to show information.

Beacon locater and context information – Using new technology based on Bluetooth Low Energy (BLE) the beacons can be configurated and implemented near each POI (Point of Interest).

Given the hyper-local and contextual capabilities of beacons, they are of immense value to both travellers as well as players in the tourism industry.

Mobile device App captures the beacon signal, and context information can be sent to the mobile APP, and we take mobile device Bluetooth address and date/time (way of checking tourist present in that place). We implement a new approach to context information used in the commercial area applied to tourism business.

For example, tourists can be alerted about information on the PoI, transportation schedules, weather updates and public services in multiple languages, and at relevant times during the day.

Offline Tracking - tracking the actual behaviour of tourists in cities so that a set of possible routes that enlarge tourist options is taking into considerations for the identification of routes. This process runs in the developed APP, and it will record the location of the tourists periodically by GPS and store the information which can be synchronised when tourists reach a Wi-Fi point. A gamification approach could be added to increase tourist's attachment to their destination choice.

Mobile Tourist survey – small survey to get tourist data, to collect demographic variables and other important data on their perceived visit to a place.

Also in an installation phase, we will get personal information like age, gender, and numbers of days in the local.

Count tourist is a certain place. Can be performed by beacon interaction or by Wifi interaction of mobile device with Access Point, see work of Baeta et al. [34], where this strategy is applied to check the number of persons in public transportation. These mobility patterns can be collected passively without user intervention based on the probe request of mobile devices. These probes requests are sent periodically broadcasting packets, which contain the unique MAC address of the client and (sometimes) the name of a network to which it had previously connected.

Tourism Big Data, a scalable Big Data management and analysis infrastructure were defined, implemented and set-up, according to the overall architectural design and the operational and functional requirements defined in the previous tasks. The resulting Big Data infrastructure provides a framework for dealing (processing and storing) data, with several characteristics as variety, volume, velocity and complexity, ingested in the system and provide the other toolkit components (data fusion and analytical modules) with the right capabilities to quickly and concurrently access and process

Data Analytics - Clustering algorithms like k-means, dbscan or heat maps identify patterns on users' movements. Data and time will be clusters and correlated with external events (holidays, festivals and weather information).

Dashboards present potentially disparate and complex pieces of information in a unified presentation view and are becoming commonplace. It is important for all stakeholders to understand the interrelated tourism dimensions and activities within a destination. We incorporate the most advanced techniques of data visualisation, especially for what concerns the ease of discrimination of the target of interest vs the rest of the picture.

4 Extracting Sentiments and Information from Social Networks

Social networks provide useful information about tourism because tourists express their opinions on it. For this reason, there is a real and concrete need to have an automatic and intelligent system to help to filter, prioritize and efficiently find the most relevant and meaningful type of situations that may inflict some type of relevant impact later on. The technological platform must also be built according to certain criteria, including ethical as well as technological and legal. The following approach of this tool was defined bearing all the above elements in mind to help experts in their tasks, as shown in Fig. 1.

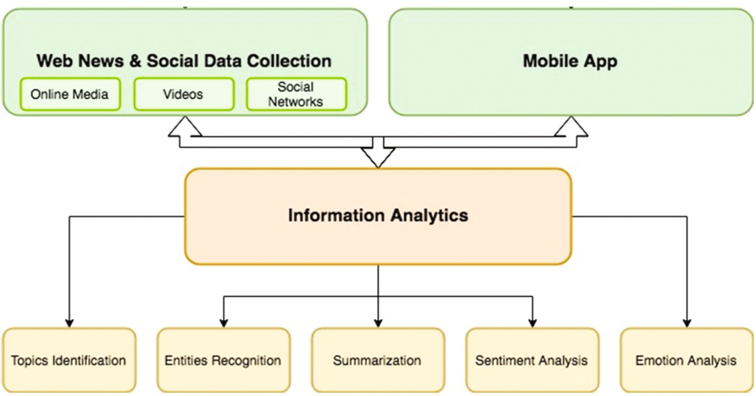

Fig. 1. Proposed Architecture to collect relevant information about tourism

Mobile App - A set of tools based on crowdsourcing mechanisms where a gamification platform is used to investigate user participation, provide relevant information, comments and interact with experts by answering pre-defined surveys. This method will improve the understanding of a particular situation/topic by listening specifically and directly the opinion of a group of people. Furthermore, in order to also expand the use of this application to as many people as possible (to create a significant statistical universe), these tools will also be using several gamification techniques, like rewards based on referrals to other users and complete answered surveys prizes.

Information Collection & Visualization - As such, we expect this interactive map of perceptions will be a measure to understand the role of perceptions and, together, a countermeasure to stop negative perceptions. It will be an instrument of cultural education, a media of creating new conscience inputs: users will be able to take a direct view of how social processes can be influenced by the formations of bad perceptions and, therefore, they can understand how important it is to have a sceptical and critical position on the veracity of some shared opinions. It will also be a methodological support.

Information Analytics - As such, and in particular for the case of online and web media like newspapers and magazines, it is necessary to process the documents to extract the relevant topics. Furthermore, a necessary step with document processing is the recognition of entities that can be useful when assessing risk situations and, in certain situations, the summarization of the all document (useful when processing a large news article for instance). As such, the following techniques will be applied as part of the data analytics set:

- Named entity recognition - An important aspect of text characterization, beyond the topics, are the entities that are referred in documents. In general, entity recognition consists in identifying entities and classifying them into one of the following classes: location, organization, person, date, time, money, product, etc. Common approaches to the problem make use of machine learning methods like Conditional Random Fields, Support Vector Machines and Neural Networks [35].
- Summarization - Summarization can be helpful by identifying the most important content of a larger information source. This can have a greater importance since documents (specifically larger documents) tend to address different topics. Also, it can be more difficult for a sentiment analysis tool to correctly assign a polarity to the whole document instead of a brief summary description, especially if different parts of the document exhibit different sentiment polarities. Therefore centrality-based summarization approaches [36] will be used to focus in identifying the main and most important topic of a document.

Additionally, with data coming from other sources, like social networks and surveys, the system will apply a set of specific analysis in order to first identify the sentiment level (positive or negative) and second, to extract the emotions that may be associated with the given opinions (like enjoy, frustration, etc.):

- Sentiment Analysis - The amount of information available in digital format, in the form of reviews, recommendations, ratings, or any other form of opinion, has been giving a prominent place to knowledge extraction tasks from of unstructured data, among which sentiment analysis stands out. When applied to data sources like tweets this task becomes a fundamental tool in several areas, allowing to perceive trends and opinions regarding a topic or an event. Sentiment Analysis can be done at different levels of complexity, where in its most basic form consists in assessing if a given document (or part of it) is positive or negative. However, the task may involve higher levels of complexity, such as identifying more than two types of sentiment or identifying the intensity associated with the sentiment. The most common approaches to sentiment analysis tasks include, on the one hand, the use of sentiment or polarity lexicons and, on the other hand, the use of machine learning methods. Semantically distributed representations of words can be used instead of the words themselves and, in general, lead to better results [37]. Recent approaches based on deep neural networks have been able to achieve performances never before achieved in many sentiment analysis tasks, especially those involving huge amounts of data.

- Emotion Analysis - An interesting type of information to extract from text in this context is emotion. Emotion extraction goes further than detecting sentiment polarity—positive or negative—and relies on a model of emotions like the one from Ekman and Friesen [38], which lists six different emotions: happiness, anger, disgust, fear, sadness, surprise. Approaches, in general, explore, on the one hand, different features, and, on the other hand, different classification methods (supervised, like Support Vector Machines, or unsupervised, like clustering or topic modelling approaches) [39]. This type of information can help to improve the characterization of the general opinion of the public. A common studied information source is microblogging, one of the defined information sources.

Finally, based on the information extracted from the all the mentioned components, the situations for each monitored topic are identified, scored and then ranked. As such, each situation or topic, depending on the data source, will have a risk impact probability and in the case of online news, a brief summary. This information will be shared with the experts to be used to better assess the overall risk probability of each topic.

5 Validation

We apply a small scale test in "Old part of the Town" in Madeira Island, (*see* Fig. 2), using a passive Wi-Fi tracking system based on AP in each point (*A, B, C in the figure*) and a central tracking cloud server we can obtain the information of how many tourists we have in this location. We track user path and beacons on position A, B and C gives context information and identify tourism running the APP.

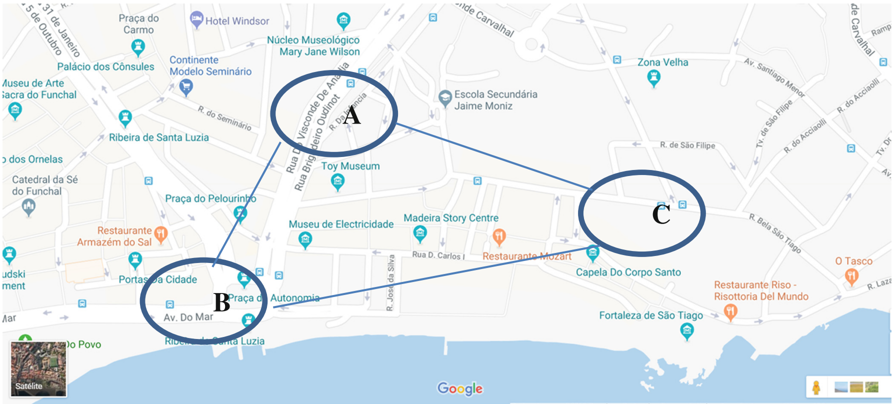

Fig. 2. Possible Path in the "Old part of the Town" in Madeira Island.

Using the Beacon technology is a solution that has aimed to provide location as context. With the power of beacons, tourists can also discover a host of experiences in the city - from easier city navigation to personalized city experiences that provide access to rich digital content on their mobile devices. Beacons with their ability to source customer data around physical locations, activities, time and personal interests, provide a huge window of opportunity to target the end users with personalized and contextual experiences to ensure efficiency in the use of the city services. Given the proliferation of mobile phones and other wearable gadgets and merging the ubiquity of these devices with beacon technology allows us to explore new opportunities in providing contextual services [40]. Providing contextual services for tourists using beacons and other information sources can be an alternative to improve the tourists' experience. These context-aware experiences through wireless interfaces using remote devices have become more common in our daily activities and are triggering technology and business shifts.

We also check behaviour in public transportation (buses) with tests performed during a week period in a series of buses. We chose buses with few passengers to facilitate the manual counting and the manual identification of each route path performed by each passenger. These requirements were made because we wanted to evaluate our current proposal with real metrics. It was possible to identify a number of tourists (persons with App on and signal caught by bus Wi-Fi) and check their path (stop in and stop out). Figure 3, shows the approach performed, where we show a small extract of data collected regarding GPS data and door sensor. The process started with data collection, cleaning and store in a SQL database. Data is available from the probe requests in AP, sensors door (open/close), timestamps and GPS, bus route schedule and route information. The second process step is the temporal and spatial correlation, where the output is hashed mobile device MAC address with information about the stop he gets in and out. The last process is the manipulation of this data towards the information (number of passengers and route path of passengers).

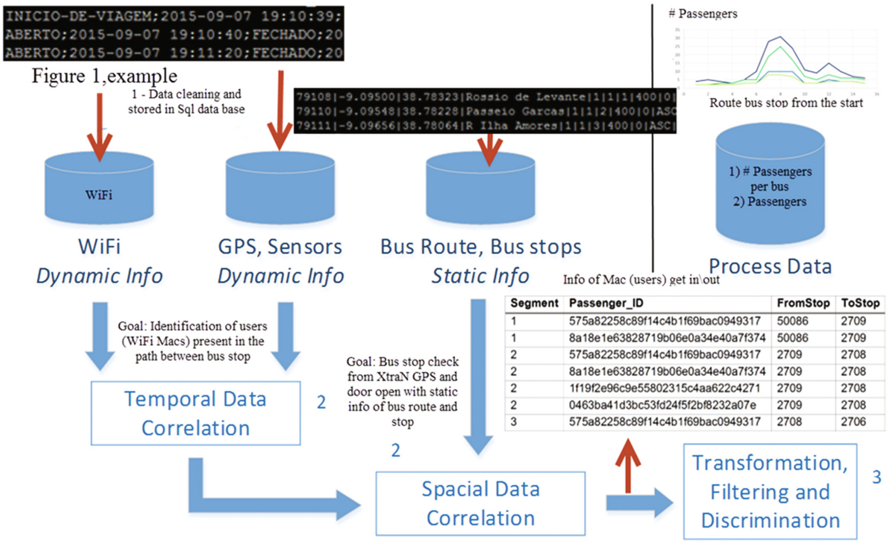

Fig. 3. System developed to track tourists at buses.

6 Discussion and Conclusions

Interaction with technology gives fresh possibilities to use it creatively while also leading to the evolution and sometimes to a transformation of that specific technology. Emerging technologies can develop better and more creative solutions to the problems that we face in our day to day [41]. As Gross et al. [42] states, making computationally embedded things demands cross-disciplinary creativity. Ambient Intelligence is designed for real-world, physical environments, effective use of sensors is vital [2].

As stated previously, one possible scenario of usage could be described as, e.g., based on a mobile device with sensor information (accelerometer) it is possible to check people's attention in a specific location or point with mobile device key pressing detection. Also, as stated before, Wi-Fi probe requests or Bluetooth can be used to identify people present at a specific point.

This position paper was written with the intention to spark an initial discussion around ambient intelligence and tourism with the simple focus of how to design new solutions that involve user interactions.

New research could be conducted, especially providing ubiquitous solutions whereby these new technologies can enhance the tourist experience. For future work we can raise an interesting question facing the high-speed evolution of technologies that is: how can we develop solutions that can be part of future environments in smart tourism?

Also we give steps towards the creation of big data for tourism and the potential of data analytics to improve tourist offers and policy.

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49. Revisiting Centrality-as-Relevance: Support Sets and Similarity as Geometric Proximity

Unraveling the Influence of the Interplay Between Mobile Phones' and Users' Awareness on the User Experience (UX) of Using Mobile Phones

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Abstract. The influence of the interplay between mobile phones' and users' awareness on User Experience (UX) of using mobile phone remains unclear. To fill that gap, a one-week logging study with 32 participants and a follow-up survey questionnaire were conducted. The usage of mobile phone applications are self-reported found to be both initiated by the self-awareness of the user and dependent on contextual factors. Active awareness of mobile phones deteriorated easily with decreasing computing resources due to increasing usage and thus triggered passive awareness in the user. We advance a conceptual model and discuss the implications for designing mobile context-aware systems and services. The outcome of this study lays the groundwork for comprehending the dynamics of UX for mobile context-aware systems and services.

Keywords: Mobile context awareness · User experience · Mobile phone usage

1 Introduction

Active mobile devices have by now outnumbered the global population with the vast majority being smart phones [1]. Utilizing mobile phones is increasingly becoming a common way of life, as mobile phones are being utilized for both personal and professional purposes. Although smart phones can make the work easier, using mobile phones at work may also distract users from concentrating on tasks and result in less productivity [2–4]. This situation is becoming more serious given that mobile phones are carried and utilized by individuals anywhere and anytime, their usage is subjected to various physical and social contexts, the amount of contextual information from smart phone services has been growing, and mobile phone users are living in an increasingly active information environment [5, 6]. Continually keeping awareness of and reacting to the changing contextual information (e.g., the surrounding light) manually is tedious and time consuming. Mobile context-aware systems and services could help mobile phone users maintain awareness of updated contextual information by mitigating the information overload [5, 7, 8].

Although mobile phones with context-awareness are technically capable of capturing contextual information, predicting users' intention and executing actions

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automatically without evoking users' awareness, involving varied levels of users' awareness in the loop instead of taking awareness away from users have touted as necessary ingredients for ensuring the quality of UX [9–12]. In the field of automation system, numerous studies have discussed human performance problems (e.g., including vigilance decrements, complacency and loss of situation awareness) in complex, automated systems control due to human out-of-the-loop [13, 14]. Human performance problems may because by over-reliance on automation, human's role in interaction with automation system as passive monitor rather than active processor of contextual information, and a loss of feedback from the automation system. We assume that providing the passive awareness of contextual information (e.g., via notifications) and maintaining the active awareness of mobile phone users in parallel, are crucial to the success of context-aware mobile services. Consequently, the interplay between mobile phones' and users' awareness constitutes a Hybrid Awareness System (HAS) that dictates the behavior of human-computer interaction systems as a collective [11, 12, 15].

This study conceives awareness as a property of both the mobile phone and its user. In a real sense, this study contributes to the working conference on Human Work Interaction Design by dealing both with the analysis of the human work, learning, play, leisure activities and with the design of the mobile interaction [16–18]. Our conceptualization of awareness hence departs from contemporary definitions that are tailored specifically for other fields of study. For example, in the field of Computer-Supported Cooperative Work awareness has been defined from the human perspective as "the amount of knowledge that a person has about a topic in particular" [19]. Conversely, within the technically-oriented context-aware community, awareness has been defined as "the ability of the system to leverage the context to provide the appropriate response to the users" [12]. In contrast, our HAS approach strives for the middle ground by theorizing awareness as the encapsulation of both mobile phones' and users' Awareness properties. In this sense, HAS should entail: (1) perception or sense for acquiring contextual information (i.e., physical, social, user, and computing contexts) to be utilized subsequently by the mobile phone or user to anticipate and determine appropriate actions; (2) comprehension for interpreting the significance of acquired information, as well as; (3) action or execution for behaving appropriately in accordance with the outcomes of comprehension.

A good UX of HAS demands seamless collaboration between mobile phones' and users' awareness by balancing both mobile phones' and users' active and passive awareness. Although mobile phones' awareness promises to reduce the mental workload on users' awareness by improving the usability of mobile phones and rendering users' interactions with these devices to be more efficient or less effortful [20], the broad range of contextual awareness afforded by mobile phones could culminate in issues like information overload, loss of control, mental distress, privacy violation, untimely distraction and unwanted interruption [21, 22]. Despite that tremendous effort has been expended to enhance and maintain passive users' awareness by pushing notifications to mobile phone users during opportune moments [23–25], studies have shown that users tend to engage in proactive "checking habits" by performing brief and repeated inspection of dynamic content which can be quickly accessed from the device [7]. Certain users have even developed obsessive-compulsive inclinations by being actively aware of their mobile phones to the extent that they interrupt their ongoing tasks to inspect dynamic content on these devices even when notifications were turned off [8, 26, 27]. Our suggestion is that users maintain a degree of active self-awareness, expecting mobile phones' awareness to complement and extend the users' awareness only when the latter is ineffective. The mobile phones' awareness should not be competing with the users' awareness by being over-sensitive to contextual information or even wrestling control away from users [9].

Although extensive research into context-aware services (i.e., conceptual algorithms, network infrastructure, middleware, and applications), little attention has been paid to the interplay between mobile phones and users in being aware of diverse contexts from a human-centric perspective [9, 11, 21, 28, 29]. We thus collected data on (a) 'Turning Screen On' events to examine the Human Active-Computer Passive mode; (b) 'Light change' and 'Auto-brightness' events to examine the Computer Active-Human Passive mode, as well as; (c) conducted surveys to ascertain users' subjective assessment of select context-aware applications. Building on our earlier work [30, 31], where we put forth a preliminary framework to explicate the UX of mobile context-aware systems and services from the users' perspective based on focus group discussions, this study embraces a mixed-methods approach to unravel UX considerations related to such systems [32]. Consequently, this study contributes to a comprehensive understanding of UX shaped by the interplay between mobile phones' and users' awareness, which in turn will inform the quality design of mobile context-aware services.

2 Methodology

2.1 Method

A mixed method was adopted to collect data and Grounded Theory Method was used to develop the conceptual model by this study. A log study and a diary study, along with post-hoc semi-structured interviews, were conducted to understand the phenomenon of the interplay mode between the awareness of the user and the awareness of the mobile phone. The post-hoc interviews and open-ended questions from the diary study were analyzed with an axial coding strategy [33] to explore the causal conditions of the interplay, the strategies of managing awareness, and the consequence of the interplay between awareness of user and mobile phone on UX.

2.2 Participants

The study was conducted with 15 Danish and 17 Chinese Android Phone users, ranging from 19 to 28 years of age. The participants were students, with 15 of 17 Chinese participants from a design department of a technical university in Beijing, and 15 Danish participants from a variety of higher education studies including law, medicine and design. All participants had owned an Android mobile phone for no less than half a year. Each participant was compensated with 350 DKK or RMB for their participation. The research tool was developed based on the Android studio software, and allowed us to capture the contextual information with open APIs.

2.3 Research Phases

Prior to consent, participants were notified of the purpose of the study and the types of data to be collected. The entire research lasted for approximately four months and was carried out in four phases consecutively.

First Phase: Collecting log data of usage behavior about application, sensor data of contextual events and diary data of UX with two tailored tools (MOCCA.Capture and MOCCA.Diary) developed for this study. This phase lasted for a week for each participant (Table 1).

Table 1. Sample of Log Data

Data tag	Time stamps
com.sina.weibo	8:00:27
Low light level	8:21:23

Second Phase: *Analysis of usage behavior, contextual events and diary data.* The sensor and log data was analyzed individually by a tool developed with MS function to illuminate the frequency of application usage, physical contextual events and computing contextual events that transpired during the 7 days in the first phase. Secondly, participants documented their usage experience with 30 separate mobile context-aware applications that had been sampled by us from the participant pools mobile phones current configurations, rated their satisfaction in interacting with these applications, and articulated the reasons behind their rating.

Third Phase: *Questionnaire survey and post-hoc interviews* were conducted to understand the phenomenon unveiled by user behavior, contextual events and diary study. Users were asked to rate their feeling of 30 context-aware services if they having experience of using them.

Fourth Phase: *Analysis of survey data.* The Grounded Theory method [33] was used to guide the coding of raw survey data to develop our conceptual model, and to revisit the interview transcripts to discover what interactional strategies were used by user to manage and handle the interplay between awareness of user and mobile phone in the mobile and dynamic contexts. Finally, the influence of the interplay mode between awareness of user and awareness of mobile phone on UX were analyzed.

3 Results

3.1 Active Human and Passive Computer Awareness

Turning the screen on by a user represents a typical type of interaction event initiated through active users' awareness (human awareness). We analyzed the relationship between preceding and follow-up usage sessions of the 'Turning Screen On' event with the aim of uncovering how the interaction initiated by active users' awareness disturbed the ongoing status of users. Results indicate that 519 (49.7%) of the 1046 usage sessions following Turning screen on is 'Turning screen off', 52% of the time from Turning screen on to Turning screen off is 5–15 s (Fig. 2), followed by less than 5 s (19%), 15–30 s (11%), longer than 70 s (10%) and 30–70 s (8%). By comparison, 36% of the other 526 (50.3%) events, which transpired after Turning screen on, were completed within 5 s, followed by 5–15 s (34%), 30–70 s (14%), 15–30 s (9%) and longer than 70 s (8%) ($\chi 2 = 11.56$, $p < .05$). These results imply that users, after turning on the mobile phone and checking the content for 15 s, display awareness in turning off the screen for around 35% of the situations. Further analysis of the preceding and follow-up usage sessions (104 of 1042 events with zero-time duration between preceding usage session and Turning screen on were excluded) of Turning screen on events illustrated that 461 (49%) of these events encompass similar behavioral patterns. Notably, it is easier for users to revert to their original status when the preceding usage status is Screen Off (64%) ($\chi 2 = 21.835$, $p < .01$) (Fig. 1).

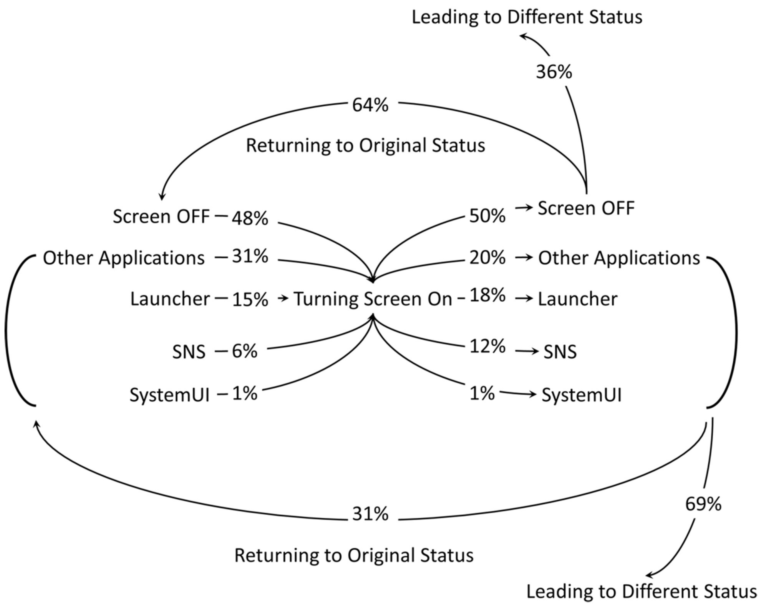

Fig. 1. User behavior related to active awareness

3.2 Active Computer and Human Passive Awareness

The level of surrounding light usually changes dynamically and an Auto-brightness feature on a mobile phone can sense the level of lighting in real-time and adjust the brightness of the screen both automatically and implicitly. Sensitivity to light events thus capture the awareness capability of Auto-brightness feature to light events as illustrated in Fig. 3. Results indicate that the temporal distribution of light events

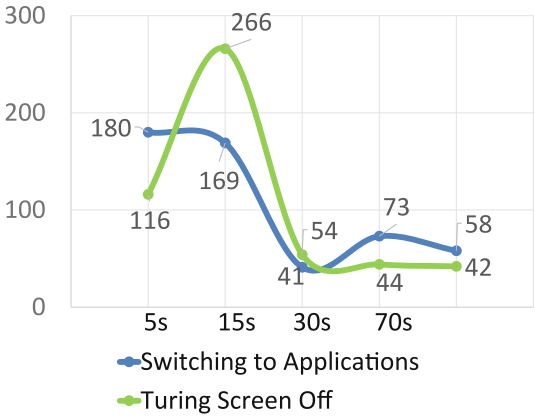

Fig. 2. Time duration from turning-screen-on to follow-up usage session

(higher than 5000 lx or lower than 200 lx) and adjustment of screen brightness are highly correlated (r = 0.76). Nevertheless, the Sensitivity to light events of the Auto-brightness feature is only 2% (Mean = 2%; Max = 18%; Min = 0), thereby implying that the Auto-brightness feature system only reacted to 2% of the light events defined by this study on average. The temporal distribution of Sensitivity to light events revealed that the Auto-brightness feature functions better in the morning and deteriorates drastically in performance at around 8 am when users began to utilize applications extensively.

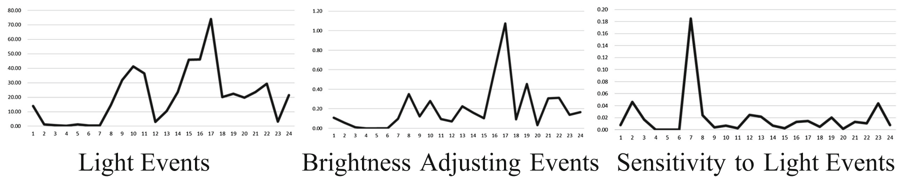

Fig. 3. Temporal distribution of contextual events

Results from the survey questionnaire show that users were generally satisfied with the Auto-brightness feature. Only six out of 24 participants (one didn't utilize this feature and seven didn't realize that this feature existed during the research) were somewhat or very dissatisfied with the Auto-brightness feature.

3.3 Formation of UX

Services which feature context-aware functions are ubiquitous in current mobile phone applications. We reviewed the context-aware services running on our participants' Android mobile phones and found a total of 30 context-aware services that were implemented in our participants' mobile phones' current applications (see Sect. 2.3 for details). In Fig. 4 we present the ratings of those of the 30 context-aware services that were utilized by more than half of our participants. The results indicate that applications, which provide services that exhibit awareness of personal and social contexts (e.g., browsing habits, hobbies, location, shopping history, and social network) were least preferred. Conversely, applications, which exhibit awareness of computing and physical contexts (e.g., internet connection, system language, and time zone) were most preferred. These results suggest that users' preference for a context-aware applications are influenced by the type(s) of context afforded by the application. User would like to keep the awareness of personal contexts in their own hands and let mobile phone sense impersonal contexts and take execution automatically.

Fig. 4. Ratings of most common context-aware services found on participants' phones.

The Open Coding of survey results produced 23 codes and 5 categories were identified in further with Axial Coding by analyzing the major UX concerns, conditions of producing UX concerns, actions/interactions of users and context-aware services produced in response to the UX concerns and resulting consequences. One of the core finding is that the UX constructs of mobile context-aware services, including instrumental value and meaning, were indeed formed by the interplay between mobile phones' awareness and users' awareness. Additionally, users also concerned about the interactive manner and implementation of mobile context-aware services. This is exemplified through a conceptual model in Fig. 5 and quotes from the interview as showed below.

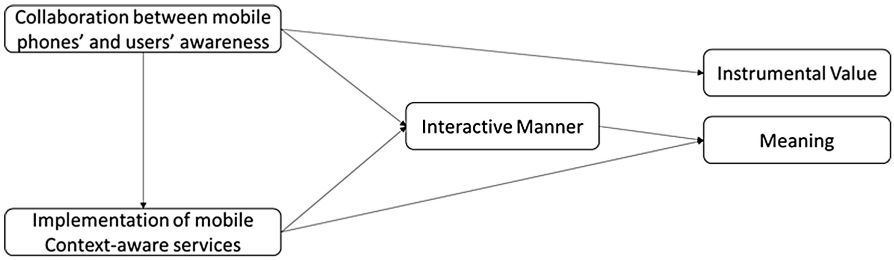

Fig. 5. Framework of UX constructs.

Collaboration Between Users' and Mobile Phones' Awareness. It's in line with our assumption that collaborations between users' and mobile phones' awareness plays tremendous role in forming the UX of mobile context-aware services. Basically, mobile phones' awareness was expected to be capable of complementing human ineptitude in allocating attention to changing contexts while in some cases it might impair the human awareness by cultivating over-reliance on mobile phones' awareness. Additionally, including user in the loop of interaction, allowing for manual correction by user in case that mobile phones' awareness malfunctions and offer visible feedback to users about the result of mobile context-aware are also considered crucial to the quality of UX. It's noteworthy that awareness of users' personal value and hobby are mentioned by Danish user which might indicate that personal value and hobby, as parts of users' context, should be took into account in designing context-aware services.

[Allowing for manual correction by human] "Saving battery. But if I was outside and it dims suddenly it might affect my usage and I have to adjust it manually" [P26].

[Complementing human ineptitude] "It's normal that I forgot to adjust the brightness of screen or night mode, so reminding me to night mode at certain time can help push me to do that." [P31].

[Visibility of executing status] "Intelligent and saving time. But sometimes I might not be aware of that it has already adapted to the current input type, so I changed it manually and later on realized that I have to change it to the correct one" [P26].

[Adaptation to personal value and hobby] "Primarily based on what friends on social media are attending, and to my own preferences…" [P8].

[User in the loop] "I'm not sure whether I used this functionality, it's probably that I didn't pay attention to whether the screen is locked when I'm in a call" [P21].

[Impairing human awareness] "I might miss some events if the volume of alarm clock to be muted when the context is quiet" [P31].

Awaretiquette. What distinguishes context-aware system from traditional system is that context-aware system is capable of initiating interaction with proactive action based on understanding of context. The proactive role of context-aware system introduces new concerns which don't exist in traditional system with reactive and passive action. The proactive actions initiated by context-aware system should be comfortable, acceptable and desirable to users, just like humans behaving in good manners in communicating with each other.

[Protecting privacy] "… it wants to know everything and it invades privacy that they can get, a little annoying for me personally" [P15].

[Polite proactive awareness] "Avoid the rudeness and embarrassment of bursting into music in quiet situation" [P31].

[Interruptability] "*It gets very invading in some kind because It's constantly asking what are you thinking… so that's where it gets, annoying or too much invades"* [P15].

[Way of presenting information] "It's very rude (not friendly) to remind me with the words "please continue to download if you are upstart wealthy", it's uncomfortable" [P26].

[Trust] "Usually the sequence of recommending stores is based on the amount of expense of each store on ads, so I don't trust the recommending ones. I tend to trust what I searched by myself, it seems that this kind of recommendations are ads to me. I do t want my phone to keep track on my behavior. It can be abused by third parties" [P31].

Implementation of Mobile Context-Aware Services. When active awareness was adopted, mobile context-awareness services should let the related tasks works in flow without interrupting or annoying users by taking sensitive, accurate and intelligent execution and letting users control the execution anytime they want to.

[Sensitivity] "But if I was outside and it dims suddenly it might affect my usage and I have to adjust it manually" [P26].

[Accuracy], "The recommendations of Zhihu is really accurate" [P21].

*[Intelligence] "… [*mobile context-aware systems and services service] enables a lot of the smart functionality is that when you walk, close to a metro station it will give you, the next departure times something even though i don't use it. So all of that isn't able by like the location right like using google maps as well location data" [P6].

[Controllability] "I'm not actually pretty sure because maybe I will feel like a little lose control. If, maybe at eleven o'clock is turned the light more down because sometimes I might not want it because sometimes I might be out, in the weekend, so, I'm not pretty sure actually what I want" [P9].

[Innovation] "I find the app very innovation but at the same time a bit unnecessary. Some of the things are very smart but some other not very necessary for me" [P9].

Instrumental Value. Not surprisingly, efficiency quality such as reducing the operations was considered valuable. However, users' feedbacks also indicated that the value of context-aware mobile services might be discounted with the lack of intelligibility and failure to show users how to function.

[Efficiency] "It help reduce the operations to switch between keyboards" [P27].

[Intelligibility] "Not satisfied. I have no idea of how to do anything. I would like a better interface" [P8].

[Utility] "It's smart, can't image how it will be used; It did not actually once remind me of anything, I guess the conditions were too specific, hence they actually never met" [P15].

Meaning. The value of context-aware mobile services went far beyond saving time, it might also bring about health, finance and even social benefits to users.

[Health Value] "To protect eyes and healthy when staring at the phone screen" [P28].

[Financial benefit] "It's good that it can help save data" [P26].

[Social benefit] "Avoiding the rudeness and embarrassment of bursting into music in quiet situation" [P31].

4 Discussion

4.1 A 'Hybrid Awareness' Experience?

This study sought to illustrate the interplay between users' awareness and mobile phones' awareness by examining the UX of a sample of 30 different context-aware services. We expected that UX concerns about mobile context-aware services would be different from those of mobile services in general and rather associated with the interplay between users' awareness and mobile phones' awareness.

In line with these predictions, we observed a different mode of usage behavior initiated by mobile phones' awareness and users' awareness, and by potential challenges to users' awareness resulting from malfunction of mobile phones' awareness. We also found that the UX concerns of mobile context-aware services were mainly associated with the interplay between users' awareness and mobile context-aware services. The results of usage analysis showed that interplay between awareness of user and mobile phone shaped the different mode of usage and users had high level of awareness about the contexts which mediated the usage of mobile phone. Data of applications with active awareness (*implicit interaction*) and passive awareness (*explicit interaction*) showed that human awareness can not be excluded from the loop of interaction in active awareness of mobile context-aware systems and servicesS and intelligibility/utility issues were major concerns in passive mobile context-aware systems and services. Finally, questionnaire survey showed that user attempted keep awareness of personal contexts in their own hands and let mobile context-aware systems and servicesS to deal with the impersonal contexts. Taking all results together, a conceptual mode illustrating how awareness of user and awareness of mobile phone interplay with each other with quality of user experience, as illustrated by the following quote from participant P14:

"*it is difficult for me to answer, because I have to be aware of what's happening on my mobile phone, when I'm using it i have to take care of what's happening on my telephone when it's just lying in my pocket do i have to be aware someone's calling me, i have to be aware what it's doing. So there are passive and active or positive use scenarios"* [P14].

Awareness of user and awareness of mobile phone form an *awareness entity*. The mobile context-aware systems and services should take awareness of user and contextual factors into consideration in capturing contexts, predicting the intention of user and executing actions. The awareness of user should be considered a type of context in designing context awareness system in addition to the temporal, spatial, social and computing. Only few studies explored how to initiate interaction with mobile phone according to contexts of user, e.g., [8]. This study showed that user's awareness of using/not using mobile phone is highly context-dependent and, furthermore, that detecting the awareness of user in certain contexts and decision of using awareness strategies should be based on collaborations with user's awareness. Users had different types of awareness which should be considered, too.

A quotation from a participant may shed light on the constituents of a hybrid awareness system:

"…I have to be aware of what's happening on my mobile phone. When I'm using it, I have to take care of what's happening on my telephone and when it's just lying in my pocket I do have to be aware someone's calling me, I have to be aware what it's doing. So there are passive and active or positive use scenarios…" [P14].

To conceptualize the varying UX of the interplay between users' awareness and mobile phones' awareness, we propose the Hybrid Awareness System (HAS) model shown in Fig. 6.

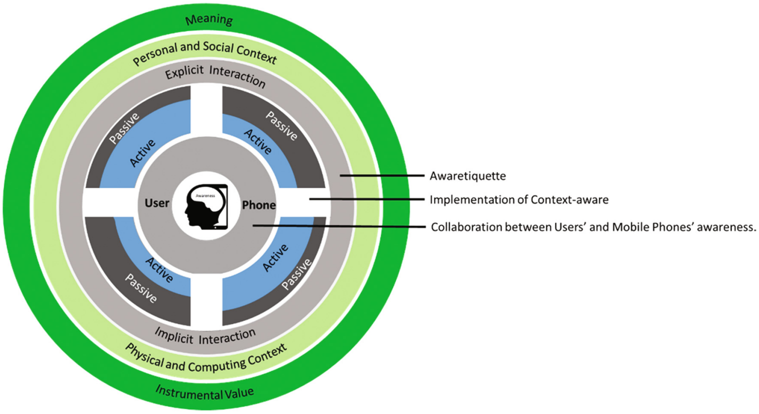

Fig. 6. The Hybrid Awareness System (HAS) models the interplay between mobile phones' and users' active and passive awareness as depending on the types of context. Varied forms of interaction are required to address UX concerns across different interplaying modes.

The conceptual model in Fig. 6. highlights the four key factors that governs the interplay between users' awareness and mobile phones' awareness. These factors include awareness, interaction, context types and UX. In this model, mobile phones' and users' awareness constitute a hybrid awareness system in which the two types of awareness collaborate with each other in a dynamical fashion. When faced with information on personal and social contexts, users' awareness takes precedence over that of mobile phones in analyzing the information and taking appropriate actions. Conversely, when faced with information on computing and physical contexts, mobile phones' awareness assumes the prominent role in analyzing the information before executing actions both automatically and implicitly. Nonetheless, keeping users in the loop of interaction is still necessary even when the interaction is automatic and implicit.

4.2 Implications for Design

Context-aware systems and services are ubiquitous thanks to the advances in sensor technology and computing capability of mobile phones. The results of this study showed that design of mobile context-aware services should take mobile phones' and users' awareness into account as an hybrid awareness entity. Compared with the traditional way of interaction featuring human-proactive and computer-reactive functions, computers in context-aware system are becoming more proactive, as they are able to detect contextual events and initiate interaction proactively based on an understanding of human intention.

From the perspective of human-computer interaction, the success of context-aware systems and services does not only depend on the efficiency and effectiveness of fullfilling the tasks delegated by humans, which is measured by usability. The success of context-aware systems and services relies on their (a) understanding the state of users' awareness, (b) adopting explicit or implicit interaction according to the dynamic state both of mobile phones' and users' awareness, and (c) predicting the intention of user and initiating interaction at opportune moments. Furthermore, the implementation of mobile phones' awareness should avoid impairing the users' awareness, and instead offer complementary solutions; designer should avoid cases where mobile phones' awareness deteriorates or even stops working while users have developed an over-reliance on such systems and services.

Second, the findings of this study call for attention to the issue of what we call 'awaretiquette' in the design of mobile context-aware services. To that end, efforts to be made not only include the traditional issues, e.g., privacy and trust, but also the emerging issues with the advent of proactive interactions should keep with the contexts. In the context of chinese culture, 'awaretiquette' refers to initiating appropriate interactive actions according to occasions (分场合) and to speaking different languages to human and ghost (见人说人话,见鬼说鬼话). The results of this study indicated that being aware of physical contexts are more preferable than that of social contexts out of considerations about controversial issues related to control of social relationships. Consequently, designing social-aware services needs to pay more attention to the issue of 'awaretiquette' by using appropriate interactions.

Finally, the design of mobile context-aware services needs to consider the contribution of context-aware systems and services to UX going beyond the instrumental values, e.g., to the meaning to life. Automation and implicit interactions of context-aware services lead to efficiency and low workload which maximizes the instrumental values. However, it also results in side effects, e.g., being out of control, out of the loop, and to invisibility of system status. The design of context-aware services should make full use of the strengths of context-awareness and avoid the deleterious effects.

4.3 Limitations and Future Work

This study was carried out with a small sample size to explore the UX issues arising from interplays between users' awareness and mobile phones' awareness. We identified the constructs and sub-dimensions of UX that is worth of further investigation in the future with a bigger sample size and a study devoted to more specific issues.

Literature showed that humans easily generalize etiquettes for human-human interaction to human-computer interaction [34] and require computers to have appropriate degree of etiquette when interacting with humans. Although the etiquette issue has attracted a wealth of attention in the field of human-robot interaction [35–37], sparse attention have been paid to the interaction between users' awareness and mobile phones' awareness [38]. As what revealed in this study, mobile phone users have experienced the problems of etiquette caused by mobile context-aware services. Research in the future can be devoted on the special issues of etiquette associated to proactive and implicit interaction, interruption for switching among users' and mobile phones' awareness, and the cultural factors.

In this study, we developed a conceptual model interpreting findings of UX concerns and interplay between users' and mobile phones' awareness. The model call on further and dedicated research with bigger sample size to investigate the specific issues such as the UX dimensions that distinguish context-aware services from context-unaware services, the interplay modes between users' and mobile phones' awareness in a specific context-aware services.

Finally, a majority of the participant in this study were students. Although learning can be considered a type of work for students, future research should investigate the potential differences between students and employees, and between classrooms and workplaces, for the influence of the interplay between mobile phones' and users' awareness on the user experience of using mobile phones.

5 Conclusion

In conclusion, our findings and proposed conceptual model support a dynamic view of UX shaped by the interplay between mobile phones' and users' awareness. We showed (a) how over time the usage behavior of mobile phone users are influenced by the interplay between mobile phones' and users' awareness, (b) how the malfunction of mobile context-aware service might risk the UX by fostering over-reliance on mobile phones' awareness, and (c) how four factors identified in this study appears to govern the interplay between users' awareness and mobile phones' awareness. We propose a 'Hybrid Awareness System' (HAS) that models the interplay between mobile phones' and users' active and passive awareness as depending on the types of context. Furthermore, we suggest that our new term 'awaretiquette' may be used to refer to initiating appropriate interactive actions according to occasions (分场合) and to speaking different languages to human and to ghost (见人说人话,见鬼说鬼话).

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Automating Engineering Educational Practical Electronics Laboratories for Designing Engaging Learning Experiences

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Abstract. This paper presents a work on understanding the effect of automated systems on learning experiences of students in practical electronics laboratory sessions. Here automation refers to the ability to provide students with contextualized information and instructions to rectify mistakes made while conducting practical experiment. A system employing mobile augmented reality (AR) and a debugging tool to assist students with physical circuit prototyping was developed. The AR provides active visualization to students regarding practical experiment. The debugger tool senses errors made while prototyping of electronic circuits on breadboard. The proposed system, named Smart Learning System, has shown to improve students' engagement in practical laboratory sessions and improve laboratory dynamics by reducing the workload of instructors.

Keywords: Augmented reality · Smart objects · Engineering education
Artificial intelligence · Qualitative HCI

1 Introduction

Educational laboratories of engineering institutes play an important role in nurturing hands-on skills in students. However, due to a number of constraints faced by students in these laboratory sessions, in terms of lack of understanding about equipment, equipment issues and debugging problems, etc., learning often becomes frustrating and cumbersome. Such issues also increase the workload on laboratory instructors who need to tend to a large number of students. This paper presents a work on understanding the use of augmented reality (AR) and intelligent automated tool in complex environments of educational laboratories to help create engaging learning experiences and improved classroom dynamics. The specific focus is in context of practical electronics laboratory session of engineering institutes. Students in these practical electronics laboratories are required to assemble physical circuits on a Breadboard [1] – a passive device used for prototyping physical electronic circuits. However, despite its widespread use, it remains prone to a number of issues such as loose wire connections, misplacements of electronic components and faulty connections [2]. In addition to assembling circuits in laboratories, students are required to operate test

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equipment like cathode ray oscilloscope, variable power supplies, function generators and at the same time make connections between theoretical and application aspects of the experiments. All these steps combined together pose various constraints and challenges for students – thus leading towards increased workload, poor learning experience and poor learner's satisfaction. The students also rely constantly on laboratory instructors for assistance. However, teaching a large number of students of varied background is often quite difficult for instructors [3]. Challenges also arise for laboratory instructors regarding teaching, giving time to students and often handling a large number of students – who face difficulties in a time-limited laboratory session.

To minimize such factors, a tool to automate circuit-debugging process for use with augmented reality (AR) is proposed that helps students to learn in engaging ways. The system provides contextualized information to students, helps them relate theory with practice and assists them in tasks like rigging up circuits and operating test equipment. Problems faced by students while circuit assembly on the breadboard are automatically detected and highlighted using the circuit debugger. The main idea is to design an intelligent automated system capable of assisting students and facilitating teaching in practical electronics laboratories. For designing such system, learning and knowledge has been derived from understanding human tutoring in practical laboratory sessions by utilizing a user centered design (UCD) [4] approach.

Since human tutoring, especially in the laboratory sessions, is mainly based on imparting experiential knowledge, it is important to provide it with the ability to guess the problems or difficulties being faced by students and guide or instruct them like human teachers. To model and design this experiential or heuristic reasoning based instructional capabilities in, emphasis was placed on user-centered design methodology and an interdisciplinary approach was adopted to combine the practices of Human-Computer Interaction (HCI) with those of Artificial Intelligence (AI). This method is mainly based on Herbert Simon's philosophy of considering AI as an empirical science [5]. The study also follows the approach of ubiquitous computing [6] as envisioned by Mark Weiser, where every day mundane objects are embedded with computational capabilities, with focus on developing learning aid for future classrooms. The proposed circuit debugger tool is based on this approach and falls under the category of Smart Learning Objects (SLO) – which are physical objects with embedded intelligence and sensors used in educational environments. The proposed Smart Learning System (SLS) utilizes both SLO and AR. AR provides an excellent means to establish interactions between users and everyday objects through interactive visualizations by superimposing computer generated graphics onto real environment.

It is posited that such augmentation and automation technologies, based on SLO and AR, can help leverage learning experiences of students in educational spaces, improve instructors teaching satisfaction and help create better learning environment.

2 Literature Review

Research studies [7, 8] on students' learning experience in engineering laboratories highlight that nearly 78% of the students feel frustrated in laboratories due to issues like troubleshooting of equipment and lack of understanding regarding experiment.

This frustration causes boredom in students which prevent them for further learning. Pass et al., Sweller et al., and Watai et al. [7, 9, 10] also report that laboratories are a place of extreme cognitive load for students which hinders with their learning process. The authors highlight need for innovative methods to provide contextualized instruction to students in laboratories. Further investigations by Booth et al. [11] report the problems faced by users during prototyping of electronic circuits and discuss the need for supportive ways to educate and assist user in these task. Dede [12] posits that the use of smart objects with embedded sensors and intelligence can help distribute cognitive load of student. Using such devices in educational settings gives rise to Ubiquitous Learning Environment (ULE), which can allow sensing learner's situation and provide adaptive support to them [13, 14]. Mattern et al. [15] discussed the capabilities of physical smart objects in terms of embedded information processing, intuitive user interface, context-awareness and highlighted the use of smartphones as a mediator between people and smart objects. Studies [13, 14] present conceptual scenarios on the use of such smart objects in laboratories to sense physiological and psychological parameters and provide intelligent feedback through text-to-speech systems embedded in the objects. Further investigations [16, 17] have been made on type of intelligence to be embedded into laboratory equipment and objects to minimize cognitive load of students in electronics laboratory. Drew et al. [2] presented a novel tool to automate checking of circuits on breadboards. Published research studies [18, 19] illustrate the use and effectiveness of mixed and augmented reality based learning systems. These contributions show that using such systems can provide enhanced learning experience in pervasive computing environment and help distribute workload of students by providing visualization capabilities.

These research works also suggest that although a significant research has been published and carried out in the field of AR and Smart Objects, their applications in context of improving learning experience of students in electronics laboratory is highly limited. Further discussion on developing guidelines for such learning aids are required. Research studies discussed by Gonçalves et al. [20] present an overview on user experiences through the use of smart and pervasive technologies to improve the quality of human-workspace interactions in various contexts including education. These studies broadly fall under human-work interaction design framework [21] that urge a need to explore possibilities of utilizing emerging information and communication technologies to improve user's interaction with workspace and its related nuances. This paper broadly falls under this human-work interaction design framework and presents a basis for design of an automated system utilizing AR and smart object for assisting human learning in practical electronics laboratories.

3 Research Questions and Objectives

This study considers the approach of ubiquitous computing [6] to address the difficulties experienced by students in electronics engineering practical laboratories by embedding computational capabilities into commonly used physical objects in electronics laboratory (e.g., breadboard) and making use of mobile AR. The primary outcome of this research is to understand how automation in practical electronics laboratories can help design engaging learning experiences for students and what influences it has on the laboratory dynamics.

A Smart Learning System prototype was developed for this experimental investigation as a part of automation solution in practical electronics laboratories. The primary objective of these experiments is to access students' learning satisfaction in electronics practical using the developed prototype.

The following research questions were investigated:

Q1: How to create automation in practical electronics laboratories to create engaging learning experiences?
Q2: What effect will automation have on learners' satisfaction?
Q3: Will students find automation useful to be adopted in practical laboratories?

The following hypothesis was formulated and tested:

H1: A positive relationship exists between learners' satisfaction and the reuse intention for SLS.

4 User Research and Methodology

This research utilizes both qualitative and quantitative methods of data collection and is mainly rooted in a UCD approach as practiced in HCI. Observational studies were carried out in live laboratory sessions and semi-structured interviews of teachers and students were conducted. Field notes, audio and video recordings were made for all these sessions. The collated data was analyzed using content analysis technique. Twenty (N = 20) second year undergraduate students from electronic engineering branch were interviewed and presented with storyboards of conceptual scenarios of SLO in laboratories. Laboratory instructors (N = 2) were also involved in the design process to provide continuous insights into laboratory practices and feedbacks on prototype development.

4.1 Scenario Based Design Approach

Scenario based design technique utilizing conceptual storyboards was utilized. The idea of storyboarding approach was adopted from authors Davidoff et al. [22] to explore divergent design concepts. This methodology allowed understanding about the concreteness of the proposed solution and helped evoke further requirements for analysis and technology probe [23]. It also enabled understanding of user's perception, acceptability and need for new technologies. Students were asked to rank the storyboard according to their needs. The storyboards depicted possible interactive learning systems that were envisioned to assist students intelligently in practical electronics laboratory sessions as well as assist instructors in teaching. Out of three conceptual scenarios presented, students ranked scenario 2 highest, see Fig. 1.

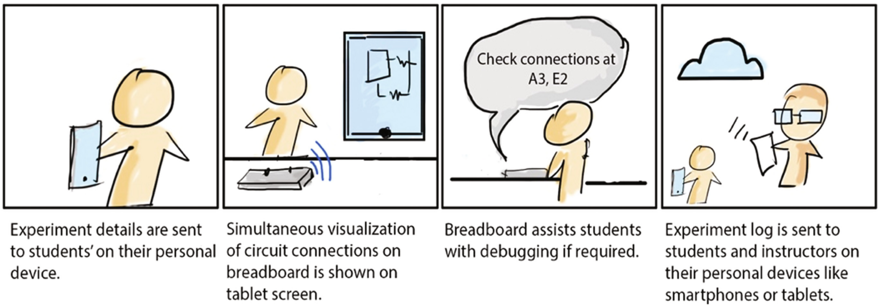

Fig. 1. One of the conceptual storyboard presented to students which depicts the use of SLO and AR in practical lab sessions. The storyboards were used to conceptualize future learning aids with embedded intelligence.

The scenario illustrates a laboratory session where students perform their experiments on a breadboard with circuit debugging capabilities. This breadboard is also referred to as SLO. The breadboard is connected to a computer or digital tablet that shows visualizations for circuit assembly. The system is also able to detect wrong connections and pin-point it to students and guides them by instructing about various theoretical concepts of the experiment. The students can simultaneously update their experimental readings to their records and upon completion of experiment; this record is sent to their instructors for evaluation. The students were strongly able to relate to this depiction but pointed out that such a learning system alone will not be sufficient in laboratories. However, they also suggested a strong need for laboratory instructors to help them out with their experiments instead of completely relying automated systems.

4.2 Interviews

Face to face open-ended interviews were conducted amongst these N = 20 participants. The participants were undergoing or had already undergone and finished basic electronics laboratory course and could narrate their experiences and difficulties faced in laboratories. The ages of these student participants were between 18 to 20 years with an average age of 19 years. Students were asked to describe the difficulties experienced by them in practical laboratory sessions. In addition to students, laboratory instructors (N = 2) were also interviewed to get insights into difficulties experienced by them while teaching in practical laboratory sessions. Table 1 presents a few responses of instructors regarding difficulties experienced while conducting practical laboratory sessions.

Table 2 presents a few excerpts from students' interviews that highlight some of the problems described by them.

The interviews provide an insight into different types of difficulties experienced by students in terms of lack of contextual information, ability to operate various equipment and difficulties experienced in physical circuit prototyping. These difficulties can be categorized under different activities that are required to be performed by students in

Table 1. Qualitative responses of laboratory instructors (N = 2) regarding difficulties experienced in laboratory

Participant	Responses
I1	*"Most of the students think that input devices, output devices and the circuit itself were connected properly even if they are not. General practice is to verify the inputs and check the intermediate results compared to expected results. However, this procedure is difficult especially when the number of stages are more or circuit having more components…"*
I2	*"…more practical knowledge on use of equipment such as CRO, function generator should be given. …even we face difficulties in operating CRO…."*

Table 2. A excerpts from a few students' interviews

Participant	Responses
S1	*"… There are many faulty equipment…breadboard were faulty, we need to ask for new breadboards… In digital electronics, we didn't know many things. We were able to perform only after coming to lab and asking friends… Big circuits take time and show problems… leads to frustration but after it works, we feel excited…"*
S2	*"…sometimes the fault is only realized after implementing the whole circuit and when it leads to wrong output or other problems…can't be pointed out initially…"*
S3	*"…lab manual only tell procedures, not the implications of errors or combination of component arrangement…"*
S4	*"Lab based learning is very helpful than doing on paper and pen. Sometime we design some circuit on paper and think that it will work. But when we practically perform it, the situation is different. That time we realize and learn what are the mistakes we are doing"*

order to complete the experiment. These activities are: Referencing, Assembling, Operating test equipment and Reporting [24]. The difficulties under each of these activities can be broadly categorized as follows:

Referencing: lack of contextual information, gaps in explanations between theory and practical experiment.
Assembling: loose wires and improper connection on breadboard, wrong connections, wrong electronic components used, power supply issues.
Operating test equipment: lacking understanding about equipment functioning, faulty equipment
Reporting: wrong measurements, wrong calculations.

These difficulties hinder with students' learning experience in electronics laboratories as they often have to struggle with trivial issues such as identifying loose wire connections. Various research studies have focused on improving the laboratory objectives and activities to overcome such difficult situations. Studies in HCI [2, 25] have focused on developing tools to overcome these challenges for end users - mostly involved in hobby electronics. Such tools can help automate trivial tasks like identifying loose wires and wrong connections. However, in case of educational laboratories, students require more than just simple prompts regarding mistakes made. The prompt needs to be instructional in nature through which students can derive learning, self-reflect upon their actions and gain the ability to understand where they are going wrong and why they are going wrong. In such cases, the automation requires a certain level of intelligence that is able to assist student in – a manner similar to that of a human tutor.

Based on this understanding derived from user research studies, a SLS was conceptualized, designed and developed so that it could assist students relate theoretical concepts, assemble circuit and debug physical circuits as well as get instructional prompts to help them understand the activity they performed. The SLS was embedded with intelligence that could assist students troubleshoot difficulties faced during physical circuit prototyping on breadboard. The following section describes the SLS prototype.

5 Smart Learning System Prototype

The SLS prototypes consists of an AR based application and an intelligent breadboard. The AR application provides active visualization to students by providing 3D animated instructions regarding circuit assembly on breadboard, operating test equipment in lab, for example a cathode ray oscilloscope (CRO), and, on-spot videos regarding theoretical aspects of the experiment. The application utilized both marker and marker-less tracking to overlay 3D and 2D graphics onto real space.

When smartphone or digital tablet were pointed towards the figures given on laboratory manual or breadboard circuit, on-spot videos and 3D graphics were overlaid onto work environment, as shown in Fig. 2(a, b, c, d).

(a) (b) (c) (d) (e)

Fig. 2. SLS Setup consisting of AR and circuit debugging tool. (a) Video instructions overlaid on a lab manual, (b) Breadboard attached with marker, (c) Close-up view of the 3D graphics overlaid on breadboard, (d) Operating instructions for CRO, (e) Snapshot of instructions provided by circuit debugger on digital tablet.

Further, to aid usability and help students working on circuit assembly, an assistive instructional AI was embedded in the debugger module attached to the breadboard that sensed input and nodal voltages of the circuit. This module could communicate with user's smartphones or digital tablet via Bluetooth and acted as mediator to provide information and voice-based instruction regarding errors made by users, see Fig. 2(e). The types of error that could be sensed are overvoltage, loose connections on breadboard, input voltage and nodal voltage. Based on the type of errors sensed,

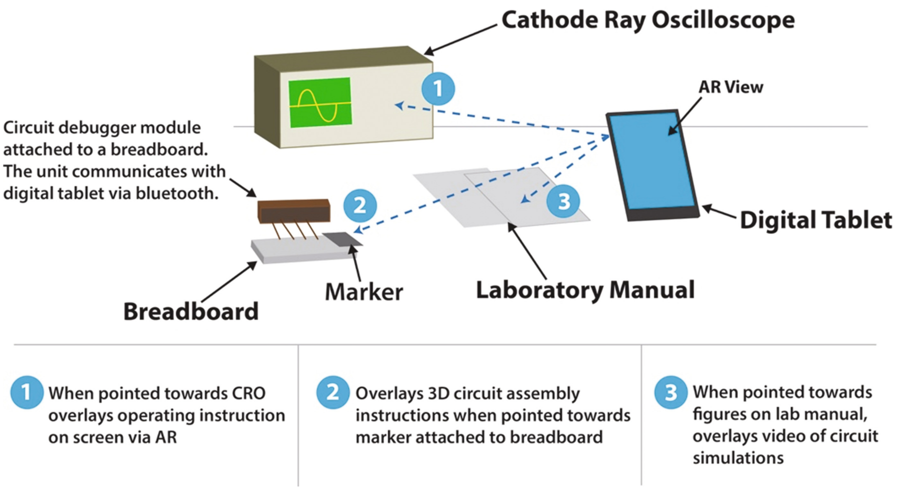

Fig. 3. SLS setup consisting of a smartphone that acts as a mediator of AR and an intelligent breadboard that is able to instruct students during troubleshooting.

corresponding instructions were generated for user. These instructions were provided to user through text-based and voice-based functionalities. Figure 3 depicts overall setup of SLS.

6 Defining Instructional Intelligence and Understanding Automation in Practical Electronics Laboratory

The SLS works on the concept of distributed intelligence [26, 27] to provide automation. The AR module help students relate to various theoretical concepts via interactive videos and 3D graphics to get information regarding operating test equipment like CRO. The AR also helps students visualize circuit assembly on breadboard. By providing this information, the AR is able to "automate" certain aspects of the activity wherein students would have required the help of instructors. Such as, during assembling of physical circuits, students often ask instructors how to arrange different electronic components on breadboard, what configuration of components is required, where should they make electrical connection on breadboard with the IC, and so on. The AR is able to address these issues. Secondly, by providing videos that are contextualized pertaining to a specific experiment and its related task, the AR is able to save students extra effort required to browse through a series of unstructured sea of information available on the internet or to wait for an instructor to come and explain them the concept or working. This way, the AR automates the task of information delivery for students – thus reducing their workload, thereby also reducing the burden of instructors to address the need of each student group in practical electronics laboratory session.

When students face problems with circuit assembly like loose wire connection, power supply issues or wrong connections, the circuit debugger senses these mistakes or errors and sends instructions to students via the smartphone. These instructions provide feedback to students depending on the level of mistake or problem being faced. For this, the possible mistakes and experimental procedures, and the required set of instructions to rectify these mistake or error are stored in a database. Various task-flows of different practical laboratory experiments need to be constructed for this. A group of such task-flows combined together provide decision making capability to the system to provide suitable set of instruction to students. For example, if a mistake is sensed by the debugger system, it checks the level of understanding required to instruct students from the decision-making module and based on that provides the required output. Figure 4 represents a block diagram partly conveys how instructional intelligence is being embedded into the debugger system.

The input or data layer contributes towards first degree of intelligence (1-DOI) and is mainly responsible for sensing and computing functions. The user interaction in this layer are mostly tangible – example, assembling circuit on breadboard that is attached with the debugger module. Thus, it is a tangible user interface (TUI).

Developing effective instructions and learning content corresponding to task-flows and errors is the second degree of intelligence (2-DOI). Designing rich learning experience and interactions with the system is third degree of intelligence (3-DOI). Based on these premise, the SLS prototype was developed which been discussed in previous sections. Study [15] further places an elaborate discussion on designing AI for smart devices based of students' feedback.

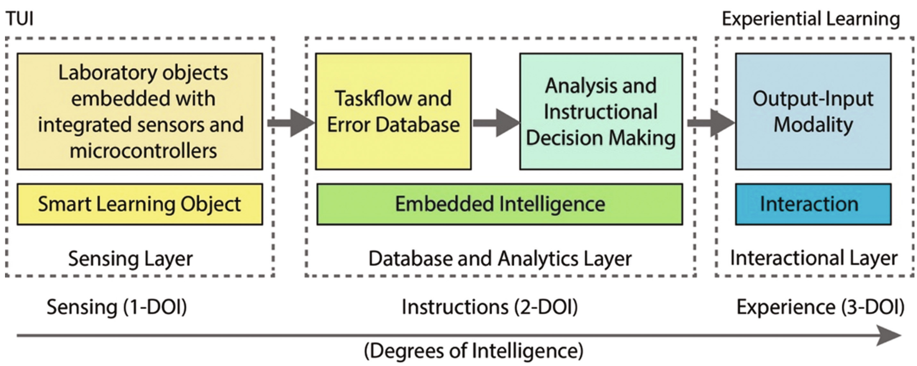

Fig. 4. Block diagram representing increasing degrees of intelligence embedded into learning system as a part of making automation intelligent.

The following pseudo-code partially defines the instructional intelligence embedded for the purpose of circuit debugging.

```
Algorithm circuit-debugging is
Input: Check connection on breadboard

Output: Voice and text based instructions

for each circuit connection on breadboard do
    scan for loose connections

if there is no mistake in connection on breadboard do
Output: Good work

else if there is a mistake in connection on breadboard do
check database for required instruction for each mistake
Output: Specific instructions
```

The intention is to embed intelligence into SLS so that it is able act as a human tutor to assist students in lab sessions.

7 Analogy of SLS with Human Tutor

In a conventional, students when they make mistake during circuit assembly or while facing difficulty in understanding the theoretical concepts, rely on lab instructors or peer to help them. The tutor helps students either by pointing or highlighting mistakes made during circuit prototyping or explaining the underlying theory behind the experiment.

The proposed SLS can be considered analogous to a human tutor. When students prototype circuits on a breadboard, it is mostly testing that is required to debug circuits. This requires a lot of effort and mental demand. Consider arrangements of electronic components and wires on a breadboard to be the syntax – i.e. the structure of the circuit and breadboard to be the console, intelligent breadboard acts a debugger – a task which is generally performed by taking help of human instructor in lab. The output modalities, such as AR or voice-based interface act as mediums to inform users regarding these errors – similar to the way instructors teach students. Hence, if any errors like loose wiring between rows of breadboard, wrong connections or varying voltages are sensed, they fall under syntactical errors and informed to user. Thus, efforts required in testing and debugging the circuits by users can be reduced. The SLS is, in this manner, able to automate several trivial processes of human tutoring.

8 Influence of SLS on Student Engagement in Practical Electronics Laboratory Sessions

This section presents the results of prototype evaluation conducted amongst student participants to understand the influence of automation on their work and overall classroom dynamics. For this, the SLS prototype was demonstrated to the participants and various functionalities were explained to them. The only limitation was that SLS was a lightweight prototype and could not be used for a full-scale testing for summative evaluation. Therefore, scenarios and mock-ups [23] were used during the evaluation along with SLS prototype to explain users how the end product will be like along with all its features and functionalities. Scenarios play an important role in evaluation of novel systems that are under constant design and development phase as the technology is often not well understood by developers [28]. Both qualitative and quantitative aspects of HCI were also utilized to overcome the limitation of evaluating a lightweight prototype. The study relies on qualitative aspects, such as semi-structured interviews and open-ended questionnaire responses, to gather experiences of students and instructors to inductively derive understanding about the influence of automation on users and their work environment. The quantitative studies focus of the usability aspect and assess learners' satisfaction. Both quantitative and qualitative aspects complement each other to capture broader aspects on the utility and usefulness of automation technology in practical laboratory scenario.

8.1 Qualitative Analysis of the Responses

Responses were collated from student participants on open-ended questionnaire (N = 24) regarding the use and influence of SLS on their learning experience and task in a practical electronics laboratory. The responses were analyzed using the method of content analysis [29]. Laboratory instructors ($N = 2$) were also interviewed to describe their opinion regarding the effect of SLS in practical laboratories: Will it be helpful to them? How will it influence students' performance?

Table 3 presents qualitative responses of student participants who filled our open ended questionnaire. These responses highlight the attitude of students towards SLS and the concerns arising regarding its usage on dependence of students on such systems. The participants have been coded P1 to P6 and their responses have been presented in the next column. For the sake of brevity, 6 responses (out of 12 received) have been described in the table. Participants reported the system to be very helpful and showed a positive response towards accepting the SLS if it is made available to them. The participants also highlighted that the system would help them learn independently at their own pace.

From the responses, it can be inferred that automation techniques such as SLS can help reduce the amount of effort students require in laboratories thereby making their work easier. There were certain concerns raised by the participants regarding how such systems might lead to overdependence on automation technology – and if it would hinder with the overall learning? While concerns like this are always there with any new technology, the upside always weights the downside. Studies [30] have shown that

Table 3. A excerpts from a few students' responses regarding SLS

Participant	Responses
P1	*"This smart learning system is easy to use and makes our work easier."*
P2	*"This will be very helpful for our learnings and will be more comfortable. It will make experiments funny and more interesting."*
P3	*"… it is very useful in lab class… Improve the durability while working in the experiment and give the best help…"*
P4	*"It will definitely reduce the efforts on our side, but won't we grow dependent on this system?…"*
P5	*"Very smart and cool system, but make sure you get all possible errors and solutions coded in the program"*
P6	*"… it is very helpful not only for the experiments but for the basic knowledge we need to understand for the experiments. … it will be fun."*

almost 78% of students face frustration in laboratories due to equipment issues and inability to understand practical experiment. Considering that automation will be able to reduce such factors leading to frustration – we posit that it will only improve the learning experience.

The findings of the qualitative study can be verified from the quantitative study that access various usability aspects and learners' satisfaction, as describable below.

8.2 Usability Testing and Hypothesis Validation

Usability testing and evaluation of SLS prototype was conducted amongst (N = 95) randomly selected undergraduate students, (Mean$_{age}$ = 18.33, SD = 0.62) comprising of 23.1% females and 76.8% male participants, see Fig. 5. All students were undergoing practical electronics laboratory sessions as a part of their coursework. The aim was to enquire what effect will SLS have on learners' satisfaction and will students find the system useful enough to be adopted as a learning aid.

Fig. 5. Usability testing in progress

The participants were asked to interact with the SLS and explore its functionalities. After interacting with our SLS prototype in practical laboratory sessions, the participants were asked to fill a 15-item questionnaire relating to Perceived Learner's

Satisfaction (PLS) scale. The participants were asked to indicate their agreement or disagreement with the questionnaire items on a 7-point Likert scale where 1 = strongly disagree and 7 = strongly agree. The questionnaire on e-learner's PLS was adopted from Wang [31] and modified for our study by introducing features for SLS. The questionnaire used learner interface (I), content (C), personalization (P), and, peer collaboration (L) to measure learner's satisfaction. Questionnaire items were modified to encompass the functionalities of SLS in terms of its interface, content and the degrees to which it would support collaboration amongst students in practical sessions. Participants willingness to continue the usage of SLS was also included.

A 4-item perceived ease of use (PEOU) [32] scale, single item perceived usefulness (PU) [32] scale and a 2-item relative advantage (RA) [32] scale questionnaire were also administered to participants after their interaction with SLS. Table 4 presents descriptive statistics obtained from the questionnaire responses.

The participants showed a good willingness to continue usage of SLS (M = 6.13, SD = 1.11), as rated on a 7-point Likert scale. In general, the users found the SLS prototype easy to use, usable and liked the learning content provided by the system.

Table 4. Descriptive statistics of students' rating PLS, PEU, PU, RA (N = 95)

	Mean	SD	Likert scale
Perceived learner satisfaction	5.86	0.13	7-point
Perceived ease of use	4.37	0.10	5-point
Perceived usefulness	4.34	0.69	5-point
Relative advantage	4.35	0.02	5-point

8.2.1 Hypothesis Validation

It was hypothesized that a positive relationship exists between learners' satisfaction and the reuse intention for SLS. To test the hypothesis, a Spearman's rho correlation analysis between the total score of PLS questionnaire items (I, C, P, L) and the sum of criterion questions was accessed, as per the guidelines provided Wang [31]. Spearman's rho correlation shows a statically significant positive relation, $r_s = 0.751$, $p = .01$, thereby validating the hypothesis.

8.3 Effect of Automation on Practical Laboratory Instructor's Task Simplification

Students in practical laboratory sessions are often dependent on instructors for getting face-to-face assistance regarding the experiments. However, in case of large batches in laboratory sessions, this face-to-face interaction often gets limited to very few student groups as the instructors often need to spend a lot of time with (sometimes) trivial debugging issues in one group. This often leaves few other groups, that require more assistance of instructors, waiting in queue for long time durations. Sometimes, these groups are not able to receive the attention of their instructor at all in a time restricted laboratory session. This causes burden on the instructors in the next practical session to help the lagging group catch up with the rest of the class. Further, as the instructor is often too busy to be available for each group at the same time, students have to rely on internet-enabled smartphones as an alternative for seeking out information regarding procedures of practical experiment being conducted by them. This causes the students to lose a lot of time searching for desired information in a time-limited practical laboratory session [33]. Since the information available on the internet is unstructured, unlike instructor's knowledge, it also distracts students from the practical experiment. All these issues lead towards lack of uniformity and quality of instructions that cause less teaching and learning satisfaction in instructors and students.

In addition to the aforementioned difficulties, issues also arise relating to lack of working equipment or proper infrastructure – often in institutes with paucity of resources. Such limitations lead towards constraints in human resources and lack of knowledge transfer capabilities for students. The interviews with instructors highlighted that the use of SLS in laboratories will be very helpful in minimizing such constraints. The following response from instructors elicits various aspects where automation technology such as SLS can be helpful:

Responses regarding assembly of circuit

> "Students often make mistakes with breadboard. They are not able to understand how to use the rows and columns properly. … I think this AR would be helpful to students in showing how they can connect the circuit properly…with a few improvements, I think this app can be useful…"

> "I think this circuit debugging is very good….it is one of them most difficult things in labs…it will really reduce the effort and save time…"

Response regarding operating test equipment

> "…. I really liked the idea of using AR for CRO. It is one of the most difficult equipment in lab. Not only students, sometimes we also find it difficult to stop the flickering…there are many faulty probes also…but showing how the CRO works will be great! If you can also add a video showing how CRO works it will be very helpful…"

Response regarding referencing

> "I think this video feature is very helpful…students mostly prefer videos over books…this will definitely help them a lot"

Response regarding SLS addressing resource constraints issues

> "Many institutes do not have the resources or large number of lab instructor that can attend all students …. This application can be really helpful in those institutes…."

> "How does it work? Does it require Internet? … I think this application will be very useful in areas where they do not have the Internet facilities….students can learn on their own…"

The instructors also highlighted that while such systems are helpful, they pointed out that there would always be a need for supervision in practical laboratories. It was also suggested that while such systems are good for addressing need of several students who require less help in laboratories, students who often find it difficult to work with experiments need continuous guidance of instructors. From these insights, it can be inferred that proving automation ability in practical electronics laboratories can help distribute instructor's workload and help them direct their attention towards those group of students that require help. For issues that are trivial in nature, SLS can help assist students with them. Thus, such systems can also save time of both instructors and students. The responses also indicate that SLS can help address issues pertaining to lack of infrastructure and paucity of human resources that hinder with teaching and learning satisfaction of instructors and students.

9 Human-Work Interaction Design Heuristics for Automation in Practical Electronics Laboratory

The study presents some interesting observations into workspace related and human-centered issues surrounding complex learning environment of practical laboratories, as depicted in Fig. 6.

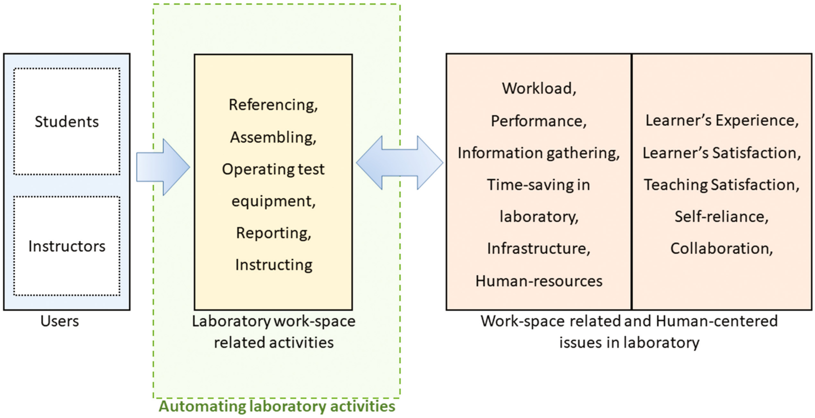

Fig. 6. Workspace and human-centered issues in practical laboratory

A useful and usable automation system should be able to address these issues in such a scenario. Based on this premise, an initial attempt has been made towards developing heuristics for designing an automated system for practical laboratory environment and are described as follows:

- **Task augmentation through automation:** Users (students and instructors) in practical laboratories are required to perform multiple tasks such as assembling of circuits, referring to laboratory manual, operating equipment and instructing. This leads towards an increase in the extraneous cognitive load of users [34, 35]. The automated system should be able to augment each of these individual tasks – thus leading towards reduced cognitive loads.

- **Designing instructional content for students:** Students mostly rely on their laboratory instructor's experiential knowledge for getting information and understanding about the practical experiment. The designed automation should encapsulate instructor's experiential knowledge (or tacit knowledge) that can be delivered to students through different modalities, such as augmented reality or voice-based instructions. Techniques like think-aloud sessions and hierarchical task analysis can be utilized for capturing and segmenting instructor's knowledge while they perform an experiment.
- **Mode of instruction:** Voice-based instructions were reported to a useful feature for independent learning that takes place individually or outside of the laboratory sessions. During laboratory sessions, students preferred visual and text-based instructions. Students also suggested including more language options for voice-based instructions in the application as they feel more comfortable getting inputs in their native language.
- **Inbuilt embedded content:** The AR application should be a stand-alone fully functional medium of instruction for students without requiring the need to connect to the internet for downloading content data. This ensures the usability of AR application in places without the internet connection.

10 Future Work

The paper presents a step towards designing smart learning systems capable of reducing students' workload and improving their engagement while learning in practical laboratory. The system presented further requires summative assessment utilizing robust prototypes with well-designed content. Such assessment will be useful in understanding aspects like quality of training and level of information recall by students. In addition, assessments are also required to be carried out in terms of understanding the effect of the proposed system on instructor's workload.

11 Conclusion

The study presents a novel automation tool, SLS, for use in practical electronics laboratory session utilizing the concept of smart objects [6] and AR. It shows that such automation techniques can help create engaging learning experiences for students and at the same time reduce the burden of laboratory instructors. The prototype presented in the study is based on the idea of distributed intelligence that helps automate several tasks and augment students' ability to gather contextualized information and instruction. The study also shows that it is possible to augment and automate existing laboratory objects, such as breadboard, and embed intelligence into it to help provide better instructional capabilities to the students.

From the study, it can be inferred that creating automation in complex learning environments such as educational practical electronics laboratories also help save time of both instructors and students and make learning easier.

Overall, the paper contributes towards understanding design of a system that supports users through the use of technology in a complex work context of educational laboratory and is concurrent with the theme of improving human-work interaction design.

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Testing Augmented Reality Systems for Spotting Sub-Surface Impurities

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Abstract. To limit musculoskeletal disorders we are working towards implementing collaborative robotics in strenuous or repetitive production work. Our objective is to evaluate augmented reality (AR) devices for assisting in near-distance tasks before applying and testing the displays in the context of human-robot collaboration in a production setting. This chapter describes the hardware setup and procedure for testing AR systems for showing sub-surface positions of foreign elements in an opaque mass. The goal is it test four types of setup in terms of user accuracy and speed, the four setups being a head-mounted see-through display, a mounted tablet-based see-through display, top-down surface projection and overlays on a static monitor. The experiment is carried out using a tracked HTC Vive controller with a needle attachment. Precision tasks are performed by 48 participants and each display is evaluated using the System Usability Scale and the NASA Task Load Index.

Keywords: Augmented reality · Usability testing
Human-robot collaboration

1 Introduction

Repetitive actions at work can cause musculoskeletal disorders (MSDs), whether it is due to non-neutral body posture in an office environment or repetitive motion patterns on a production line [7]. Introducing human-robot interaction (HRI) and augmented reality (AR) can assist in strenuous physical tasks and present data in a seamless and non-obstructive ways, improving work flow and employee welfare by addressing and reducing causes of MSDs.

The main context of this study is cellular meat production in which employees stands on the meat processing line, performing one or few tasks each on every piece of meat. This type of work involves lots of repeated strenuous movement. The theories and experiments will, however, pertain to creating an efficient and sustainable workplace in the general sense, regardless of the type of working environment.

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The robots will act as assistants, aiding in production by pointing out details such as impurities in the meat before moving on to human-robot collaboration where the robot will aid in physical tasks, such as flipping over the meat or bending it for easy trimming and deboning of pork bellies. The overall goal is safe and efficient communication and collaboration between human and robot, aided by AR technologies.

Human-robot collaboration is an emerging field within HRI, as can be seen from dedicated workshops and track at HRI conferences [5]. A particular challenge in HRI is the asymmetrical communication capabilities of the human and the robot partner, creating a need for a multi-level coordination between them to achieve successful interaction: The communication level, the physical level, the social level and the task level, the communication and physical level being the main focuses of this experiment.

The objective of this experiment is to evaluate the utility of AR systems for close-distance tasks relevant to the meat production context before applying them to human-robot communication. In this case the task is finding impurities in pork bellies in the context of cellular meat production. In more general terms this means showing positions in space within and opaque mass. The display types used are an arm mounted see-through display, head-mounted see-through display, top-down surface projection and overlays on a static monitor.

We propose a method of helping workers maintain a healthy posture implicitly while directing their attention towards a target. One way of doing this is to use the arm-mounted display and placing it in a position that would require the user to correct their posture in order to properly utilize the display. This poster describes the procedure for an upcoming preliminary study in AR systems, the results of which will be used for further study in HRI.

2 Related Research

The communication from the robot to the human in the manufacturing context will involve conveying the details pertaining to current task, and for this study we seek to utilize the AR for this purpose. Elia et al. proposed a 4-step model for preliminary evaluation of AR devices to be applied in specific manufacturing processes, starting with a multi-criteria analysis for ranking the most effective AR systems for the purpose. This involves considering hardware and output modalities as alternatives and evaluating them in terms of reliability, responsiveness and agility using pair-wise comparison followed by analysis and ranking of the AR alternatives. Elia et al. categorize AR hardware as head-mounted displays (HMD), handheld devices, projectors and haptic force feedback systems [3].

Kruijff et al. classified potential perceptual issues with AR between environment, capturing the environment, augmentation, display device and user while pointing out whether they are predominant with particular display types: Head-mounted displays (video see-through or optical see-through), handheld mobile devices or projector-camera system (stationary or mobile) [6]. For this experiment each display type is evaluated.

Schwerdtfeger et al. go into depth describing the projected AR, specifically using lasers, pointing out the cons of HMDs; small field of view, limited resolution, swimming effect, multiple focus planes and eye fatigue. While laser-projected AR can address some of these issues it is limited to displaying information on surfaces in the environment and the image must be pre-distorted to compensate for geometric surface distortion, whether the projector is head-mounted or stationary. In addition, it also introduces the challenge of occlusion by either the user or other objects [8]. In order to avoid surface distortion for this test an even and level surface is used.

Studies have shown that depth perception while using AR is affected by a bias; subjects tended to underestimate distance in AR when they are projected at less than 23 meters distance to the user, after which the bias switches to overestimation [10]. Singh et al. estimated a distance judgment error of -5.5 cm at most for distances less than 50 cm [9]. However, this was tested in 2010 using an nVisor ST display, so modern see-through displays may lead to different performances. Augmented reality has previously been used to imitate x-ray vision: Avery et al. emphasized that when showing the content beyond the surface using an graphical overlay it should include an edge overlay representing the surface as a depth cue, so the object does not appear to float in front of the surface [1].

3 Setup

Spotting sub-surface impurities is tested using a tray of sand where the impurities are virtually projected beneath the surface using each of the AR displays. Between test sessions the surface of the sand is smoothed out to hide the previous entry points.

The main component for measuring the user's performance is a six degree of freedom tracking space. For this an HTC Vive setup is utilized: One of the controllers is used to point to the virtual impurities with a needle mounted to it. The other controller is used to confirm when they are touching the impurity. This is to prevent shaking the dominant hand when confirming a target. The setup for the test is show in full in Fig. 1.

In order to display the targets on the mobile AR devices, the head-mounted display and the see-through display, the PC that runs the software and tracking also acts as network host while the mobile units act as clients and receive target positions as the tests are running.

The position and orientation of the sand's surface are calibrated using the needle mounted to the Vive controller along with a tracking guide printed on paper. This is also used to align the positions of the printed tracking markers used for the mounted see-through display and the HMD.

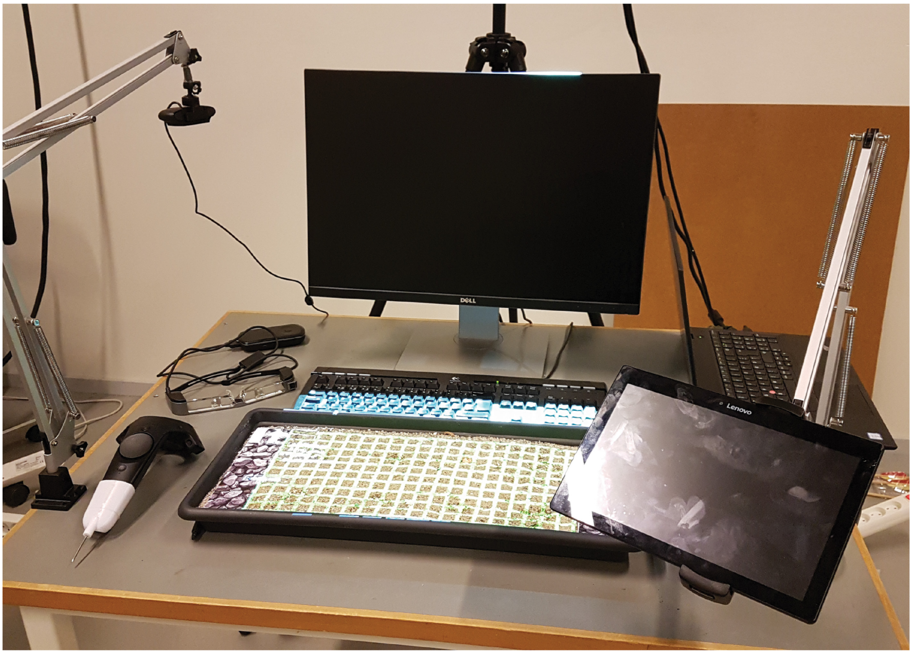

Fig. 1. The full setup for the AR test.

3.1 Mounted See-Through Display

The concept of the arm-mounted display is that it should be held by a robot arm, allowing it to orient the screen towards the impurity, thereby guiding the attention of the user. However, for this test will be mounted to a manually adjustable mount. The see-through display is tracking the tray and the targets using the Vuforia AR framework running in the Unity game engine compiled to Android.

The tracking markers are printed on paper and are placed at either end of the tray so that they are not obscured by the participants' hands during the test. When positioning the screen for the participant, its camera is pointed toward the tracking opposite to the participant's dominant hand, making it unlikely for them to reach over it.

The display is an Android tablet showing the back-facing camera feed where the impurities are shown as a red sphere of 10 mm diameter projected into the sand. In addition, this view will feature an overlay aligned with the surface of the sand to assist in depth perception similarly to [1]. This setup is illustrated in Fig. 2.

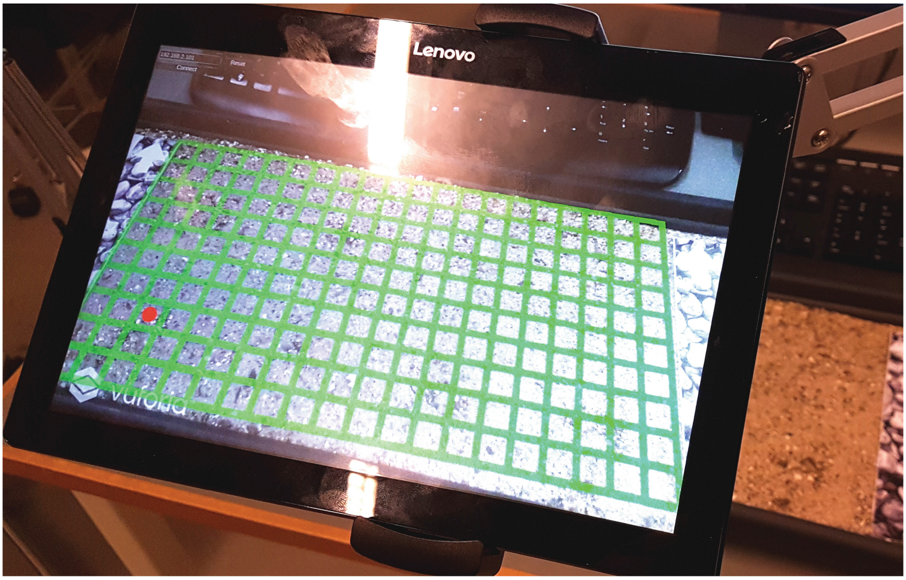

Fig. 2. The arm-mounted see-through display setup with impurity projected into the sand as a red dot assisted by a grid overlay aligned with the surface. (Color figure online)

3.2 Head-Mounted Display

For testing see-through head-mounted displays an Epson Moverio Bt-300 is used. These are shown in Fig. 3. Similarly, the AR glasses are running using and Android-based mobile unit acting as a client, receiving target positions from the host PC running the tracking space while tracking its own position using Vuforia and Unity.

The position of the impurity are shown on the glasses in a similar fashion to arm-mounted display while also utilizing the overlay grid. However, due to the limitation of not being able to track the gaze of each eye of the participants and thereby determining the convergence point, attempting to render the position in stereo would leave the user with difficulty focusing. Therefore, the target is rendered as a 2D overlay similarly to the see-through display, and when analyzing the data the participants' dominant eye must be taken into consideration.

3.3 Top-Down Projection

The top-down display is implemented using a projector mounted to a tripod using a custom 3D-printed mount. It projects the position of the impurity in the surface of the sand using a 10 mm red. Because the projection does not allow for perspective rendering like the see-though display and the HMD, the red dot is rendered along with a number indicating the depth of the impurity.

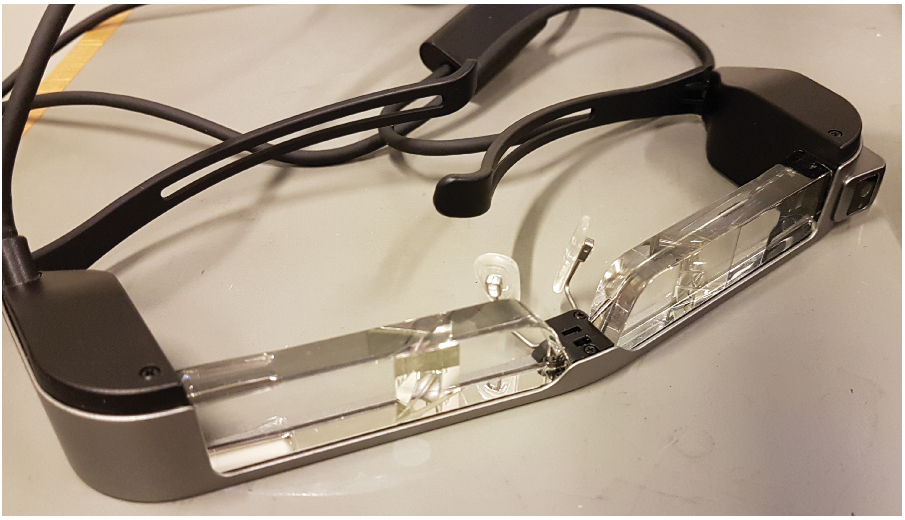

Fig. 3. The Epson Moverio Bt-300 glasses used for the experiment.

Fig. 4. The projector mounted for the top-down projection setup.

Fig. 5. The grid projected onto the sand with the targets shown as a red dot. (Color figure online)

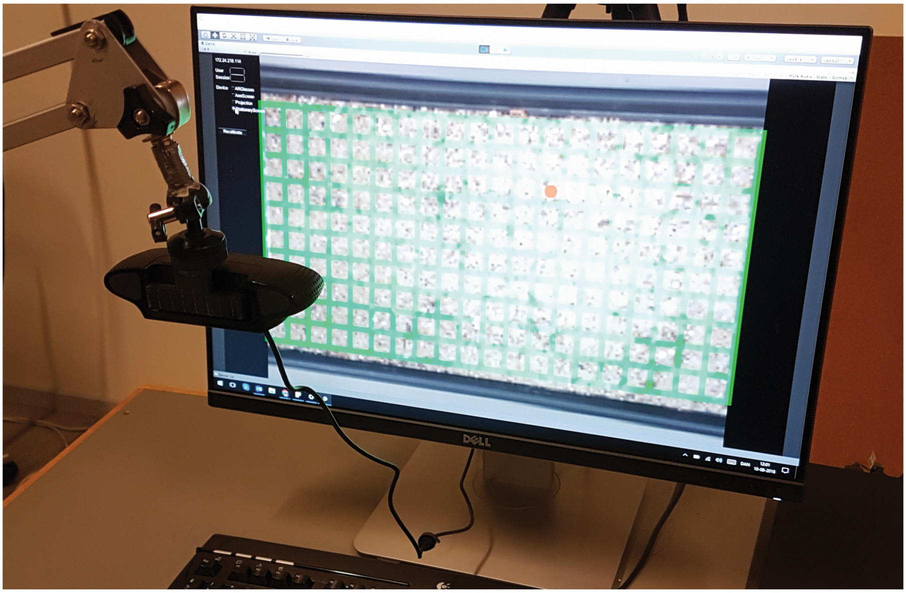

Fig. 6. The monitor and top-down camera.

The camera used is a Logitech C920. During the calibration of the setup, the position and orientation of the camera is calibrated using the needle on the Vive controller. The mounted projector is shown in Fig. 4 and the top-down projection is shown in Fig. 5.

3.4 Monitor

The static display involves a monitor positioned at the opposite side of the tray to the user showing a top-down camera feed of the surface of the tray while showing the position of the impurity, similarly to the top-down projection. Similarly to the mounted see-through display the user will be looking at their hands and the impurities through the monitor. This setup us shown in Fig. 6.

4 Procedure

At the beginning of each test the participant is introduced to the subject of the experiment, the setup and the tasks they will be performing. User information gathered before the test starts will include sex, age, height, dominant hand and dominant eye.

4.1 Pointing Tasks

The experiment is run with 48 participants. This is to counterbalance the order in which the participant tries the display in order to counter bias or possible confusion at the start of the experiment, either pertaining to the pointing task or the questionnaires between test sessions. Four systems yield 24 possible combinations and going through them twice will yield an acceptable number of samples for analysis.

For each AR system the participant must point to 24 impurities projected into the sand by the AR display. They will do this by pointing into the sand using a needle-like object mounted to an HTC Vive controller in their dominant hand, shown in Fig. 7. The participants are instructed to point as quickly and precisely as they can with the goal of getting the tip of the needle as close to the center of the impurity as possible. To confirm that they are pointing at the impurity the participants must press a button on the controller in the non-dominant hand while the needle is in the target before moving on to the next target.

In order to prevent participants accidentally confirming two targets in succession, new targets appear with a one-second delay. This also allows the participants to retract their hand to a neutral position before searching for the next target.

The body of sand is 25 cm wide, 55 cm long and 5 cm thick. Impurities in the meat most often occur on the surface, but can occur as deeply as 3 mm under the surface. The impurities will be projected at 24 predetermined position distributed between three layers, two row and four columns in order to test the effectiveness of the systems at various depths and in relation to dominant hand. The layer will be at depth 0 mm, 5 mm and 10 mm, and the layers and columns will be spaced by 10 cm on a square grid.

Fig. 7. The needle used for the experiment, made from a 3D printed mount and a nail and attached with a bolt in the loop designed for the wrist strap.

4.2 Measurements

The data gathered for each target in the experiment will be the distance between the needle tip and the center of the target as well as the time between target spawn and user confirmation. The distance measurement will include the distances on the X, Y and Z-axes as well as the direct distance.

In addition to the data gathered from the software, between testing the displays the participants are asked to fill in two questionnaire regarding their user experience: A System Usability Scale [2] and a NASA Task Load Index [4] are used to evaluate each of the AR displays in terms of user acceptance and ease of use.

5 Conclusion

This chapter presents the hardware setup and procedure for a preliminary comparative study of the usability of a collection of AR displays for showing subsurface impurities in meat by having the participants point to targets inside an analog made of sand. The goal is to determine suitable interfaces for augmented meat production while being able to implicitly correct the worker's posture while directing their attention towards the target. To this end, we expect that the collaborative robot arm will show the greatest impact, as it allows for dynamic display adjustments in relation to the workers posture.

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ESISTE: Supporting Inclusion of Students with Special Needs in Mainstream Classrooms

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Abstract. This chapter presents the outcomes of the first stage of ESISTE (Expert System Interaction Structured To Education), an interdisciplinary research project aimed at designing and developing an interactive system for the management of ICF-CY classification (International Classification of Functioning, Disability and Health – Children and Youth) in primary, secondary, and higher education levels in Italy. The goal of the project is to enable the inclusion in the education system of students with special needs involving in the process their teachers, family members, close friends, healthcare professionals and other stakeholders.

Keywords: ICF classification · ICF-CY · Functioning · Disability Special needs · Health · Education · Collaboration · Teaching Human Work Interaction Design · Mainstream classrooms

1 Introduction

The International Classification of Functioning, Disability and Health (ICF) is a classification defined by the World Health Organization (WHO) in 2001 for providing a standard language and framework to describe health and health-related components of well-being (e.g., education, labour) [1]. In 2007, WHO published a further version of ICF specific for children and youth, called ICF-CY, from birth to 17 years of age. The ICF classification uses three main codes to describe an individual: Body functions and structures, activities and participation, and environmental factors. The ICF-CY classification is in use in Italian education system since 2007 but there is not yet a complete and widely-used interactive system to support its use and what is more important, there are no tools to support the collaboration between all the stakeholders involved in the student's evaluation. Healthcare professionals and teachers most of the times use different systems for ICF management (mostly paper based) and in order to exchange their views on a student they need to physically meet and/or send digitalized documents and discuss them over the phone or via email. One of the reasons why ICF-CY classification is adopted in educational systems is that it supports the stakeholders to identify special needs in students.

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In literature, a number of studies discussing the inclusion of special needs students in mainstream classrooms (e.g., [2–5]). The main idea is that inclusion may help the students in integrating themselves in society and in dealing with their difficulties and eventual disadvantages.

This chapter presents the outcomes of the first stage of ESISTE (Expert System Interaction Structured To Education), a National project that aims at exploiting ICF-CY potentials for facilitating the inclusion of students with special needs in mainstream (i.e. non dedicated)classrooms. To this aim, the authors designed and developed an interactive high-fidelity prototype for using the ICY-CY classification by empowering all stakeholders; according to the authors' analysis, teachers, clinicians, and system administrators are the three user groups that have to be considered. Given the deep diversity of these three classes of users, the Human Work Interaction Design (HWID) discipline [6–9] helped in analyzing the user and functional requirements addressing their needs.

The chapter is organized as follows. Section 2 presents the ICF-CY classification. Section 3 illustrates the ESISTE Project. In Sect. 4, the design and development activities for the creation of an interactive prototype are presented, while in Sect. 5 the results of usability evaluation are illustrated and discussed.

2 ICF-CY

The International Classification of Functioning, Disability and Health [1] defines a classification for describing the state of health of people in relation to their community environments (social, family, work context) for grasping the difficulties due to the socio-cultural context of reference that can cause disability. The International Classification of Functioning, Disability and Health - Version for Children and Adolescents (ICF-CY [10] provides precise descriptions of the health status of children and youth. As a derived classification, it includes further detailed information on the application of the ICF when documenting the relevant aspects of functioning and health in children and youth.

The ICF-CY shares the same classification properties with its reference classification the ICF and offers a common and standardized language to describe and measure health and disability up to eighteen years of life. This classification system helps clinicians, teachers, researchers, administrators, policy makers and parents to identify the health, development and education children and youth's needs.

In practice, the ICY-CY is a model that describes different children and youth's levels of ability in functional areas, such as learning, mobility, communication, self-care, social relationships, and other similar characteristics. It encourages the development of interventions that targets at the development of individual' functioning in relation to their environment and personal conditions.

According to the model depicted in Fig. 1, the ICF-CY functioning codes can be classified in (i) body functions (i.e., physiological and psychological), (ii) body structures (i.e., anatomical parts such as organs, limbs and their components), (iii) activities (i.e., execution of a task or action), and (iv) participation that is the involvement in life situations such as learning, self-care, communication, relationships or participation in school activities [10]. Contextual factors interact with the individual with a health condition and determine the level and extent of the individual's functioning. Environmental factors are extrinsic to the individual and can related to the social support, relations, the attitudes of the society, the legal system. Personal Factors (e.g. gender, race, age, lifestyle, habits) do not have categories within the ICF-CY, and open to the subjective view of the users [10].

3 The ESISTE Project

The ESISTE (Expert System Interaction Structured To Education) Project has as main goal to identify the difficulties related to ICF model complexity of use. The need is to simplify the use of ICF model as a tool for supporting special needs students' inclusion. The idea is to create an interactive system to be used in Italian schools in all of its levels of instruction: primary (elementary schools), secondary (middle school) and higher education (high school). The system would be aimed at understanding which inclusion approaches to apply with students with special needs on the basis of body functions and structure, activities and participation, environmental and personal factors, and other information related to the severity of their disability and their age.

The seven main objectives of the ESISTE Project are:

1. to analyze, in the various context diversified by instruction level, which types of approach are more favorable for the students' integration in relation to bodily functions, activities and participation, environmental factors and the type of disability;
2. to study how to retrieve information related to contextual factors that act as facilitators in the process of inclusion of the students in classrooms;
3. to adapt the ICF classification in the perspective of a guided and finalized use to the proposition of didactic paths, educational tools or integrative activities;
4. to realize a dynamic and functional tool, which can act as facilitator and catalyst of the individual's attention and at the same time as data detector by the teacher (i.e., the definition of the expert system) using the classification scheme ICF-CY;
5. to use the expert system for detecting needs and proposing inclusive strategies with a view to improving the performance of the student in the school environment and in the social sphere;
6. to propose an innovative and accessible man-machine interaction modality as a facilitator in the breaking down of barriers in situations of limitation of activities and participation;
7. to implement a network approach, which can involve not only the school environment but also all the other stakeholders that during the life of a disabled person come into play.

The ESISTE system will be used by a network of stakeholders – a Community of Interest [12] – constituted by all the people who are involved in the life of a student with special needs, with different roles, in different times and in different ways, not only related with the school environment. The use of a shared tool would help in designing an ad-hoc education plan focused on inclusion and education and will enable family

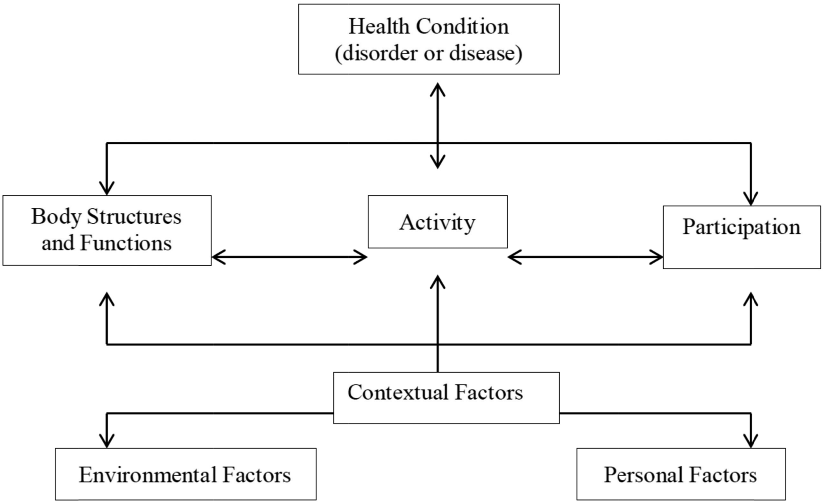

Fig. 1. Interactions between the components of the ICF-CY Model [11].

members, healthcare assistants, close friends and teachers to collaborate. Collecting evaluations based on the ICF classification and allowing the stakeholders to compare the different evaluations on the same students will help them to consider all the different points of view on the issues that can affect the student's life at school and her/his learning process.

The final goal of the ESISTE Project aims at designing a shared tool that provides a screening for pupil inclusion according to ICF-CY parameters and able to support integrative teaching actions for the formulation of functional diagnosis and individualized educational plans. The idea is to simplify the use of the ICF-CY dropping it into the school realities of different orders and degrees through the use of an usable expert software system accessible according to the Italian Stanca Act[1] (AA according to the W3C standard). Through a set of auxiliaries and integrative strategies, this shared virtual environment allows teachers, parents and clinician specialists to follow pupils with special needs during their scholar paths, from primary school through graduate school. The result is the definition of guidelines to use for the implementation a real life plan that takes into account all ICF aspects from the body condition to the contextual factors. Teachers, parents and other collaborators can actively cooperate in the design of these paths with the aim to achieve better performance in different areas of their sons and pupil's life.

This chapter presents the outcomes of a first stage of the ESISTE Project, aimed at participatory designing a prototype of the user interface for the interactive system. Particularly, the authors capitalized on their experience in Cultures of Participation, Participatory Design and Collaboration at large (e.g., [13–17]) and focused their work

[1] The Italian accessibility law: Stanca Act http://www.agid.gov.it/dm-8-luglio-2005-allegato-A.

on the Human Work Interaction Design aspects of the Project: this chapter presents in fact the participatory design approach and the usability evaluation of a prototype.

4 Design and Development of ESISTE Prototype

In the definition of the requirements' specification the authors considered two main aspects: the profiles of the users who will use the system and the necessary functional requirements, which strictly depend on the type of user. For this first stage of the ESISTE project, three main types of users have been identified and have been involved in a participatory design process and in further usability evaluations:

- Teacher: Differentiated by education level (primary, secondary and higher education), they know the student, her/his special needs and education history so far.
- Clinician: Typically, a neuropsychiatrist, knows the student and starts to fill the ICF checklist creating a subset of parameters that are suitable for her/his profile. The clinician is usually the one who plays the facilitator role in managing the relationships with all the stakeholders involved.
- System administrator: Typically, a technician who works regularly with inclusive technology and contributes to the removal of barriers.

Several meetings with one or more representatives of these three user groups have been organized and they have been invited in discussing about expected metaphor and style of interaction and also in the preliminary design of a paper prototype. The outcomes of these meetings allowed to proceed in the preparation of a first interactive vertical prototype that has been tested with a predictive method. The results of this first evaluation led to the development of an improved prototype that has been tested involving representatives of the actual final users. A screenshot of the prototype is depicted in Fig. 2. The system allows to assign several evaluators to each student and all evaluators are able to compare their ratings with the ones of the other evaluators (see Fig. 3).

Fig. 2. A clinician accesses the system for rating some students.

Dott. Paolo Fusari - Visualizza Valutazioni

Nome soggetto: **Marcella Baglio**
Valutatori coinvolti:
Fusari Dott. Paolo
rossi marco

D - Attività e Partecipazione

Codice	titolo_campo	Performance	Capacitá
d110	Guardare	0 0	N N
d115	Ascoltare	N 0	N N
d120	Altre percezioni sensoriali intenzionali	3 N	N N
d130	Copiare	N 0	N N
d131	Imparare attraverso le azioni con gli oggetti	N 0	2 N
d1312	Imparare attraverso azioni che mettono in relazione due o più oggetti tenendo conto delle loro caratteristiche specifiche	N 0	N N
d1313	Apprendere attraverso il gioco simbolico	N 0	0 N
d1314	Apprendere attraverso il gioco di finzione	N 0	N N
d132	Acquisire informazioni	3 0	N N
d133	Acquisire il linguaggio	3 0	N N
d1330	Acquisire singole parole o simboli significativi	3 N	N N
d1331	Combinare le parole in frasi	N N	N N
d1332	Acquisire la sintassi	N N	3 N
d134	Acquisire un linguaggio aggiuntivo	N N	3 N
d135	Ripetere	N N	N N
d137	Acquisire concetti	N N	N N
d1370	Acquisire concetti di base	N N	N N
d1371	Acquisire concetti complessi	N N	N N
d140	Imparare a leggere	N N	N N

Fig. 3. A teacher accesses a students' evaluation and compares his ratings with the ones of the clinician.

5 Usability Evaluation

The heuristic evaluation method [18] has been applied to test the usability of the first prototype. Four usability experts have been involved in the evaluations. For the evaluations the authors applied the ten Nielsen's heuristics: (1) Visibility of system status; (2) Match between system and real world; (3) User control and freedom; (4) Consistency and standards; (5) Error prevention; (6) Recognition rather than recall; (7) Flexibility and efficiency of use; (8) Aesthetic and minimalist design; (9) Help users recognize, diagnose, and recover from errors; (10) Help and documentation. The Nielsen's severity ranking [19] has been used to classify the usability issues: (1) Cosmetic problem only; (2) Minor usability problem; (3) Major usability problem; and (4) Usability catastrophe. The results of the heuristic evaluation highlighted the need of a deep improvement of the prototype. Figure 4 shows the number of violations for each heuristic.

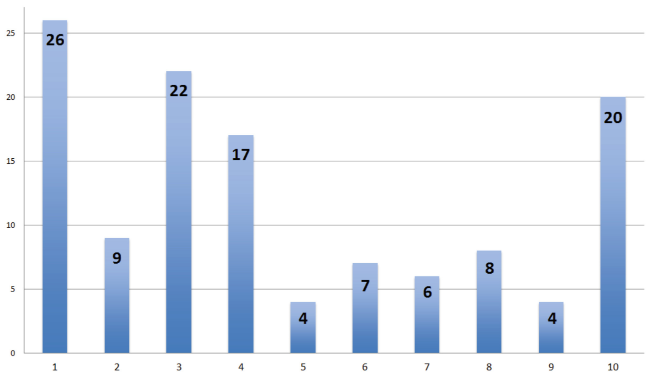

Fig. 4. For each of the 10 Nielsen's heuristics the chart shows the number of violations detected during the usability analysis.

The improvements have been illustrated and further discussed in a meeting that involved both the developers and the final users' representatives and informed the preparation of the second interactive prototype that has been tested with the final users. The authors invited to the participatory design activities 7 people, all ICF expert users, who usually collaborate in Italian schools taking care of several students with special needs: 5 teachers (working at different education level), 1 clinician, and 1 system administrator.

The participants have been provided with an initial demographic questionnaire aimed at knowing better their profile and skills in using interactive systems for work or personal matters. The results are presented in Fig. 5.

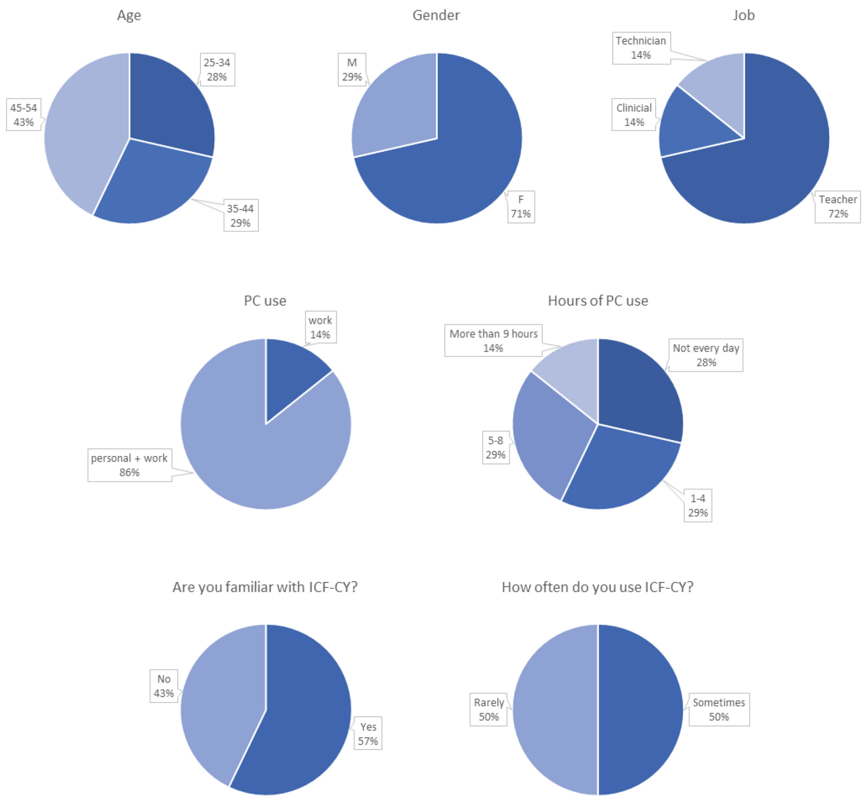

Fig. 5. The results of the initial demographic questionnaire.

Different tasks have been assigned to the participants on the basis of their role. The system administrator has been asked to register the other participants as evaluators and a student in the ESISTE system. The clinician has been invited to complete the student evaluation by using the ICF classification tool. The teachers have been asked to complete their own evaluation of the student and to compare their evaluation with the ones registered by other colleagues. To conclude the user test the participants were asked to fill in two final questionnaires, SUS (System Usability Scale) [20] and CSUQ (Computer System Usability Questionnaire) [21], and to respond to two open-ended questions. SUS is a usability questionnaire very broadly used, especially in industry that can return reliable results even when administered to small sample of users. CSUQ is a questionnaire developed by IBM and is mostly focused on measuring the satisfaction in using the application or tool under evaluation.

The SUS questionnaire results are presented in Table 1. The average is 67.14 and is slightly below the average as defined by the creators of the SUS method (that is 68).

Table 1. The results of the SUS final questionnaire.

Participant	SUS
System administrator	70
Clinician	60
Teacher 1	72.5
Teacher 2	77.5
Teacher 3	67.5
Teacher 4	62.5
Teacher 5	60
Average	*67.14*

To interpret the CSUQ questionnaire results, these four factors were used: System Usefulness (SYSUSE), Information Quality (INFOQUAL), Interface Quality (INTERQUAL), and Overall Satisfaction (OVERALL). The minimum value for the factors is 1 and the maximum is 5. The results, presented in Table 2, show that the system has been evaluated above the average for all the four factors considered.

Table 2. The results of the CSUQ final questionnaire.

Participant	SYSUSE	INFOQUAL	INTERQUAL	OVERALL
System administrator	3	2.8	3.5	4
Clinician	3	3.3	3.5	3.1
Teacher 1	3	3.7	4	4
Teacher 2	4.5	3.8	4	4.1
Teacher 3	3.5	3.7	3.5	3.9
Teacher 4	4	3.3	4	3.1
Teacher 5	3	3.2	3	3.2
Average	*3.4*	*3.4*	*3.6*	*3.6*

The first of the two open-ended questions was about the comparison of this system with other existing systems for ICF classification. None of the participants is familiar with other systems. The second question asked the participants to describe what and how the system should be changed to better meet their needs and expectations. Six out of seven participants responded to this question and asked the following enhancements: a help tool for the ones who are still not familiar with the ICF classification, and an online chat tool and sticky notes to discuss the evaluations in real time and asynchronously with the colleagues.

6 Conclusions and Future Developments

This first stage of the ESISTE project was focused mainly on the participatory design of a prototype of the system. Final users of the system (clinicians, technicians and teachers) were involved to a participatory design process that informed the authors about the ICF-CY classification and its adoption in primary, secondary and higher education in Italy. After this first stage of the project, the prototype will be further developed leading to the creation of a full system to be tested on large scale in different schools and with real use cases. New users' representatives will be involved, like family members and close friends whose contribution will be fundamental in the correct implementation of the ESISTE system and process of collaboration.

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Exploring Potential of Traditionally Crafted Textiles to Transform into e-Wearables for Use in Socio-cultural Space

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Abstract. With digital wearables becoming a popular trend, this paper explores understanding user behavior and acceptance of e-textile prior to designing a textile wearable that has roots in Indian culture. The potential of traditional textile designs to become part of the emerging e-textile wearable scenario is crucial in order to preserve design traditions and also to prevent redundancy of crafts skills due to advancement of technology. In order to explore attitudes and acceptance of embedding traditional design elements by the younger generation of e-wearable adopters, a study was conducted in India, wherein prototypes were tested for their potential and acceptance of becoming interactive communication aids in the social space. A hand-embellished scarf with micro RGB LEDs named as *Aster*, has been prototyped with traditional motifs local to India so as to gather response for the capacity of e-textiles to aid non-verbal communication. The perception of respondents towards acceptance of Aster based on Technology Acceptance Model was analyzed. Thirty users took part in the preliminary study to understand user behavior and sixty users took part in the subsequent study pertaining to assessment of the digital wearable scarf. The analysis of responses reveal high acceptance towards textile wearables for daily interactions and improved self-expression. Usability assessment indicates positive experience of users while using Aster for daily interactions in specific social contexts. The inferences drawn from the study are encouraging and indicate optimism for inclusion of traditional craft design elements in digital textile wearables. The results provide optimism for craft makers to expand their traditional skills towards embedding electronic components thereby ensuring relevancy of traditionally skilled work without having to face work redundancy due to technology advancement.

Keywords: Wearable · Non-verbal expression · Acceptance
Usability · Behavior

1 Introduction

Textiles have a rich history, lineage and evolution in terms of their designs. They carry cultural traditions within their folds. Like every other mass manufactured product, textiles in India have a wide range of colors, textures, motifs, patterns and materials that are unique and contextual to Indian cultural milieu. Throughout centuries one can find

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traditional motifs, borders, embellishments, weave pattern and the like, being retained and continued with a sense of pride in India's visually rich ethnographical and cultural landscape. Textiles have been embedded with colors and motifs since prehistoric times to celebrate, protect or symbolize cultural beliefs [1]. They have been largely inspired from flora, fauna, architectural forms and everyday things. Entwined with the continuation of traditional designs are lives of the skilled craft makers for whom textiles are a source of work and livelihood. Technological advancements, like elsewhere, has cut short avenues for growth for the craftsperson unless one is open to re-training and acquiring techniques that are more machine oriented [21]. The threat of being displaced by electronics and machines is more true of craft makers who are involved in creation of textiles with patterns, colors, motifs, laces, weaving, stitching, etc.

How can designers ensure the continuity of skills and livelihood while embracing technology is the question that motivates the exploratory research study in this paper. Not many Indian researchers have explored and published work pertaining to the impact of or potential of e-textiles emerging in India. Of the few works that can be cited are those of Designer Gaurav Gupta who created LED *saree-gown* in association with IBM for Vogue Women of the Year Award ceremony 2017 [17]. Designers Pankaj and Nidhi created LED embedded collection *Geometrica* showcased at Wills India Lifestyle Fashion Week 2012 [18]. Although these designs are unique in terms of fashion statements and couture wear, they may need to be enriched so as to become a part of users' daily lifestyle and also augment user needs, such as for example communication, protection and facilitating new forms of social interaction that open up due to social networking. To remain relevant fashion couture will need to become part of the emerging internet of things (IOT). The very use of e-textiles will open up new and interesting applications. The question facing the researchers is - Will such new applications be readily adapted by young Indian generation? Will the young Indian population, which is comfortable with today's smart devices, accept new e-textile applications, such as, for non-verbal communication or starting a silent conversation with an unknown person in a public space? Will the early adopters of innovation also accept textile designs loaded with traditional signs and symbols such as motifs and patterns? We posit that India is a culturally diverse country and since users have diverse preferences, designing culture specific e-textile products could enrich the textile market segment for both the Indian and the global markets. In particular, it would offer ways and means to integrate traditional textile craft artisans' work with the promising new markets that are emerging out of embedding textiles with electronic capabilities.

In Europe, extensive research studies are being conducted to adopt designs for e-textiles. Bubelle dress by Philips [14], is based on emotion sensing and changes colors in response to physiological changes of user's body. Galaxy dress [15] is world's one of the largest wearable display with 24000 color pixels embroidered on silk. Nemo dress [16] comprises 2000 LEDs creating a retro-futuristic couture dress.

With digital technology becoming part of daily lifestyle [2], textiles have become an interesting and useful medium for embedding, collecting and transmitting information in several domains such as health, sports, military, security, interiors, clothing, automobile, etc. E-textiles – which are essentially textiles with embedded electronics, will find interesting applications through artificial intelligence and Internet of Things (IOT) connected technologies by augmenting user lifestyles. E-textiles have untapped design potential for increasing their usability as mediums for interactions and communications in every day social space. Designing e-textiles or textile wearables will involve aspects such as usability, communicability and intractability for the wearer as well as for others in the wearers' environment, apart from functionality (Fig. 1).

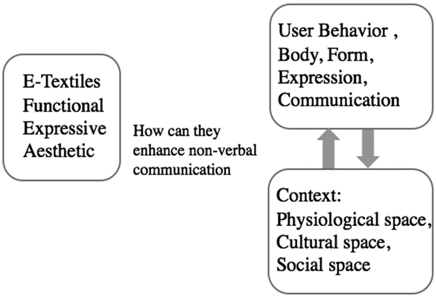


Fig. 1. E-textiles and social space as studied;

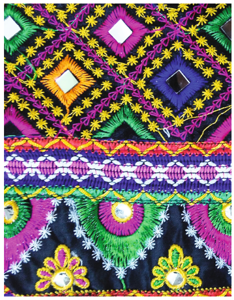


Fig. 2. *Lambani* embroidery design

The research reported in this paper finds its inspirations in the elaborate textile crafting traditions of India and an inquisitiveness to merge it with smart materials for context specific applications in the social space. Researchers believe that doing so could lead to preservation of hierarchical crafts and merge them with technologically advanced e-textile trends of the future. The idea is to embed electronics seamlessly by reinforcing traditional design elements such as motifs, patterns, colors with smart materials to enhance the functions of a static traditional textile. Figure 2 represents a traditional *Lambani* embroidery design and potential of incorporating embedded electronics neatly within the motifs.

2 Wearables and the Socio-cultural Context

Dolan and Holloway in their research on traditional garments of Europe mention that textiles are cultural transmitters as they are emotionally stimulated due to several traditions associated with crafting, community bonds, admiration of skills, their closeness with skin and memories involved [3, 4]. Textiles thus become a natural extension of self. Textiles have been known to influence the moods and emotions of the wearers and the viewers in a social space [5]. Traditional textiles comprise of several motifs that protect or symbolize cultural traditions [1]. Since, textiles through their colors and motifs communicate traditions, the researchers hypothesize that textile wearables of present times could enhance social intelligence [8] of the user and collective intelligence of the space through non-verbal communication. For instance, the colors and motifs could become flowing fluid dynamic elements instead of static patterns, to enhance self-expression through nonverbal signaling so-as-to communicate with like-minded people in a social setting, i.e., formal or informal get together.

Users are specific, guarded and selective in terms of how they communicate and express themselves in a social space which in turn depends on the context. Similarity in traits, attitude, behavior govern individuals likes and dislikes and how social groups are formed [6, 7]. Proximity principle mentions how individuals build relationships through sharing beliefs, experiences and social exchange [6, 7]. If textiles could enhance social facility, social cognition and synchronicity [8] with known and unknown individuals around non-verbally, this could lead to collective intelligence of the users' social space. Social space in this research is believed to be usable for not only socializing and leisure activities but also is a 'formal and informal working space'. It is the belief that social space in India has always been utilized in an interactive informal way when Indians of different age groups interact with each other in different contexts, such as – in school, at college, at work, while commuting, at a social gathering, at a park, and so on. In such socio-cultural space, interactions, apart from being polite, also accomplish community level work by reinforcing cultural beliefs and practices. This form of work though differing from formal work for money in an office or industry, does generate and contribute value notionally.

In this paper, we first attempt to understand user behavior of young Indian generation communicating with each other with reference to the nature of boundaries that they create around themselves based on sense of privacy limits, comfort levels and emotions they experience with different categories of individuals in different social contexts. This was followed by assessing the levels of acceptance of use of digital elements in textiles. A traditionally handcrafted interface in the form of a e-scarf, named as *Aster,* was designed, developed and tested for non-verbal communication in the social space. The scarf has been assessed for technology acceptance [9], usability [10–12], emotions evoked [13] and social intelligence pertaining to non-verbal communication [8]. The handcrafted textile is a micro RGB LED embedded stole capable of changing colors through three buttons, named as *Aster* in this study.

The objectives of the data collected through a questionnaire were as follows: – (i) Understanding boundaries created by users and comfort levels experienced for sharing information and if they differ from close friends than strangers; (ii) To understand emotions experienced by users in different social spaces; (iii) To design a traditionally crafted wearable which could communicate non-verbal expression of boundaries, comfort levels and emotions; (iv) To probe if emotions evoked by the traditionally crafted wearable influence technology acceptance (perceived usefulness and perceived ease of use); (v) To identify if aesthetics of the traditionally crafted wearable influences technology acceptance (perceived usefulness and perceived ease of use); (vi) To experiment if variables measuring non-verbal expression influence technology acceptance (perceived usefulness and perceived ease of use); and, (vii) Usability assessment of users' experience while using *Aster* for non-verbal communication.

3 Methodology for Data Collection

Figure 3, describes the experimental overview with objectives addressed in each phase leading to findings being discussed towards the end of the paper. A questionnaire based study was conducted in two phases with young students between the age group 18–32 years studying in a national technical institution located in the North-East of India.

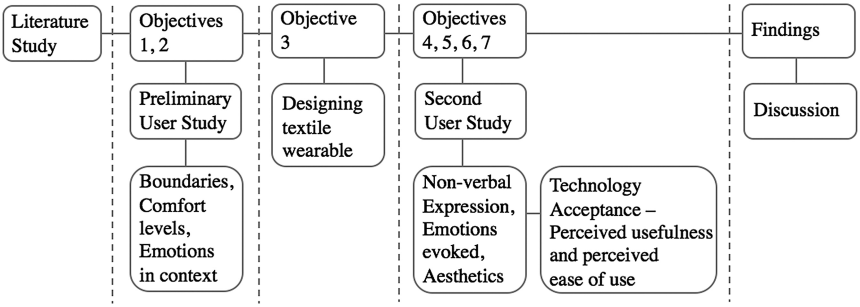


Fig. 3. Experiment overview

Phase one was carried out with 30 respondents (Table 1) for understanding boundaries and comfort levels experienced as part of a behavioral study. Phase two was carried out with 60 respondents (Table 2) for analysis of *Aster's* acceptance, usability, social intelligence and emotions evoked. Data collected has been analyzed quantitatively on SPSS (Statistical Package for Social Sciences).

Table 1. Demography for preliminary study 1

Sample size	Age (years)	Male	Female	Place of origin	Educational background
30	18–28	10	20	Semi-urban (18), Urban (12)	Undergraduates and Post Graduates

Table 2. Demography for user study 2

Sample size	Gender	Age (years)	Place of origin	Educational background
60	Female	18–32	Semi-urban (36), Urban (24)	Undergraduates and Post Graduates

The experimental set up for preliminary study comprised of six categories of response, of which three parts (Annexure 1–3)– boundaries, comfort levels and emotions experienced in certain contexts, have been discussed in this paper. The second study with *Aster* was conducted in groups of 2–3 users at the same time in a defined space where users were to interact with *Aster* and communicate with each other to see if they could understand one other via non-verbal visual cues. For example, when the viewer asked “Could you spare some time” and if the wearer of *Aster* responded through ‘Blue’ it was understood that the wearer did not have enough time to spare and could be approached later again. The participants were acquainted with the meanings of signaling color codes before the scenario was enacted. After a brief interaction with *Aster,* the users had to mark their response in the questionnaire provided. This questionnaire was printed both sides on A4 sheet in a three-column format with 5 matrices, 3 sets of Likert scale questions, 3 binary questions and 6 descriptive questions. Few parts of the questionnaire on Emotions, Social intelligence, Usability and Technology Acceptance Model have been included in the annexure at the end of this paper (Annexure 4–7).

4 Preliminary User Study Analysis

30 respondents mentioned the boundaries they create for sharing intellectual, emotional, political, physical, sexual and material beliefs or information with known friends, intimate friends and strangers on a scale of 0–10. The data has been represented in a radar diagram and was also analyzed quantitatively on SPSS. The Cronbach's Alpha for reliability was 0.883. ANOVA results showed significant values as described in Table 3. The diagram in Fig. 4 reveals that respondents share information with intimate friends most openly, known friends openly and with strangers restrictively. 3 respondents discussed restrictively with intimate friends and 4 respondents shared information with strangers openly.

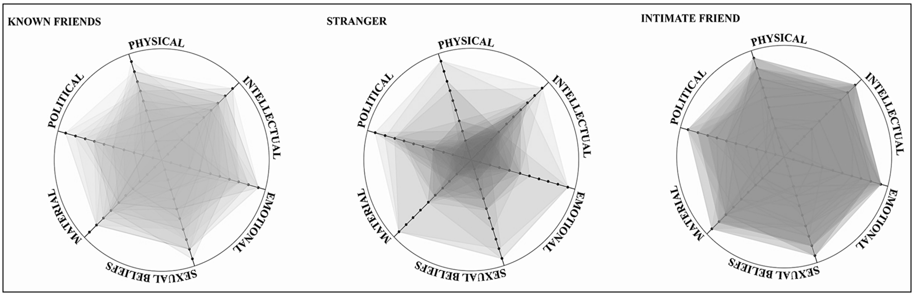


Fig. 4. Line diagram and area diagram for boundaries for sharing belief systems

Table 3. ANOVA results for boundaries of sharing information

	Physical	Intellectual	Emotional	Sexual belief	Material	Political
F	21.271	11.878	29.952	8.816	15.500	3.796
Sig.	.000	.000	.000	.000	.000	.026

Respondents had to mention their comfort levels on a scale of 0–100 (0–20 very low, 21–40 low, 41–60 average, 61–80 high and 81–100 very high) while interacting with six categories of people namely – stranger from different community, stranger from same community, acquaintances, social friend, close friend and intimate friend for sharing information such as – social life, academics, professional life and relationships. The Cronbach's Alpha value for reliability test of the data collected was calculated as 0.843. ANOVA results revealed that respondents were restricted in sharing information with strangers from different community, same community and acquaintances. Comfort levels with intimate friends was high for some and low for some respondents, response for which was not significant as mentioned in Table 4.

Table 4. ANOVA results for comfort levels expressed by users

	Different community	Same community	Acquaintance	Social friend	Close friend	Intimate friend
F	5.433	5.770	7.598	5.657	3.020	1.603
Sig.	.000	.000	.000	.000	.012	.162

10 Emotions [13] – Joy, Trust, Optimism, Love, Vigilance, Admiration, Surprise, Fear, Pensive, Remorse, Annoyance and Fear - experienced in 6 different contexts – Office, School, College, at a Wedding, Park and while commuting were denoted on a scale of 0–100 (0–20 very low, 21–40 low, 41–60 average, 61–80 high and 81–100 very high). The Cronbach's Alpha was. 0.767. It was revealed that emotions are significantly expressed in each of these contexts by respondents (Table 5).

Table 5. ANOVA results for emotions experience in different contexts

	Office	School	College	Wedding	Park	Commuting
F	4.237	13.186	13.323	10.092	11.726	5.618
Sig.	.000	.000	.000	.000	.000	.000

4.1 Implications of Preliminary User Study Analysis on Designing Wearable

The preliminary user study was conducted to understand how young respondents create or draw invisible boundary limits for sharing information, different comfort levels experienced when interacting with different categories of people and which type of emotions are experienced while interacting in certain contexts. Significant results imply that identifiable unexpressed boundaries and comfort levels in certain known and unknown social settings exist. Known settings and unknown settings, both could be college library, café, college premises, at office, commuting, airports, bus stops, parks, etc. depending on the person.

Based on the above results, the researchers hypothesize, that if textiles worn could express, when needed, the comfort levels and boundaries being experienced in a subtle non-verbal manner to the people around, it could help in creating a conducive atmosphere with decorum in a socio-cultural space. This would lead to increased understanding among individuals besides assisting and reinforcing users through non-verbal mediums. This would also empower users to express themselves in contexts when words can't be used. Thus, make them socially intelligent through textiles worn which in turn leads to collective intelligence and well-being of the individuals in their social space.

Aster, the wearable prototype scarf was designed with sequins and petal shaped embellishments hand embroidered on poly-dupion fabric surface with micro RGB LEDs embedded in the center of floral configurations of Embellishments (Figs. 5 and 6). The design elements for *Aster* have been inspired from architectural reliefs of a fort located in Madhya Pradesh, India [20]. Four LEDs have been embedded in the bottom row and other floral centers have been embellished with sequins. The LEDs are connected through conductive thread, three switches to control 3 colors – red, blue, green and 3.7 V Li-Poly battery source. 60 respondents took part in an interactive session, where they were asked to imagine being in any one or more of the scenarios, such as travelling alone in a metro, bus stops, college library, strolling in a park, etc. The users then communicated meanings through visual cues/colors of *Aster*. The study captured the experience and functionality of *Aster* when it changes its colors/visual cues to express certain additional meanings, such as red glow could mean *I am uncomfortable, do not approach, I am not interested, I am angry, I disagree*, etc. Blue glow could mean *I am slightly comfortable, slightly approachable, I am slightly interested, I am not very pleased, I slightly disagree*, etc. While a Green glow could mean, *I am comfortable, you may approach, I am interested, I am pleased, I agree,* etc.

Fig. 5. Embroidering *Aster*; *Aster* static-dynamic rendered on mannequin; Respondents (Color figure online)

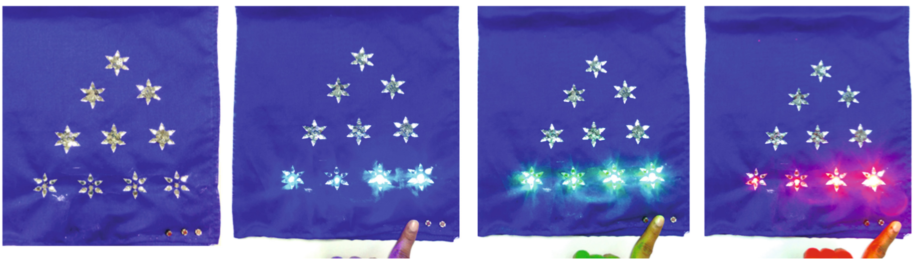


Fig. 6. *Aster* – Static and Dynamic - three colors controlled by three buttons (Color figure online)

5 Analysis of Second Phase of User Study

Positive emotions were evoked much higher than the negative emotions as described in Table 6 and is evident from Friedman's ANOVA and post-hoc analysis in Table 7. It was thus indicated that traditionally crafted textile wearable *Aster*, evokes positive emotions strongly in users than negative emotions. 10 emotions were rated on a 5 point Likert scale by the respondents (Annexure 4).

Table 6. Descriptive statistics of emotions evoked Experimental study 2 – *Aster*

	Happiness	Optimistic	Awesome	Interesting	Admirable	Sad	Pessimistic	Boring	Annoying	Disgusting
MEAN	3.98	3.81	3.61	4.1	3.85	1.25	1.46	1.33	1.41	1.18
STDEV	0.96	0.89	1.01	0.96	0.89	0.63	0.94	0.68	0.81	0.65
MODE	5	4	4	4	4	1	1	1	1	1

Table 7. Friedman's test statistics and wilcoxon signed ranks test - statistics

N	**60**
Chi-Square	243.682
Asymp. Sig.	.000

	Positive and Negative emotions
Z	-6.674[a]
Asymp. Sig. (2-tailed)	.000

Spearman's Correlation results for *Aster* revealed that– positive emotions were positively correlated with perceived usefulness and perceived ease of use of Technology Acceptance Model (TAM, Annexure 6), $\mathbf{r_s} = 0.589$ and 0.464 respectively, significant at $p < 0.01$ for a two-tailed test. Negative emotions were negatively correlated with perceived usefulness and perceived ease of use $\mathbf{r_s} = -0.258$ significant at $p < 0.05$ for a two-tailed test and $\mathbf{r_s} = -0.366$ significant at $p < 0.01$ for a two-tailed test. Aesthetic attributes were positively correlated with perceived usefulness and perceived ease of use $\mathbf{r_s} = 0.660$ and 0.516 respectively, significant at $p < 0.01$ for a two-tailed test. Results indicated that *Aesthetics* of *Aster* has significant effect on technology acceptance - perceived usefulness and perceived ease of use for traditionally crafted wearables. The five Attributes of Aesthetics - Attractive, Desirable, beautiful, Pleasing and Enjoyable, were rated on 5 point Likert scale by the respondents (Annexure 4). 7 variables of non-verbal communication (Social Intelligence-SI) were positively correlated with perceived usefulness and perceived ease of use $\mathbf{r_s} = 0.487$ and 0.461 respectively (significant at $p < 0.01$ for a two-tailed test). Results indicated, that traditionally crafted wearable *Aster*, significantly enhances non-verbal expression among users in a given social space leading to high perceived usefulness and perceived ease of use. The seven variables of non-verbal communication (NVC) were rated on 5-point semantic differential scale by the respondents (Annexure 5). The results for *Aster* in the form of associations, have been described through a connected model in Fig. 7 and also tabulated in Table 8. Cronbach's α for reliability for the model (Fig. 7) ranged between .767 and .883. Usability assessment of *Aster* based on System Usability Scale (SUS, Annexure 7) revealed positive results as SUS score for *Aster* = 72.54. This indicates that respondents preferred usage of *Aster* for non-verbal communication and their experience of using *Aster* was 'good', as per the SUS score [12].

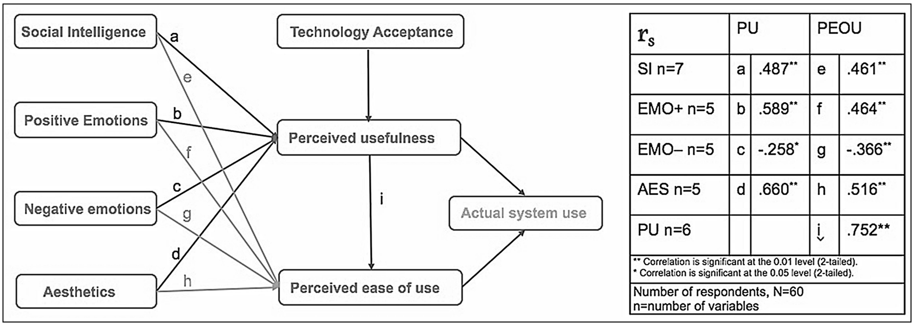


Fig. 7. Posited model for non-verbal communication with *Aster*

Table 8. Summary of evaluation for Spearmans' correlation of Posited model for *Aster*

	PU	PEOU
NVC	.487**	.461**
EMO+	.589**	.464**
EMO–	−.258*	−.366**
AES	.660**	.516**
PU	1	.752**

**Correlation is significant at the 0.01 level (2-tailed test).
*Correlation is significant at the 0.05 level (2-tailed test).

Principal component analysis for 7 variables measuring non-verbal communication (NVC/Social Intelligence-SI), [8] with respect to perceived usefulness and perceived ease of use was carried out for *Aster*. KMO test for sampling adequacy was 0.799. Bartlett's Test for component correlation was significant, p = 0.00. 2 components were extracted on the basis of Eigen values. The 7 variables of NVC loaded together (Table 9) and hence accurately measure non-verbal communication with traditionally crafted wearable *Aster*.

In a descriptive section, respondents were asked to write their opinions about interacting with *Aster*. 89% of respondents rated *Aster* to be very interesting and smart. Some respondents suggested that *it could help people with impairment*, *something should be designed for men as well*, *a common language of colors is required* and that *the number of LEDs could be increased in Aster*. 11% of respondents seemed apprehensive about the disadvantages of wearables on health, they were not ready to use unless *it became popular*, they were skeptical about *electronics working well* and *communicating effectively at times* and that *the world would become too robotic with automation embedded in clothes*. These 11% of respondents can be categorized as late and cautious adopters of technology.

Table 9. Pattern matrix for *Aster*

Pattern Matrix SI-PU-ASTER				Pattern Matrix SI-PEOU-ASTER		
	Component				Component	
	1	2			1	2
SI1	.032	.712		SI1	.076	.671
SI2	.086	.696		SI2	-.052	.778
SI3	.328	.635		SI3	.168	.759
SI4	-.044	.612		SI4	.092	.501
SI5	-.112	.761		SI5	-.181	.786
SI6	.317	.492		SI6	.002	.698
SI7	-.034	.640		SI7	.108	.543
PU1	.898	-.044		PE1	.881	-.090
PU2	.951	-.128		PE2	.756	.119
PU3	.848	.066		PE3	.759	.158
PU4	.900	.029		PE4	.793	.091
PU5	.852	.017		PE5	.817	.111
PU6	.723	.156		PE6	.971	-.164

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 5 iterations.

6 Discussion

As inferred from the experiment results, E-textile *Aster*, enabled non-verbal communication in a social space. Interaction with *Aster* takes place in 4 parts – (i) When user expresses through colors; (ii) when user presses the button on textile to change color, or undo the previous action; (iii) when the viewer perceives the color and understands expression; (iv) if the viewer has a similar textile, responds through same language (which is not a part of the experimental set-up). This was a preliminary study about perceptions of young Indian users. Study needs to be conducted on much larger scale for complex interactions in actual scenarios. In the present experiment users are in a hypothetical social situation with basic interaction happening to express degree of comfort, agreement/disagreement, like/dislike, yes/no/maybe in three stages of low, medium and high according to the three colors of LEDs. Studies with larger sample size are required to be conducted further.

Proximity principle [6, 7] states that there are two main reasons why people form groups with others nearby rather than people further away. First, human beings like things that are familiar to them. Secondly, the more people come into contact with one another, the more likely the interaction will cultivate a relationship which is the benefit or payoff for interaction. Also, proximity promotes interaction between individuals and groups, which ends up leading to liking and disliking between the groups or individuals. The Johari Window [19] by Joseph Luft and Harrington Ingham (1955) mention the following about boundaries that people create for sharing information (Fig. 8).

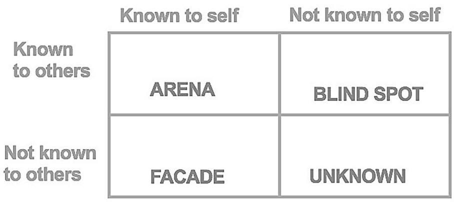


Fig. 8. Johari Window (1955)

Based on the user study conducted in two phases and the proximity principle and the Johari Window, the researchers formulate that boundaries for sharing information have not been found to be rigid. Boundaries for sharing belief systems differ for different kinds of individuals in the social space of the user. It was observed that different comfort levels are experienced with different kinds of people in known and unknown settings. If textiles could communicate these subtle boundaries that users create and dissolve for others, it could lead to subtle non-verbal expression of boundaries around users through visual cues. It was also inferred that these visual cues can be embedded using traditional textile design crafted elements thereby opening up new avenues of gainful employment of craftsmen.

7 Inference and Future Work

This research paper presents a study on the effect of embedding electronics into a static textile which can enhance non-verbal expression of users in specific contexts. The aim to is to understand the role dynamic textiles could play by first understanding the behavior of users pertaining to boundaries they create around themselves and comfort levels experienced in specific contexts. The wearable thus designed augments expression and non-verbal communication of users in the given scenarios to enhance inter-personal interactions and reinforce personality traits of the users. The second phase of user study reveals that changing visual cues for non-verbal communication, leads to improved social and collective intelligence. Technology acceptance study (TAM) indicates strong inclination of users for using such wearables for daily interactions.

Usability assessment encourages user study with larger sample groups for further insights and redesigning of the prototype for better experience and reduced efforts while interaction. Assessment of cognitive load subsequently becomes important to understand the effort, stress, frustration being experienced by the respondents while interacting with these smart products. In further studies, it will be important to correlate usability, acceptance and cognitive load parameters with a larger sample size of respondents to gain further insights on the effects of one on another.

Digitized textile wearables with traditional design elements have high probability to be accepted by the younger Indian generation. Their openness to adopt and experiment for using them in social and cultural interactive spaces would mean an optimistic work outlook for craft makers in the digital era where the craft traditions are on a gradual decline.

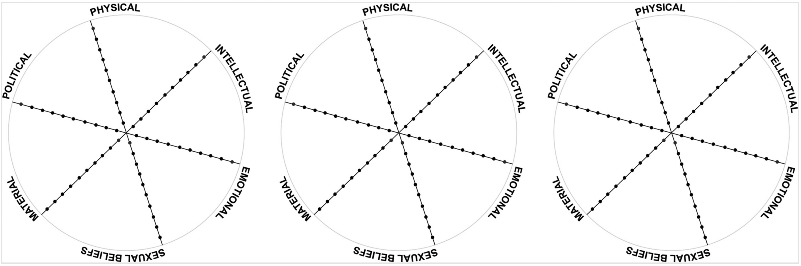
Acknowledgment. Participants who took part in the user studies. Research scholars at the Usability Engineering and Human Computer Interaction Lab, Department of Design, Indian Institute of Technology, Guwahati, Assam, India.

Annexure

Parts of Questionnaire as administered has been mentioned below:

1. **Please rate by circling a point between 1–10 on each axis indicating the limits of boundaries you would create when socializing with – (center = 0, perimeter = 10)**

KNOWN FRIENDS - STRANGER - INTIMATE FRIEND



2. **Please mention the percentage of comfort levels (0–100%) about sharing the below mentioned details with the following categories of people –**

Types of Information	Stranger from different community	Stranger from same community	Acquain-tance	Social Friend	Close Friend	Intimate Friend
Sharing your Past 1. Social						
2. Academic						
3. Professional						
4. Relationships						
5. Family						

3. **Please mention the percentage (0–100) of feelings corresponding to the contexts that may be expressed –**

	Emotions	Office	School	College	Wedding	Park	Commuting
1	Joy						
2	Trust						
3	Optimism						
4	Love						
5	Vigilance						
6	Admiration						
7	Surprise						
8	Fear						
9	Pensive						
10	Remorse						
11	Annoyance						
12	Aggression						

Pertaining to experimentation with *ASTER*

4 **Please tick the emotions, aesthetic appeal and attitude associated with *Aster* when LIT UP in the tables below, 1 is least and 5 is highest score.**

EMOTIONS	1	2	3	4	5
Happy					
Optimistic					
Awesome					
Interesting					
Admirable					
Sad					
Pessimistic					
Boring					
Annoying					
Disgusting					

AESTHETICS	1	2	3	4	5
Attractive					
Desirable					
Beautiful					
Pleasing					
Enjoyable					

5. **Understanding social intelligence pertaining to the usage of *Aster* in the given scenarios –**

1. Do you think that *Aster* can create a dignified decorum by letting you understand the visual language of changing colors, thus create a better understanding among the people around non-verbally?

O Agree **O Slightly agree** **O Neutral** **O Slightly disagree** **O Disagree**

2. Do you think you were able to understand wearer's feelings, non-verbally better with *Aster* if not necessarily put in words?

O Agree **O Slightly agree** **O Neutral** **O Slightly disagree** **O Disagree**

3. Do you think you could *hear* or *feel* the wearer's feelings, non-verbally through *Aster*?

O Agree **O Slightly agree** **O Neutral** **O Slightly disagree** **O Disagree**

4. Do you think that using *Aster* is letting interaction among people around you happen smoothly and socially dignified (within social norms)?

O Agree **O Slightly agree** **O Neutral** **O Slightly disagree** **O Disagree**

5. Do you think that *Aster* lets wearer express his/her personality effectively?

O Agree **O Slightly agree** **O Neutral** **O Slightly disagree** **O Disagree**

6. Do you think *Aster* can modify/influence the outcome of people's behavior around the wearer, if symbolic messages are sent visually?

O Agree **O Slightly agree** **O Neutral** **O Slightly disagree** **O Disagree**

7. Do you believe colors could be used as signals to communicate and interpret feelings and make people around act accordingly?

O Agree **O Slightly agree** **O Neutral** **O Slightly disagree** **O Disagree**

6 **Technology Acceptance Model –** Analyzing acceptance of *Aster* among the users. Please tick appropriate cells below, 1 is least likely and 7 is most likely, for non-verbal communication –

Perceived Usefulness	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Aster could enable quick communication							
Aster could improve the process of communication							
Aster improved the productivity of communication							
Aster could enable effective communication							
Aster could enable easier communication							
I found *Aster* useful for communication							
Perceived Ease of Use							
Learning to understand *Aster* is easy for me							
I find *Aster* easy to use for communicating							
My interaction with *Aster* is clear and understandable							
I find *Aster* to be flexible to interact with							
It is easy for me to become skillful at using *Aster*							
I find *Aster* easy to be used							

7 **System Usability Scale -** After using *Aster* for the scenarios as specified above, please tick appropriate cells below to convey how efficient, effective, engaging, easy to learn and error tolerant the experience of using *Aster* for communicating through visual cues was to yourself; **1 is *low*** and 5 is ***high***.

	Usability factors	**1**	**2**	**3**	**4**	**5**
1	I think I would like to use *Aster* frequently					
2	I found *Aster* unnecessarily complex					
3	I thought *Aster* was easy to use					
4	I think I would need support of technical person to be able to use it					
5	I found the functions were well integrated					
6	I found there was too much inconsistency					
7	I imagine most people would find it easy to learn how to use *Aster*					
8	I found *Aster* very cumbersome to use					
9	I felt confident while using *Aster*					
10	I needed to learn a lot before I could get going with *Aster*					

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Human-Computer Interaction – Game-Based Learning

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Abstract. Throughout the past few decades, the use of technology has far exceeded the expectations of all of us. Different users with different profiles and expertise are using technology to help them on daily life tasks. In particular, 21st Century students have grown up using different technology from that which their professors grew up with. The World Wide Web has had a significant effect on the way they think and learn. Against this backdrop, the paper seeks to, through the use of a case study based on polytechnic students learning human-computer interaction fields and their absence of motivation to learn the subject, suggests a game environment to learn; a questionnaire was designed to get student's opinions about learning through games. The results expression proposed the necessity to change the teaching/learning traditional approach.

Keywords: Human computer interaction · Teaching · Learning Games

1 Introduction

The challenges surrounding modern technologies influence every aspect of society, and life worldwide and the way the human interacts. The results of this technology rising use impacts the way the world evolves. Conversely, young people learn to use technological devices sooner in their lives. Summing their experiences with technologies it leads to a normal and natural way to start playing games as an entertainment approach.

The use of games have support people cultivate a mood towards collaboration, problem-solving, communication, experimentation, and exploration of identities, all attributes that promote success in a rapidly-changing, information-based culture [1]. Research into the cognitive and socio-cultural aspects of gaming has exploded in the last decade as people have begun to realize the potential for game-based learning [2, 3].

Since the early 2000s simulation games have gradually become professionalized [4]. The potential of video games as vectors for learning was recognized from their beginning. Nowadays, there is substantial interest in serious games for formal education, professional training, healthcare, advertising, public policy and social change.

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Playing is by its very nature educational. And it should be pleasurable. When the fun goes out of play, most often so does the learning [5]. There is also evidence that games allow students to focus well enough to learn better [6].

This paper presents a summary research concerning the state-of-the-art about the importance of games in teaching/learning process. Departing from a questionnaire answered by students who learn human-computer interaction (HCI) subjects at a polytechnic institution, we concluded that traditional ways of teaching/learning could be changed following a game approach. Students did some suggestions about the way they will like to play a game to learn HCI.

2 Background

Online games have a great impact on undergraduate students. Games have a great potential for students to learn. Some games aim to increase content knowledge by letting the players live the scenario. Games seem to be particularly successful in helping people develop problem-solving and decision-making skills and encouraging innovation [3].

Games are often classified into genres, which means to define games in terms of having a common style or set of characteristics (perspectives, gameplay, interaction, objective, among others):

– Real-time strategy (RTS) games defined a number of goals around resource collection, base and unit construction and engagement in combat with other players.
– Role playing games (RPGs) are characterized in terms of providing the player with flexibility in terms of character development and problem resolution.
– Multiplayer online role-playing games (MMRPGs) normally present a persistent virtual world populated by thousands of other players.
– Racing games place the player behind the wheel and involve competing in a race against other drivers.
– Sports games which are games that simulate the sporting experience – including sports such as football, baseball, golf, boxing, skate boarding, tennis, etc.
– Educational games are designed to teach new skills, which can span from preschool onwards.

This section presents a summary description of games' example that students are used to play, according to the results of the questionnaires from our research. A reference to serious games and those who apply them for learning is also presented.

2.1 The Games Students Play

The games to be described are: Ages of Empires, League of Legends, Minecraft, HearthStone and Sports games. These games have inspired the researcher, either to study them, or for research-based development and for solving problems.

Ages of Empires – Defined as a Real Time Strategy game, first released in 1997, developed by Ensemble Studios and published by Microsoft Studios. Since then, four series and other spin-off´s have been released with great success. This game features real historical events in Europe, Asia and Africa, between the Stone Age and the Classical Period.

The games are demarcated by several goals around resource collection, base and unit construction and engagement in combat with other players or computer opponents who also share similar goals. Emphasis is often placed upon managing logistics, resources and production.

Age of Empires (1997) – This is described as a combination between the games *Civilization* and *Warcraft.* This first sequence, allows the player to choose twelve civilizations from the Stone Age to the Iron Age.

Age of Empires II: The Age of Kings (1999) – Increased the civilization selection to thirteen and is now set in the Middle Ages, specifically from the Dark Ages to the Imperial Age.

Age of Empires III (2005) – Set in the period between 1421–1850, with the introduction of new game mechanics, "home-cities" which helped provide the players with further resources, troops, upgrades, among other.

Age of Empires IV (no release date) – Developed by Relic Entertainment, after twelve years of hibernation, this fourth sequence is expected to collect the historical features from the previous games in a different graphic aesthetic [7].

League of Legends - League of Legends is a multiplayer online battle arena (MOBA) game developed by Riot Games [8] where players participate in teams of five versus five where the goal is to destroy the opposing team's nexus, which will ensure the victory. Each player assumes the role of one of over 120 different characters battling each other to destroy the opposing team's "towers"—structures that fall after suffering enough attacks from characters. The 120 different characters are divided into six different roles:

- **Assassins:** are able to move quickly and dish out lots of damage to single targets. They're best for jumping in, killing high-value targets, and jumping out.
- **Fighters:** dish out and take decent amounts of damage, and are well suited for extended combat. They jump into battle and use their balanced stats to lay down damage.
- **Mages:** excel in ranged combat, and often have area-of-effect (AoE) attacks that damage multiple enemies. They need to keep enemies at bay to survive.
- **Marksmen:** deal damage from a distance. If they're well protected, they can dish out a lot of pain to single enemies, but they are usually vulnerable to attack.
- **Support:** characters don't do much on their own, but they can amplify the abilities of their teammates. Some are able to do solid amounts of damage to help other champions control the battlefield.
- **Tanks:** can soak up massive amounts of damage as well as put the hurt on groups of enemies. They generally don't go for lots of kills, but help control the battlefield so other champions can fight with an advantage [9].

Typically, a league of legends gamer will elect a preferred role in the game. Different roles will allow the creation of a diversified and effective team of players.

This MOBA demands great mechanical, analytical and strategic skills from the player. It is a game filled with tactical variety and fictional characters with improvised stories, which bring the game to life. Released in October 2009, League of Legends has successfully caught the attention of 67 million monthly players and numerous international tournaments with professional gamers for a prize in the millions.

Minecraft is a game about breaking and placing blocks [10]. At first, people build structures to protect against nocturnal monsters, but as the game grew players worked together to create wonderful and imaginative things. It can also be about adventuring with friends or watching the sunrise over a blocky ocean. The brave players battle terrible things in The Nether, which is scarier than pretty [11]. The service features huge worlds to explore and a lot of freedom, allowing players to choose how to play the game; The game has several activities including exploration, gathering resources and crafting. Minecraft can be a very realistic game that will almost make players addicted to it, because of all the creative possibilities it contains. With the mob side, turning survival harder to achieve day by day, it will appeal a player to win, to explore, discover different biomes, get more experience, build better houses, castles, bridges, etc. [11].

HearthStone is considered an electronic sports game (e-sports), which has over 50 million players as of April 2016 [12], and is one of the most profitable games for e-sports. HearthStone (HS) is a popular online video game in which players fight one another using virtual playing cards. To defeat their opponent, players have access to a large number of cards that they can use to trigger a variety of offensive or defensive moves. The cards in HS have complex synergies, which are exploited by most experienced players to set up powerful strategies. Over the time, experienced players have accumulated a large body of strategic knowledge about the combinations of cards and how to use them. However, this knowledge remains mostly inaccessible to novice players [13]. Matches in HS involve two players, playing in turns, one at a time. Each turn starts with one player drawing a card from his deck, and then playing a small sequence of actions using the cards in his hand. When the player has performed all the actions that he wants to play, the turn ends, and the other player can start playing. Players are required to build a deck before they can play any match, which is a small set of cards they want to play with. Doux and their colleagues demonstrate how to extract strategic knowledge from gaming data collected among players of the game HearthStone [13]. Taralla develop a modular and extensible clone of the game HearthStone, such that practitioners from all over the world can have a new benchmarking tool to test their algorithms against [14]. Bursztein presents the first algorithm that is able to learn and exploit the structure of card decks to predict with very high accuracy which cards an opponent will play in future turns [15].

2.2 Games Based Learning

Game based learning is not a new concept. It dates back to at least 1900s, and paper-based educational games were quite popular in the 1960s and 1970s. But advances in technology have taken game-based learning to a new level. Video games are used to thinking on multiple tracks at once, but have little patience with linear reasoning or delayed gratification [16]. We think that using games for teaching/learning is one way to shift to a more appropriate learning format for the digital generation.

Serious games are games designed for a purpose other than entertainment. Serious games use game environments and techniques to train or educate users or to promote a product or service in an engaging and entertaining way. The "serious" aspect comes from the fact that they are used by industries like: defense, education, scientific exploration, health care, emergency management, city planning, engineering, religion, and politics.

Serious games and gamification share similar traits and even goals. However, there are some differences in the context and elements of both. Gamification is more than a serious game, as it expands game thinking and mechanics into non-game environments, such as the classroom or everyday life [17]. The discussion of this subject is out of the scope of this paper. Serious games apply game thinking and mechanics to "serious" subjects. If gaming elements are compelling and fun, the results we want will be obtained easily. Andrew Hughes explains the concepts of Gamification vs. Game Based Learning [18].

3 Study

The argument that lead us to state that games have impact on undergraduate students is based on a research carried out with students from a Polytechnic institution learning HCI.

Students' profile – the students were first and second year undergraduates' students enrolled in (HCI) and interactive systems design courses.

The study – students were asked to fill a questionnaire and to give their opinions on playing games as an entertainment habit and the challenge of learning HCI through games.

The questionnaire - comprised twelve questions, five of them were closed questions concerning information about time duration they played, if alone or within a team, if they have dependency, if they have pleasure and what types of games they play. The other questions were open questions about personal opinions regarding what they considered they learn with games and what a game for learning should be like.

The questionnaire was available to fill about two weeks on a Moodle platform for the course-registered students. One hundred and thirty eight students answered the questions from the one hundred and fifty registered students.

Data analysis – the data was analyzed following the grounded theory method (GTM). Glaser and Strauss created Grounded Theory Method (GTM) in 1965, while analyzing data for their research [19]. Later, other researchers such as Corbin, Bryant and Charmaz [20] did different interpretations of that approach. GTM allows developing a theoretical account while simultaneously grounding it in observations. Strauss and Corbin [21] proposed three stages in analysis in grounded theory: open coding, axial coding and selective coding. During open coding the researcher reads the text and asks questions to identify codes that are theoretical or analytical. Axial coding is used to relate categories to subcategories. It specifies the properties and dimensions of a category. According to Strauss and Corbin axial coding answers questions such as 'when, where, why, who, how' and with what consequences. Selective coding involves the process of selecting and identifying the core category and systematically relating it to other categories [21]. It involves validating the categories' relationships. The main goal of GTM is a constant comparison. Previously coded text also needs to be checked to see if the new codes created are relevant. Grounded Theory Method was chosen since it gives guidelines and grounding than most approaches.

The strategy used using GTM was, first, coding which is the basis for category building and with constant comparison of data, categories emerged. An example of initial coding stage is presented on Fig. 1 in Sect. 4 of this paper. At this point an analytical pause was made to write analytical notes (memos) as will be explained later in this section. The goal was to explore the researcher's ideas about the categories and to write about the codes and data and move up to theoretical categories. The codes were analyzed and those that related to a common theme were grouped together. From these data we obtained the main concepts to consider and maintain on the development of the new game for teaching/learning.

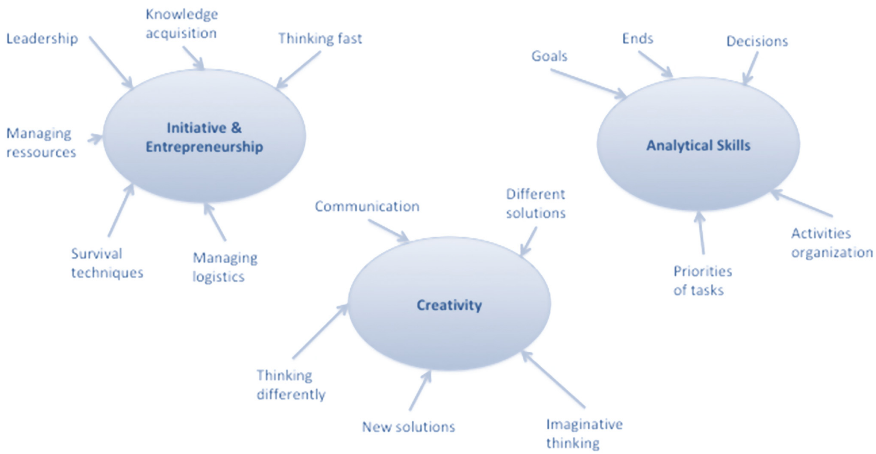

Fig. 1. Initial coding stage with GTM

4 Results and Discussion

This section presents the research comments about the data gathered on the study. The kinds of skills identified on students playing the games are listed (see Table 1). Then, some negative and positive aspects of playing games are stated. Finally, Fig. 1 presents a summary analysis about the data gathered using GTM approach. This section ends with final important comments that will conduct to the game development.

4.1 Abilities and Skills Worked on Playing Games

There are several skills that a player can obtain by playing games. This section presents some examples collected from the literature about Minecraft and HearthStone games. Then, we describe other skills we consider a gamer has, however some of them were ascertained from the applied questionnaires on the presented study.

Table 1. Example of questionnaire' answers

Frequency	Type of Game	Addiction	Play alone	Play in team? Why?	Results	Violence influences	Serious Game	Learning Outputs
5 h/day	Call of Duty, Battlefield	Yes	Yes	Yes	Mission accomplishment, Skills development, Reaction time, Competition	No	Educational games, Knowledge acquisition	Historical evidences, Skills training
1 to 3 h/day	Survival, strategy, cars, building	No	Yes	Yes	Entertainment, To find nice people	Too much violence, I give up	Learning & entertainment	World War History, Ancient ways of living, Strategy, Creativity, Logic
4 to 5 h/day	Strategy	Yes	Yes	Yes	To be with friends, to distract from everything	No	Real evidence based	Knowledge acquisition
1 to 2 h/day	NBA 2K18, Sports	No	Yes	No	Fight with difficulties	Yes	Educational content	Knowledge acquisition
2 h/day	Competitive (Sports)	No	No	Yes	Entertainment, living together	No	Competitive games	Relax
More than 5 h/day	Strategy	No	Yes	Yes	To win	No	To learn	English Language
2 h/day	Multiplayer	No	Yes	Yes	To win, to play with friends	No	Challenge the player	Entertainment
30 minuts/day	Offline games	No	Yes	No	Distraction	No	Entertainment	Entertainment
3 h/day	Fifa and open-world	No	Yes	Yes	To be challenged	No	Work	Observe challenges and ways to overcomes them
Sometimes	Offline games	No	Yes	No	——	No	Challenging	Nothing
1 to 2 h/day	Offline games:GTA, FIFA and Watch Dogs	No	Yes	No	To do impossible things	No	No opinion	War facts, historical events, English Language
2 h	Mobile: CabdyCrush Last Day of June, Life is Strange	No	Yes	No	Like single player games	No	Educational games	Abilities exercises, strategic thinking
2 h	Offline games: Sports and Cars	Yes	Yes	No	Achieve objectives, entertainment	No	…	Survival techniques; knowledge acquisition
2 to 3 h/day	Fortnite and Counter Strike Global Offensive	No	No	Yes	Distract with friends	No	Educational games	Overcoming challenges, thinking fast

(*continued*)

Table 1. (*continued*)

Frequency	Type of Game	Addiction	Play alone	Play in team? Why?	Results	Violence influences	Serious Game	Learning Outputs
2 h	RPGs or MMORPGs	No	Yes	Yes	Win, sort problems	No	Simulation games to learn	Mythologies
2 to 3 h/day	League of Legends, Multiplayer online	No	Yes	Yes	Friendship, Communication	No	Serious Games, Educational	Collaborative work, lidership, controle, communication

Minecraft's main objective is surviving. There are different skills that the player needs to perfect if they want to go far in the game, such as mining and farming. In order to understand more of what Minecraft is about, the player needs to have a basic understanding of the extent of the game and the necessary traits and tricks to succeed in it. There is a skill focused around mining stone and ores. A notable perk of this skill is the higher potential yield from each ore, increased even further when using as an active skill. By mining through caves and ravines, the player can find ores like iron, gold, diamond. This skill covers a wide set of activities, from planting flowers to actual farming. For instance, players can make a basic farm with a hoe and a block of water. After building the groundings, players can then plant wheat seeds, carrots, potatoes, pumpkins, melons and many more. Since this is a survival game, one of the most important skills is this one. Either with a block of dirt in the early stages, or with a full enchanted armour, sword and shield, battling down the terrific menace that is the Nether. The player will learn how to battle the threats that lurk in the shadows of the full moon. Some will even build an experience farm, or, in Minecraft terms, an automated mob farm, so they can gather it and gain levels. This is accomplished by creating a creature spawner, an easy fast way of killing an enormous quantity of mobs. The most commonly built ones are skeleton and zombie spawners, in designated rooms for that purpose only [10].

According to students this is an educational game that demonstrates, in a straightforward way, the difficulty of agriculture, farming and building. It can also develop a person's social skills since most people play it in multiplayer servers, where they build true friendships that sometimes are more important than the ones that they gather in their life offline.

HearthStone - Abilities are special effects, powers, or behaviors found on cards. For spell cards, the ability describes the total effect of playing that card, while for minion and weapon cards, abilities are special effects or powers additional to the basic functions of the card. Abilities may be described in the card's text, or granted by enchantments. This game requires a thorough understanding, a great analytical and decision-making sense to be able to gather an effective and powerful deck of cards. Players must study and explore the endless possibilities this game has to offer to reach triumph.

Professional and other skilled gamers are known to have a distinct set of skills, which allow them to reach the higher ranks of the games. Some say that these skills and qualities are necessary to the development of a person who aspires prominence in the gaming community as well as gaming expertise.

Dexterity

To play games motor action is required. To play competently, a swift, smooth and controlled movement of the upper body is required. Special consideration is also given to the agility of the fingers, as they need to press keys rapidly and effectively for the actions in the game to be executed. This motor dexterity is mostly necessary in first and third-person shooter, MOBAS and Sports games.

Coordination

In games where map awareness is required, the gamer must be direct and organized in their movements, to avoid the enemy team from spotting them. Hand-eye coordination allows the gamer to respond quicker. Researchers have discovered that sensorimotor skills can be improved through video games, which may also develop the motor coordination of people with Autism [22] and in the treatment of amblyopia [23].

Communication

Interaction between team players can assist to solve in-game dilemmas and increase the chances of winning the game. A good communication skill is essential in multiplayer games, and many gamers have been exposed to negative and positive communication. Negative communication in gaming terminology is known as "flaming". In most online games, if a person insults another or has an inappropriate behavior other players can report them. These reports when accumulated can lead them to being banned from their account in the game.

On the positive side, a study has shown that the collaboration between players in an environment of similar interests and gaming objectives, can lead to the formation of lasting relationships, laying the foundation for a sense of community. Barr demonstrated through his pilot study, that video games have played an important role in development of the communication skill [24].

Analytical Skills

Reputable gamers are known for their thorough understanding of the game, and for their efficient decision-making and problem-solving skills. The mind of a gamer must also be dynamic, ready to reassess itself and the others' actions whenever possible [25]. Their ability to analyze their actions or circumstances affects the positivity of their outcomes.

The common and necessary traits of a gamer are, in a way, endless. The listed above are essential skills seen in professional gamers, which can be developed through gaming.

Authors consider that these are the basic skills a gamer use when playing an entertainment game or a serious game. These skills will be practiced on HCI game to teach/learn.

4.2 Negative Aspects of Playing Games

According to literature there are some negative aspects that a game can have on a player. The principal aspects are violence and addiction.

Violence - A significant amount of research suggests that playing violent video games negatively influences players' behavior in a variety of ways. Meta-analytic reviews [26, 27, 28] discovered that playing video games increases children's aggressive cognitions [29, 30]; aggressive emotions [31], aggressive actions [32], and physiological arousal [33]. McLean conducted a study to determine if there was a connection between gaming violence and concern victims and culpable victims, and the results indicated that a direct correlation was evident [34].

The American Psychological Association [35], in a research review, found that people who played violent video games were very slightly more likely to engage in aggressive behavior (actions like playing a loud sound that people they were competing against could hear over an audio system). However, the APA said playing games was not enough to cause aggression.

Ferguson as a researcher who has studied violent video games for almost 15 years, states that there is no evidence to support these claims that violent media and real-world violence are connected [36]. You, according to a study's results indicated that violent video games have a significant direct effect on aggressive behaviors, and a significant indirect effect on pro social behaviors. Specifically, empathy and behavioral self-control were found to mediate the relation between playing violent video games and pro social behaviors [37].

One of the questionnaire respondents stated that "a game about cooking does not make a professional cooker and a book about advocacy does not make a lawyer… it depends on each one personality and behavior".

Addiction - Technology and gaming addiction have become a concern in recent years as technology use has become ubiquitous. The World Health Organization considers a gaming disorder on its list of mental health conditions. Gaming behavior could be a disorder if it meets three characteristics: if a person loses control over their gaming habits, if they start to prioritize gaming over many other interests or activities, and if they continue playing despite clear negative consequences [38].

The psychological effects of video games might vary depending on how much people play and how they consider games in their way of living.

4.3 Positive Aspects of Playing Games

The main positive aspects, according to literature are stated. Playing games improve people's ability to pay attention and process visual information, and it can also be a way to relax and de-stress. Researchers have found that video-game players can outperform non-gamers on visual tasks, and several studies have shown that video games can 'train' visual processing skills in ways that translate to other activities. Action games can improve visual acuity and ability to find objects in a distracting setting. Video-game players appear to outperform non-game players on several different visual tasks [39–44]. Kids who played sport video games were more involved in sports. The games provided knowledge of the sport, which gave the children confidence to get more connected in the real life [46]. Video games could also improve problem – solving capacities and change the way people learn [16].

People who played shooter games were better able to filter out distractions while engaged in attention-demanding tasks. The players were less distracted by other visual information [45].

Gamers are exposed to a creative process [47]. Creativity is presented, for example, on players' ability to find new, and/or different solutions when facing with problems and situations. Also, sometimes, rules can be managed in very different ways.

Games can elicit a range of emotions, positive and negative. Gamers play video games to relax, feel better and trigger positive emotional responses [48]. This can help to regulate emotions, to learn to cope with situations, and challenge themselves.

4.4 Methodological Approach Analysis

The data obtained from the questionnaires was organized on a table structure. Table 1 presents a short sample. The selection represents differences among the answers and they were randomly chosen.

The table contains the information about the frequency that each student spends playing, which is 2 or 3 h/day in media, the type of games that they play, the information about addiction and playing alone or in teams. Students do not consider themselves addicted. They play either alone or in teams. We were also interested to know if violent games influenced student´s behaviors: all of the answers, to this question, were negative. Concerning serious games, students had different opinions about it. Some of them considered that an entertainment game could also be an educational game. They learn while they play. Games are somehow related with real life situations, which challenge the gamer to act as such. Finally, questions approaching results and outputs permitted to understand some of the positive aspects of playing. The goal was to get information about students' opinions and feelings concerning the importance that playing a game had in their lives. We obtained different answers, for example: knowledge acquisition in different domains; learning survival techniques; communication and collaborative work, and development of different personal skills (handling techniques, thinking fast, solving problems…).

4.5 Final Comments

The information registered on the table structure was then analyzed using GTM approach. Several steps were followed and Fig. 1 presents a summary of the data analysis-using GTM.

From the data interpretation and data comparison processes a list of terms was created, as well as, explanatory texts. On the coding procedure, a category is located at the center and a network of relationships is developed around it. For example, the category "analytical skills" has relationship with "goals" and "ends". These categories were selected from those a gamer uses when playing a game; these are the decisions, priorities of tasks and activities organizations that the gamer needs to execute.

From the final data analysis, on the theory generation phase, we concluded that students agree that learning HCI and similar subjects would be interesting through a game approach. The justification for this argument was based on the answer to the question: "Do you think that a game methodology would be accepted to learn HCI discipline?" Ninety percent of the respondents answered 'Yes'. The others had no opinion. Another reason for the argument gained value from the abilities and skills found from the questionnaires results analysis: Students who play videogames tend to be more creative, make increasing use of their analytical skills and demonstrate higher levels of initiative and entrepreneurship. These outputs are some of the necessary traits for achievement when learning a subject. The game will be designed either for a purpose (to learn) or to entertain. It will be a game environment with techniques and rules to be followed. The results of playing a game will give students the opportunity to learn HCI materials and to pass the course.

4.6 How It Would Be?

Playing games accentuate several students/teachers abilities, such as those referred in this section. To learn a subject as HCI, which is a multidisciplinary field, a game can be an interesting and motivating tool. Before presenting the idea of the game we investigated about a common HCI curricula (Table 2).

Churchill and colleagues stated that HCI students and scholars learn about basic human characteristics and develop the necessary skills to study people's activities with and around technologies. Students need to develop investigative, analytical, technical, communication, and advocacy skills to help them shape interactive technologies that augment people's abilities, enhance their creativity, connect them to others, and protect their interests [49].

According to Churchill et al. study, they presented important survey items across time frames and across populations. They suggest a valuable starting point for articulating a unified vision of HCI education [49].

These authors considered that clear regional and contextual differences became evident, raising concerns about the relevance of a single HCI curriculum that would be globally applicable. This makes sense, and invites an HCI curriculum that acknowledges geographic and cultural differences in terms of user "need" and that offers locally relevant content [49].

From the overall analysis, answers to questionnaires, games content description and literature review, the following outcomes abilities gave us motivation to develop a game for HCI teaching and learning: innovation, initiative and entrepreneurship, problem-solving, risk-taking, continuous improvement, value of effort, disciplinary skills improvement, analytical skills, foreign language improvement, capability of planning and organization, strategy skills, technological competence, independent learning, creativity, responsibility, resource management, among others.

The positive aspects of playing games, as presented on Sect. 4.3 will be considered on the game to study HCI subjects, namely the provision of theories and practices knowledge. The game will require a through understanding, a great analytical and decision-making sense allowing students to be able to gather as much as possible information to digest and apply.

The game will be a learning tool, taking into account the students profile and the field to study in our proposal, not forgetting that suitable tutoring must monitor it.

Table 2. HCI living curriculum [49]

Subjects in HCI	
Very important	Interaction design
Important	Cognitive science, communication, computer science (general), design (general), digital media, information science, psychology (general), sociology, statistics
Topics in HCI	
Very important	Experience design
Important	Accessibility, group dynamics/teamwork, HCI for development, history of HCI, information architecture, social computing, ubiquitous computing, universal design
Interfaces and Displays	
Very important	Desktop, mobile, tablet
Important	Embodied, large displays, shared displays
Input Modalities	
Very important	Gesture, keyboard, sensor, touch
Important	Haptic, location, voice
Design Paradigms	
Very important	Agile/iterative design, experience design, interaction design, participatory design
Important	RIP (rapid iteration and testing), value centered design
Design Methods	
Very important	Brainstorming, field study/ethnography, interactive/high fidelity prototyping, interviews, observations, paper/low-fidelity prototyping, prototyping (general), scenarios and storytelling, surveys, think aloud methodologies, usability testing, wire-framing
Important	Affinity diagram analysis, cognitive walkthrough, contextual inquiry, discount usability testing, focus groups, heuristic analysis, mental models, personal development, remote usability testing
Empirical Methods	
Very important	Principles for empirical research, qualitative research methods, quantitative research methods, experimental methods, problem formation and research design, data analysis, analyzing and applying research
Important	Current research topics, critical evaluation of theory, statistics

Our proposal is to create a game play with pleasurable activities, such as learning. The structure of the game will be characterizes by rules: the rules that define how the game works but also defines the goal of the game.

The interface of the game is expanded. The first is the interface of the computer and an additional interface is a narrative, which teaches the students how to use the game features and how to proceed to achieve the different goals. The narrative provides also an explanation and meaning of the change of rules.

The main goal is that the game to teach/learn HCI will be a game based on some of the characteristics of HearthStone – a cards' approach and the game of Empires – a strategy game. Students will face several challenges such as: playing a strategy game with several levels of difficulties, with problem solving situations. They collaborate with other players; they will have fixed rules to accomplish and feedback for mistakes. Figure 2 presents a draft of the content structure.

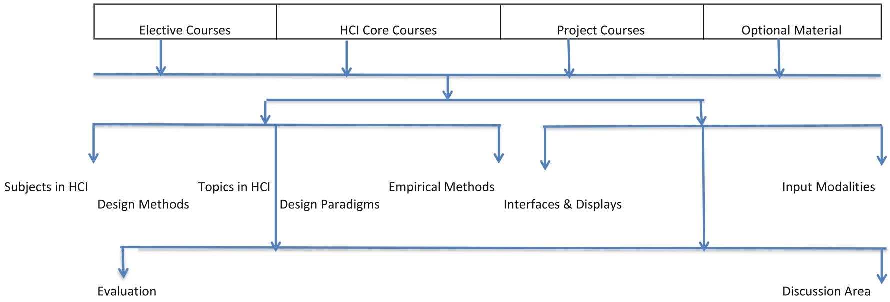

Fig. 2. Game content structure

The context information for the HCI game design is:

– The game should be based on concrete and well defined course aims;
– Objectives must be straightforward settled because it is easier to plan the lessons or modules. Objectives will be broken down into challenges;
– The game will have two options: to be played individually and/or to be played in teams. These options will not be optative, which means there are compulsory tasks to be done by each student and other tasks will be done in collaboration.
– Games could allow students to assess their knowledge for themselves giving them a chance to see where they are having difficulties before a test. The success could be rewarded with immediate admission to the next level, for example.
– The game should include prizes for completing or winning a game. These prizes will be attributed before the final prize (the grade).
– Grades can tell students if they failed to learn something, but for a variety of reasons, students may not make good use of the feedback, but this is another focus.

4.7 Learning Through Games in Other Subjects

This section serves to highlight our proposal, learning through games. Educational games help build a better connection between student teacher and student learning. Games can build an interactive bridge between the participants in education and the motivation of these to complete their tasks. The use of technology is not decreasing any time soon, and we must reap the benefits it has brought us by diversifying it and including it in spaces that rarely see the use of it for other purposes. According to Statista the number of active video gamers worldwide is expected to reach 2.37 billion by 2021 [50]. Therefore, we can assume that a high percentage of students in classrooms are involved in some form or other in video games.

Many education sectors face the increasing need of maintaining the motivation and continuous work of students for the taught subject. The nature of games and education are similar as they both present: goals, objectives, achievements and rewards [51]. For instance, in Music Education we can see a number of game applications designed to increase the participation of all students and facilitate the task of the teacher when conveying ideas to a large number of students. Solfeg.io is an online platform, which provides many activities and games, which aid music teachers in classroom activities. Guitar Hero is a popular music game for 1–2 players available on many gaming platforms such as Playstation, Xbox and Nintendo. This is a rhythm based game utilizes a simulator shaped like a musical instrument. On the screen, a number of colored notes glide down and the player must press these on the simulator at the correct time to achieve the maximum points. This game can develop the rhythmical and coordination abilities of the player. The number of video games directed to music education and other areas is rising. Gower and McDcDowall agree that video games are a valuable addition to education, and are also impactful to the learning and teaching of important fundamentals in Music [52].

Hargreaves and North state that music education should teach children to not just learn but also love music [53]. This belief should be transported through all areas of education. Gower and McDcDowall further state that much importance needs to be given to the potential of interactive video games in the classroom, and that these also act as a breath of fresh-air to the demands of educators and intensive curricula [52].

There is undeniable proof of the benefits video games can bring to the learning and motivation of students. As we approach this digital age, we must also reshape and rejuvenate the present education models to guarantee the preparation and development of our future generations.

5 Conclusion

This study does not contribute too much for research. However, several positive aspects were experienced. The opportunity for asking students about their opinions and suggestions to develop a game approach to teach/learn HCI; the research about games that students play and about studies that other researchers already did concerning this subject gave us important knowledge and cues to replicate or adapt games to use for an educational approach different from the traditional.

Authors consider that the basic skills to play a game are the same of those to play an HCI game: dexterity, coordination, communication, and analytical skills. There are other complementary skills for playing the game, which are referred on the positive aspects of playing a game' section: concentration, visual processing, acuity, engagement, and problem-solving capacity.

The HCI game will improve students' acquisition knowledge in an entertainment scenario approach. It will be a strategic game – with a number of goals around HCI resource collection tools, allowing the opportunity to construct challenges and to engage with other colleagues.

The future work will be the development of a game, which already started, based on the results obtained from this study. The design process is made and the structure to follow is settled.

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Engaging Automation at Work – A Literature Review

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Abstract. Automation pervades workplaces in an increasing pace and its effects on work practices and roles are far-reaching. Work tasks are typically automated with efficiency, effectiveness and safety in mind, but less attention is paid on the user experience aspects. As the amount of direct human control over technology is often decreased with automation, the human aspect of those systems might seem less essential and thus human-system interaction designers may not be consulted when automation is designed. Yet, fully autonomous and unmanned systems are rare, as humans often still have to monitor, intervene, maintain and control the automated environments – be it on-site or remotely. This paper discusses the need for better interaction design of automated systems with a focus on engaging user experiences in work environments. Results of a systematic literature on engaging user experience design in automation solutions used at work revealed that experiential human-automation interaction design is a neglected research topic. Therefore, we call for more research on automation design that improves not only efficiency, i.e., the pragmatic aspects of user experience, but also employee engagement and other emotional aspects of user experience. It is time for a turn to the experiential to take place also in the work automation context.

Keywords: Work automation · Interaction design
User experience · Engagement · Human-computer interaction
Human factors · Literature review

1 Introduction

The amount of research on the human aspects of automation is increasing rapidly. These human aspects include, for example, topics such as human-automation interaction (e.g., [1]), the ethical aspects of automation (e.g., [2] and acceptance issues [3]. However, the user experience (UX) factors with automation especially in complex work environments has gained little scholarly attention [4].

Bainbridge [6] was among the first to briefly discuss some engagement issues of automation, such as boredom, reduced feeling of achievement, and lower job

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satisfaction. User experience research is mostly focused on consumer products, e.g., Hassenzahl et al. [5] raised the question of the experiential cost of automation using a coffee machine as an example. Both lines of research agree that the automated process may become meaningless to the users, and what might have previously been engaging tasks for the users may be degraded to, for example, waiting time [5, 6]. Following these lines of thought, this paper discusses the relevance of designing for engaging automation, especially at work environments where the users of technical systems can seldom decide on the level of automation they want. The specific focus on work here means that we study employees as expert users of automation. In addition, the work context serves as a specific environment for studying engagement, since long-term engagement with the tools at work may often rise from professional, rather than entertainment aspects.

We see engagement as a consequence of successful user experience design, which has gone beyond removing problems and frustration to providing motivating, exciting or pleasurable experiences. The design of engaging user interactions with automation is an important, but largely neglected area of research. Interaction designers may see automation as a threat to their jobs, because the common thinking is that with higher levels of automation, no user interface or human interaction is required. However, workplace automation progresses in stages, and on different levels of automation (LoA, see e.g. [7]), the human operator has a different role. While there are several models of LoAs, it is typical in all of them that the amount of human control decreases with the increasing automation level. In many cases automation can proceed only to a level where human still has the opportunity to intervene and change the decisions of the automated system. This means there will be interaction with many automated systems, and automated systems will have an impact on our experiences with technology [41].

From the human perspective, automation refers to a device or a system that accomplishes (partially or fully) a function that was previously, or conceivably could be, carried out (partially or fully) by a human operator [8]. By engaging automation design for work, we refer to design that changes the related work processes less human-dependent, but with the goal of making the work more interesting for the employees instead of making the work more monotonous and boring, which can often happen [9].

Engagement has been interpreted in many ways, as it can mean different things depending on the context. This paper tackles the question of *what is known about engagement in relation to using automated systems at work.* Our approach to answer the question is a systematic literature review. Specific research questions regarding the literature review are as follows:

RQ1: How much is published about designing experiential automation systems for work contexts?
RQ2: Where this topic is being researched?
RQ3: What are the limitations of the current research?

2 Related Research

Before going into the literature review, it is important to clarify the key concepts of this paper, namely, engagement and automation.

2.1 Engagement with Technology

To better understand the concept of engagement in the specific case of using interactive technical systems at work, we approach the concept from two neighboring research areas: work engagement and engagement with interactive tools. Work engagement can be defined as "a positive, fulfilling work-related state of mind that is characterized by vigor, dedication, and absorption" [10], see Table 1 for details.

Table 1. Work engagement factors by [10].

Factor	Definition
Vigor	High levels of energy and mental resilience while working, the willingness to invest effort in one's work, and persistence even in the face of difficulties
Dedication	Being strongly involved in one's work and experiencing a sense of significance, enthusiasm, inspiration, pride, and challenge
Absorption	Being fully concentrated and happily engrossed in one's work, whereby time passes quickly and one has difficulties with detaching oneself from work

Specifically, we are interested in the role of interactive work tools in the formation of work engagement, and in how to maintain work engagement as the level of automation increases. Therefore, our focus in this paper is on the research of engagement with technology and with interactive work systems.

The definitions of technology engagement are context-specific, and only a few publications in the field of interactive systems provide a definition for engagement. Publications on student engagement in e-learning and beyond provide perhaps the most developed view to the concept of engagement. In this field, [11] identified that the key problem in engagement literature is mixing the state of engagement, factors that influence student engagement, and the immediate and longer-term consequences of engagement, and provides a framework making this distinction in higher education setting. While the context in [11] is not work-related and many of the factors and consequences are not applicable in the domain of interactive tools used at work, we utilize the state of engagement, the factors affecting engagement, and the consequences of engagement as one conceptual framework that we will use in the literature review analysis.

Turner [12] sees engagement with technology as being positive and exploratory. The exploration aspect creates a "space" in which engagement occurs, and this space includes affordances of the technical artefact, which people subsequently exploit. According to [12], people engage with something and continue to do so basically because they enjoy doing that activity. Therefore, affect has an important role in engagement. In addition, people engage with technology, because it allows them to achieve their purposes and these purposes can be considered as a reciprocal expression of themselves (ibid.).

Sidner et al. [19] defines engagement in human-robot interaction as "the process by which interactors start, maintain and end their perceived connection to each other during an interaction". This definition is also applicable with automated systems in which interaction between the human and the automated system is an active one, such as with service robots.

The publications discussing designing for engagement with automation are becoming more popular as the automation level of different environments increases. Automotive user interfaces seem to be the latest arena for engagement research, and in this context, engagement means the focus of attention. For instance, in cars, if drivers are disengaged from driving, it takes around 40 s to resume adequate and stable control of driving [23]. It is clear that in emergency situations, disengaged drivers are not able to react quickly enough. Instead of requiring drivers or users simply to keep their attention in the system, we should ask how to motivate the users to keep their attention on the system. Engagement to us means not only the focus of attention, but also motivation and enjoyment.

As we can see already from the literature above, there are many varying definitions for the term engagement. Since it is hard to follow a single definition, in this paper we build on [10] and discuss engagement in a continuum of short- vs. long-term engagement, from absorption (full concentration in work activities) to vigor (energy and mental resilience) and dedication (e.g., significance, enthusiasm, pride). This helps us to analyse the existing definitions and position them. For example, the definition of Sidner's human-robot interaction [21] engagement is on the short-term side, i.e., during an interaction episode, while work engagement is typically long-term.

2.2 Automation of Work Tools and Relationship with Usability

The strive for more automation in the workplace has been driven by a set of considerations that proved useful before the computer age, but must be reconsidered nowadays. One of the first considerations was the one proposed in the MABA-MABA (Machine Are Better At - Man Are Better At) by Paul Fitts [26] which was considering the best player, according to abstract tasks, between a human and a (steam) machinery (see Fig. 1).

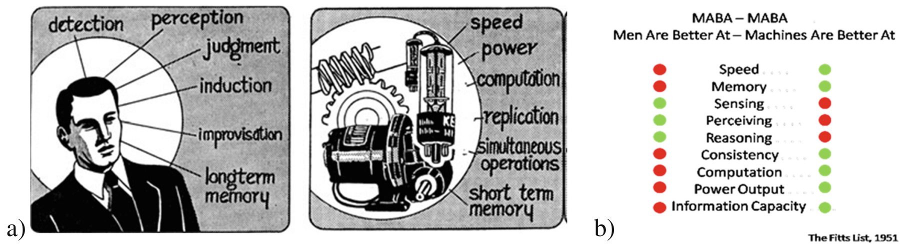

Fig. 1. (a) Illustrations of the Fitts list ([26], pp. 7–8) – (b) MABA-MABA list from Fitts [26]

From this figure it is interesting to note that only in number of functions, machines were better than human (3 positive scores for human and 6 for machines). Carver and Turoff [25] extended this notion of best player, replacing the steam machinery with computer systems (see Fig. 2).

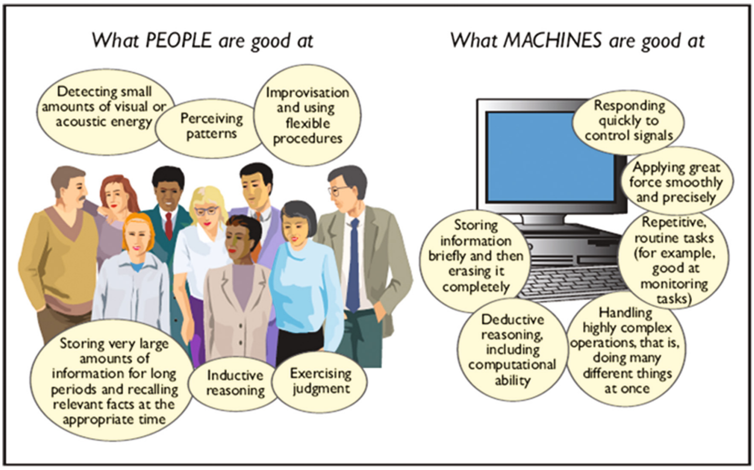

Fig. 2. Best player between human and computer from Carver and Turoff [25]

These two classifications (and especially the first one) have been extensively used both as a design driver and as a mean of assessing the adequateness of function allocation between humans and machines/computers. However, in research, it has been clearly identified that actual work requires the involvement of both machines and humans ("In modern defence systems, the majority of functions need both humans and machines to undertake complementary tasks" ([27], p. 53), cited in [28]).

Another major consideration pushing towards more automation in the workplace, came from studies on human error. Indeed, while some HCI contributions such as the Human Processor Model [29] were describing human behaviour as "flawless", other work (e.g. [30]) was highlighting that (within this human processor model) there was room for error within each processor (perceptive, cognitive and motor). While computer technologies were not getting more reliable (due to the fact that the computing field is evolving at high speed), the human error was always seen more prominent due to the impression that systems failures can always be fixed and fixing human errors is (due to the human nature) unfeasible. It was only much later that work from the dependable computing field was providing a more comprehensive view on failures, errors and faults integrating both human and systems errors in a single conceptual framework [31]. This kind of work highlights the fact that having more automation does not mean less errors as automation will fail, at least as much as other parts of the system will fail.

The fact that human and partly-autonomous systems are jointly involved when work has to be performed requires preventing as much as possible errors from both sides keeping in mind that allocation of function between the two is not a "zero sum" game: "automating a function does not necessarily result in a reduction in workload equivalent to the human work necessary for that function" [42]. This means that human work and the technical system with which the working human is cooperating have to be carefully designed. It also means that considering that the human will be able to take over when automation fails is not acceptable [43], especially when automation has been designed to replace the human operator.

An example of careful design can be taken from aeronautics where the accident rate is so low (less than one in ten million flights for the new generation of large civil aircrafts) that the underlying processes can be seen as exemplary.

Landing an aircraft may be perceived as an activity requiring very highly skilled operators and being safety critical, as an error might have catastrophic consequences. However, since the early 40 s work has been carried out by the aircraft industry to provide pilots with an Autoland function. It was only on December 28th 1968 that the first civil aircraft (Airbus Caravelle) was qualified to use the Autoland function with a focus on reliability of the system offering segregation, diversity and redundancy mechanisms. Landing activities require performing flare (the nose of the plane is raised), managing thrust (reducing the value gradually), managing the roll (rotation of the aircraft along the axis running from nose to tail) and managing the alignment with the runway. Developing the Autoland function was done gradually performing first AutoFlare only, then adding AutoThrottle servos to handle thrust, and finally utilizing the autonomous management of roll leading to a fully autonomous landing system. While this system replaces humans very efficiently when visibility is low (including levels of zero visibility) its use is also extremely limited depending on other weather conditions, such as wind. For example, for a Boeing 747-400 the limitations are a maximum headwind of 25 kts, a maximum tailwind of 10 kts, a maximum crosswind component of 25 kts, and a maximum crosswind with one engine inoperative of five knots. This demonstrates the fact that careful design and deployment of automation in the workplace might increase feasibility of operations and the overall performance of a system. However, while work (and working conditions) and automation are considered, nothing is said about user experience and engagement of operators in such contexts even though the Hedonist magazine has a dedicated column called "on wings" dedicated to flying aircrafts [1].

In other domains such as walk up and use systems, automation is added mainly to reduce required labor and thus to reduce the cost of workforce. This usually comes along with a reduction of the number of tasks covered, more sequential tasks, more cumbersome and less enjoyable. Cash machines are a widely used example demonstrating this when comparing with getting cash at the cashier. At the cashier, one can request a 100 Euros note because it is green and the person wants to make a green gift to a kid. In the user's own branch, it is often not necessary to prove identity as the cashier would know personally most of the clients. At the cashier, a PIN number and a card are not required, etc. Beyond cost of workforce reduction automations increases ubiquity and availability of service throughout the day. 2.3 Designing Interactive Systems for Engagement

Designing for engagement shares much of its history with user experience (UX) design. UX has been a research topic, since the 3rd wave of human-computer interaction started to pay more attention to the emotional, and not only the pragmatic aspects of technology use [13]. Since user experience design in practice often equals to user interface design and simply improving usability, we chose to focus on engagement, which requires more than problem-free use of interactive systems.

Ramsay, Barbesi and Preece [14] were among the first ones to raise engagement as one of the web site design goals, and since then, the means for designing for engagement has been studied, for example, in the contexts of e-learning [15–18], games [19], and interactive public displays [20]. In automation contexts, designing for engagement has been mostly studied in human-robot interaction (e.g., Sidner et al. [21]; Rich et al. [44]), especially with service robots. Robots are one way to replace human work with automation, but at workplaces, automation often comes in other forms.

3 Method

The main method used in this work, a systematic literature review, aims to find all scientific literature in a specific topic. According to APA [45] p. 10, literature reviews can help to

- define and clarify the problem;
- summarize previous investigations to inform the reader of the state of research;
- identify relations, contradictions, gaps, and inconsistencies in the literature; and
- suggest the next step or steps in solving the problem.

In this chapter, we report the literature review method used in this research, including the suitable parts of the structure recommended by Kitcheman et al. [24]. The publications filtering process was similar to the one used in [22].

3.1 Search Process

First, we tested three databases of scientific publications to investigate their coverage of relevant publications in the area of engagement with automation. Scopus database was selected, as the search with keywords 'engagement' and 'automation' yielded the highest number of publications. The final search was executed in October 2018.

The search process was done in 4 phases. In phase 1, one of the researchers executed the Scopus search and extracted the results to a table with publication information, including the title, keywords and abstract. In phase 2, the researcher checked the keywords and title to estimate the potential relevance of the publication. The same continued in the phase 3, where the researcher evaluated the abstract. In the last, 4th phase, the full text was studied to determine relevance of the remaining publications. In this last phase, the selection of potentially relevant publications was distributed to three researchers, so that each publication was examined by one researcher.

3.2 Inclusion and Exclusion Criteria

During the 4 phases of filtering, we included publications that focused on the engagement while interacting with automated systems at work. We did not set any criteria for the quality of the publication venue or publication. In phase one, the search keywords were selected based on our focus on *engagement in relation to using automated systems at work*: 'automation', 'work', 'interaction', and 'engagement'.

Based on the initial search results, which were very limited, we expanded the search criteria to cover not only 'engagement' but also any emotional user experience, and not only 'automation' but also 'cyber-physical' as we expected cyber-physical systems to be used in industry. Conference reviews (cr) and other reviews (re) were excluded from the search criteria. The final search phrase for Scopus was:

TITLE-ABS-KEY ((automation OR cyber-physical) AND work AND interaction AND ("user experience" OR engagement OR emotional)) AND (EXCLUDE (DOCTYPE, "cr") OR EXCLUDE (DOCTYPE, "re"))

In phases 2 and 3, evidence on emotional aspects in work automation were searched from the keywords, title, and abstract. Publications that were clearly out of scope were excluded, others were kept in for a more careful study. The most typical reason for exclusion was that 'work' did not refer to a work context, but 'work' appeared in phrases referring to the research reported in the publication, such as 'this work' or 'future work'.

In phase 4, a more thorough evaluation of the full publication was done to see if the publication was reporting some emotional aspects of interacting with automation systems at work. The most typical reason for rejection in this phase was, still, that 'work' did not refer to work context. In addition, papers that did not investigate human-automation interaction were excluded at this point of the filtering process.

4 Results

4.1 Search Results

The total number of publications found in phase 1 with the Scopus search phrase was 56. In phase 2, 19 publications were excluded based on keywords and abstract. Out of 37 publications entering phase 3, 26 were excluded based on the abstract. Out of these, 22 were excluded because they were not addressing work context, but smart home or city, or e-services for elderly or young people. One publication was excluded because term 'automation' was appearing only in the copyright statement that Scopus appends to the abstract (International Journal of Automation and Smart Technology). This paper was not about automation but smart technology and thus, did not fulfil the search criteria. Another publication was an extended abstract of a keynote talk, which did not go into the required level of detail to be analysed. Two other publications were excluded in this phase due to lack of automation or human-automation interaction focus.

Only 11 publications made it to phase 4, the full text study. Out of these, one was excluded due to lack of work context and one because it discussed human-automation interaction only as a motivation behind to the reported risk management study. The remaining nine publications are discussed in the next section.

4.2 Relevant Publications

The nine relevant publications were analyzed by the three main characteristics of relevant applications: Automation, Engagement/User experience, and Work context. A short description of each publication follows with analysis on the engagement.

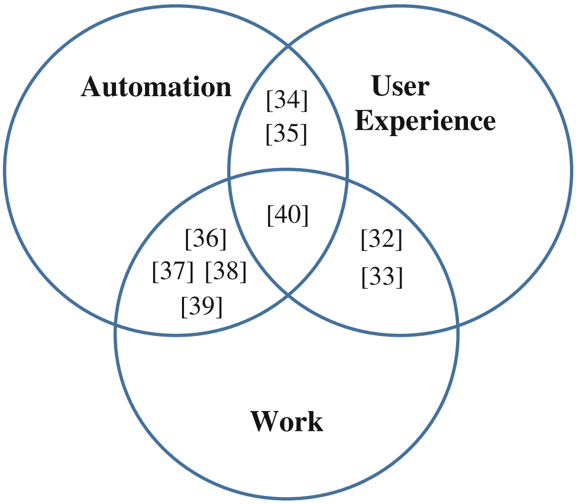

Fig. 3. Positioning of the literature with respect to the three relevant aspects; user experience/engagement, automation, and work.

[32] presents a prototype that exploits gesture-based interaction technique in the domain of flexible manufacturing systems (partly-autonomous loading stations controlled by operators). The objective of the paper is to assess the impact of novel interaction techniques (more precisely gesture-based ones) on user experience. While the loading stations are party autonomous, the paper focusses on UX (especially emotional UX, frustration and competence) and the work of the operators in terms of tasks. In that paper, automation is not part of the design space and is only considered as a behavioral aspect of the loading stations. For this reason, the paper appears in Fig. 3 at the intersection between Work and User Experience.

[33] looks at the UX elements in machinery automation from interaction design perspective. In addition, the authors describe the design implications of these elements and the benefits and challenges of applying UX to this domain. However, in the paper, machinery automation is used as the name for big machines in mining and forestry. Therefore, it is not related to automation beyond the actual device. Based on this, taking into account the sections in Fig. 3, the paper recognizes very well the aspects of work and UX, but not automation and thus appear in at the intersection of Work and UX.

[34] present a prototype called intelligent interaction and emotion that offers to a user a standard WIMP (Windows Icons Menus and Pointing devices [46]) user interface to control an air-cleaning device. The command and control system embeds contextual information affecting its behavior and good user experience is triggered by the possibility of breathing air of good quality produced by the device. For this reason, the system (device + command and control system) is autonomous and automation is distributed between these two components of the system. As this device belongs to the category of home appliances, it does not contribute to the work to be carried out by the user. This paper thus appears at the intersection between UX and Automation in Fig. 3.

[35] presents a theoretical study about how current emotional status of persons influence their reliance on automation. The case study is taken from security scanning systems (for instance at airports) and the use of an Automated Weapon Detection system. The experiment has only been performed with students and does not relate to any work practice, hence its positioning at the intersection of automation and UX in Fig. 3. However, the paper concludes that positive emotional status increases reliance (i.e. likelihood to follow recommendations from an autonomous system) on automation.

[36] is a theoretically oriented paper examining how to combine the two traditions of activity theory and semiotics. In specific, the interest in [36] lays in analyzing technology-mediated work both from activity theory and semiotics perspective. The paper discusses various automation examples from ship control and wastewater treatment domains. The emphasis is on understanding the work activity and automated tools used in work. However, the UX or engagement aspects of these automated tools are not considered in the article, so this publication is placed in the intersection between work and automation in Fig. 3.

[37] is a practical paper describing the technical solution for the use of smart glasses as part of a cloud computing system in factory context. [37] aims to improve employee experience by freeing their hands to the actual work with wearable glasses, and by making communication more fluent with real-time video coming from the glasses to, e.g., the helpdesk operator. This makes communication between the back office and the shop floor more effortless, therefore we categorize this work as a work automation case. Beyond the general recommendation of using wearable technology, the paper does not discuss emotional aspects of automation. Therefore, it is placed at the intersection between work and automation.

[38] is very similar to [37] in its approach to provide good experiences in context of industrial fieldwork via wearable technology. The user experience goal is to provide employees "the right information to the right user at the right time and place". In addition to this pragmatic user experience, the emotional experiences of workflow automation are not discussed. The paper lists workflow automation as one of the keywords, and we categorized it as such a case: it is about automation and work but not about engagement.

[39] focuses on training for operators in the domain of manufacturing systems. The paper presents a tutoring system exploiting augmented reality interaction techniques integrating motion detection and force feedback. When manufacturing systems are getting more complex and embed more automation, classical on-the-job training is more difficult to perform. The paper is thus centered on work and how automation influences the acquisition of needed skills to perform that work. The user experience aspect is only touched in the paper through the notion of emotional knowledge (i.e. trainees and trainers being able to share information together with the emotions they were feeling), which was facilitated by the new technology made available at training time. The publication was placed between Automation and Work.

[40] investigates conducting experience design research in industrial work context based on UX goals. The particular focus is on a science-fiction prototyping method: how to utilize futuristic interaction videos as means of UX-goal driven design. The system featured is an automation system utilized in a production environment.

Therefore, all the three elements of UX, automation and work are featured in this paper and the paper is placed in the middle of Fig. 3.

5 Discussion

The overarching research question that motivated this study was *what is known about engagement in relation to using automated systems at work?* The answer is simple: very little. This paper reported a systematic literature review in the intersection of automation, work, and user experience/engagement, and identified only one publication covering all three. Due to this limitation, eight closest works were included in the analysis as well. With this set of publications, we were able to answer our four specific research questions:

RQ1: How much is published about designing experiential automation systems for work contexts?

The literature review revealed a clear lack of research in the area of engaging work automation. Even after expanding the scope from engagement to user experience and emotional aspects in using automated systems, only one publication was identified to cover automation, work, and engagement or user experience.

RQ2: Where this topic is being researched?

It was interesting that 4 out of the 9 publications closest to the scope of this research originated from the Nordic countries. These countries are the ones that developed the participatory design approach to take the employees' perspective into account when designing work tools. This is known as the Scandinavian Tradition of democratic design. It is thus not surprising that the first publications introducing human-centred, experiential design of automation at work come from Scandinavia, especially Finland [32, 33, 35].

RQ3: What are the limitations of the current research?

Automation is a vast field of research. Thousands of scholars are studying automation from technical, business, societal, human factors, etc. perspectives. Similarly, the research on work expands to various topics with a huge volume of scientific publications. Also user experience research has exploded during the previous years, as businesses have realized its importance to long-term business success. Given the volume of research done in these three fields, it is surprising that only a handful of scholars have investigated user experience of automation in work context. The answer to question of the limitations in the current research is simple: there is still a very limited number of publications tackling this recently born research topic.

5.1 Limitations of This Study

A literature review is always dependent on its defined scope. We used only one literature database, Scopus, for this literature review, so the set of literature might be wider if other databases would have been covered. This literature review required the search keywords to appear in the title, keywords, or abstract of the publication.

While we consider this search criteria adequate to find the key publications focused in the specific scope of ours, more examples of engaging work automation could be found in publications whose main focus is not on this topic. Finally, the selection of search keywords limits the scope of literature reviews, and the review could be expanded by adding new keywords.

6 Conclusions

We have discussed the concepts of engagement and automation, reviewing their definitions and providing examples. We found that these concepts are highly context-sensitive, and there is little research on them in the work context.

Automation design requires a multitude of skills and cross-disciplinary research, as automated systems should be reliable, dependable, resilient, secure, usable, accessible, and provide good user experience. Much attention has been placed on the first aspects, but on designing for user experience in automation where users' role is to monitor, intervene and control automated processes is still in its infancy. As working with automation is an increasing part of our life, the experiential aspects, such as engagement, become more important.

For safety-critical environments, increasing engagement via playfulness or gamifying the work might not be a good approach as these types of activities can draw too much attention and compromise safety in some situations. Especially, engagement to secondary tasks on the cost of the primary task would not be beneficial in work environments.

The concept of user experience is not well defined, therefore, it is hard for automation researchers to start working on this area and publish their research. Also the definition of engagement is highly context specific, and there are different interpretations of it even within the field of automation. In the case of car driving, engagement refers to the driver's focus of attention (e.g. in [23]), while in human-robot interaction, engagement refers to the perceived connection between the human and the robot during their interaction ([21]). The analysis of engagement literature, reported in chapter 2, we found it useful to analyze the definitions of engagement on the continuum from short-term to long-term. As the focus of this research is on work context, we are promoting engagement with automation as an emotional, motivational concept, in line with Schaufeli et al.'s definition [10] of the concept of work engagement.

This paper reported a systematic literature review to tackle question *what is known about engagement in relation to using automated systems at work.* The nearly empty intersection of automation, work, and user experience research in Fig. 3 may be due to the following reasons. Bringing automation to work context is motivated by increased efficiency and workforce savings, and the role of employees is seen disappearing as automation proceeds to levels where human operation is not required any more. Therefore, the human aspects in automation are considered of minor importance, while full attention is placed on the internal functionality of the automation system.

We hope this research opens the discussion on the need for further investigation of the experiential aspects of automation systems. A natural next step in future research is to broaden the literature review to automation engagement outside work context, and then test if the means of engagement in other contexts are applicable in the work domain. Since this literature review pointed us to an unexplored territory of research at the intersection of engaging user experiences, automation, and work, the list of relevant research questions for this area is long. Some of the interesting questions include:

- What does good user experience mean in case of work automation?
- How does engagement with automation differ at work and in leisure contexts?
- What does appropriate level of engagement mean in case of work automation?
- How can automation systems contribute to improving work engagement?
- Is design for engagement possible before acceptance and trust are there?
- What are the engaging interaction techniques and data visualizations for work automation?

The fundamental idea behind this work is that automated systems do not entirely eliminate the interaction between humans and the system, but there are different levels of human control. Humans must be able to intervene automated processes when needed. Instead of dismissing user experience design for automated systems, we need to rethink the interaction style [41]. The need for good user experiences does not disappear with automation.

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Methodological

Artificial Intelligence Awareness in Work Environments

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Abstract. Based on the concepts of situation and automation awareness, we present a new concept called "artificial intelligence awareness". We also examine in detail how these three phenomena relate to each other particularly in work environments. To open this discussion, we shortly go through the ideas behind these concepts and focus especially on artificial intelligence (AI) from the machine-learning perspective and on some related human-AI interaction issues. In addition, we present an illustration of a theoretical taxonomy where our understanding of the relationships between the three key awareness concepts is visualized. We conclude by giving pointers for further research and design regarding how to support automation and AI awareness of intelligent systems users in work environments.

Keywords: Artificial intelligence · Work · Automation · Situation awareness AI transparency · Intelligent systems · Trust in automation · Human factors

1 Introduction

We are living in an era of work transformation: much of routine work tasks have already been replaced with different kinds of automated solutions. It is foreseeable that in the future increasingly complex work assignments will be taken care by automated systems that use artificial intelligence (AI). On the way to that change, new kinds of interaction issues in work environments between automation, AI and humans need consideration. Already now it has been noticed that in automated work environments the workers might not be in some situations able to understand what the complex automation is doing, why it is doing that, and what it is going to do next.

Related to these issues, the concept of automation awareness (AA) has been recently discussed [1–4] as a human factors concept to be taken into account with modern automation solutions. Similarly to what good situation awareness (SA) allows in complex work environments, AA enables the workers to stay in the loop with the automated system and operate it in an appropriate way in highly automated environments. An example of a complex work environment here could be ship operation from the command bridge of the ship. In contrast, as a highly automated environment, the remote monitoring (and possible intervening in case of exception situations) of the operations carried out by an autonomous ship from an office-type control room could serve as an example. We see that AA becomes important especially in the latter case, but it nevertheless does not exclude SA as the remote operators still need to comprehend and take into account also the demands of the work situation at hand in the object environment.

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Currently, novel technologies for work environments are being rapidly introduced to address the increasing demand for systems with adaptive and autonomous capabilities. Many new advances are based on different AI technologies, such as machine learning (ML), which includes also deep learning (DL). An example of these technologies in the work context would be predictive maintenance approaches, which can detect anomalies in temperatures indicating a possible upcoming engine failure. We see that the increase of these AI technologies brings along further awareness-related interaction challenges for the users of these systems.

The focus of this paper is to consider the concepts of SA, AA and AI awareness (AIA) and discuss how these phenomena relate to each other especially in work environments. To open this discussion, in this paper we suggest a theoretical taxonomy where these concepts are visually presented to illustrate their relationships between each other. However, before going into the details of this taxonomy, the definition of the related key concepts and issues here is essential.

2 Definition of Key Concepts and Issues and Their Relevance to the Topic

Key concepts related to this paper are situation and automation awareness, artificial intelligence, machine learning and artificial intelligence awareness. Next, each of these concepts and their relevance to the topic of this paper will be discussed in detail.

2.1 Situation and Automation Awareness

The most cited definition of situation awareness is the one by Endsley [5], who stated that SA is '*the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future*'. Therefore, in detail, this definition presumes three separate stages referring to different information processing events: (1) *the perception* of relevant data and elements in the environment, (2) the interpretation of these perceptions and *the comprehension* of their meaning for the situation at hand, and (3) the ability to *project* how these elements will change in the future [5]. In this paper, we utilize these three stages to consider also other types of awareness concepts (i.e., automation and AI awareness), which we see are relevant in highly automated and artificial intelligence-supported work contexts.

Automation awareness has been mentioned in previous human factors literature (e.g., [6]) already, but it is not yet an established concept. In line with the definition of SA stages by Endsley [5], the development and maintenance of AA has been defined as a continuous process that comprises of perceiving the current status of the automation, comprehending this status and its meaning to the system behaviour, as well as projecting its future status and meaning [1]. From a work contexts' operational perspective, AA can be seen to be the worker's conception of the utilized automation system's state in such a manner that enables the operator to observe, control, and anticipate the events initiated by the automation [7]. Therefore, the difference of AA to SA is that in AA, the focus of awareness is specifically in the automation system. Therefore, we see that AA can be counted to be as a part of SA, which is a much broader concept concerning all the relevant matters in a situation.

2.2 Artificial Intelligence and Machine Learning

Artificial intelligence is another concept without a single agreed definition. Some of its definitions focus on the capability of an AI-based technical system to understand its environment and make rational decisions accordingly (e.g., [8]), whereas others emphasize the technologies used to develop such capabilities. In this paper, we focus specifically on the group of AI technologies with machine-learning characteristics.

Much of the current excitement around AI technologies is based on the advances in ML methods, which are increasingly founded on the utilization of artificial neural networks (ANNs). ML technologies have produced impressive results, especially when trained with large data sets – the approach now known as deep learning [9]. DL includes a network of mathematical connections (or neural networks) that are initially random. However, through trial and error, for example, by using manually pre-labelled data, this network modifies its connections so that it is capable of generating robust predictions. Simply put, the network's "routes" towards successes are strengthened, while the error-producing connections are weakened in the learning process.

In industrial work environments, ML technologies can be used, for example, in various image processing and object recognition tasks. These tasks are needed especially when building advanced sensor systems for increasingly autonomous machines. An example of this kind of machine could be an unmanned and autonomous forest harvester that has been trained with machine learning (e.g., by going through a large number of pictures where certain types of trees have been pre-labeled) so that the harvester's environmental sensors are able to detect the trees that are supposed to be cut from the forest.

Additionally, ML technologies are planned to be used in work environments in different decision-making tasks, such as path planning of autonomous vehicles. This kind of decision-making is typically based on complex algorithms that process data, for example, from the system's environmental sensors and their sensor fusion. For instance, an autonomous car should be able to detect objects (e.g., the road, people, traffic signs, and other cars) from the environment to be able to adjust its speed, plan its path and navigate accordingly. In addition, for example, vehicle-to-vehicle communication may be utilized, which can also potentially increase system complexity from the perspective of the users and bystanders.

2.3 Underlying Machine Learning Paradigms

While a majority of ML applications utilize ANN algorithms in their implementation, there are also underlying fundamental ML paradigms that need to be considered when moving towards increasing machine system autonomy and in supporting AIA. These paradigms can roughly be divided as follows [10]:

1. Supervised learning is used in situations where training data includes both the input data and the corresponding desired results. Typical use cases are classification and regression problems. In classification, the input data is placed in predefined classes, such as in the harvester image classification example discussed above where a pre-labeled data set of trees may be used for training. Regression problems, on the other hand, involve the prediction of continuous variables. For example, a prediction of a

machine system performance can be performed based on sensor data if the historical data of relevant parameters is available. Due to their versatility, supervised learning methods are currently the most widely used ML method.
2. Unsupervised learning is used when only unstructured data is available. In other words, this refers to a situation where no labeled training data is available and the aim is to describe the dataset in a useful way. This description can be achieved, for example, by clustering the data or by detecting anomalies from the data [11].
3. Reinforcement learning is based on the interaction between the AI system and its operating environment. A reinforcement learning system observes responses of the environment when performing various actions and the system is "rewarded" for desired responses. While supervised and unsupervised learning paradigms are powerful for various perception and classification tasks, reinforcement learning provides a potential solution for implementing dynamic decision-making capabilities [12].

Implications of ML Paradigms for AIA

Each of the above general-level ML paradigms contain a number of different methods and algorithms that can be used for the actual implementation. From the system user's point of view, it is not typically evident which paradigm (or, even on a more detailed level, which algorithm) was used to implement the system. However, the implications of these paradigms for ML system design and AIA are important: the user should be provided with sufficient information about the limitations there might be associated with the ML system, because of the paradigm it is based on.

For example, a supervised learning system should be capable of providing the user a sufficient overview of the data it has been trained with, and to demonstrate the limitations arising from the used data. For reinforcement learning systems, on the other hand, it could be beneficial for the user to be aware, for example, of the logic how the ML system is rewarded for its various actions.

2.4 Unsolved Issues in AI-Worker Interaction

While the use of AI technologies can be seen as beneficial from a purely technological point of view, there are still major unsolved issues regarding their use in work environments involving the systems' interaction with workers. Some of these key issues will be next discussed in separate subsections.

System Transparency

System transparency refers to how transparent the functioning of the AI is (see, e.g., [13] and [14]). In this context, AI awareness means that the human is to some extent able to understand the process and estimate the results of ML and can therefore decipher the decision-making rationale of the AI system. This comprehension can be supported, for example, with understandable explanations of the process, reasons behind certain decisions and results, and simplifications or illustrative visualizations of the used algorithms to tell the human about the basis of how they are working and why they ended up in a certain solution. In this way, the worker can anticipate the functioning of the intelligent system in the work context the system is utilized.

Consequently, the worker should also be able to better understand the grounds of the possible decisions made by the AI system and choose whether they are made on a suitable basis or not considering the work situation at hand.

Currently, many ML systems can be described to some degree, as "black boxes", which process input data and produce predictive outputs without providing a clear logic or justification for the results. The deep neural networks include a myriad of connections that have been produced through trial and error training and the particularities of these networks are therefore not easily understandable for the user. To support AI transparency, the black box of ML should be replaced by a more transparent one, which tells simply and clearly the intentions, capabilities, and limitations of the systems in an easily understandable format for the human. We know this is a difficult task, but at least the probabilities of the predictions in tasks, such as image recognition, could be presented for the user to enable the estimation of their reliability.

In addition to the probabilities involved in the output parameters, a worker using and monitoring an AI-based system should have a generic understanding and view of the input parameters. For example, the worker should understand what variables produce the predictions of the AI system. By understanding this prediction basis, the worker could have a better understanding on the limits of AI system; for example, the system might not be comprehensive enough and might not consider all the possible elements involved in the generic situational awareness. For instance, a fire-detection system AI's object detection functioning might or might not involve data from a smoke-detection system. With smoke detection-based input variables, an AI that would try to detect, for example, wild fires, could provide results different from object detection based on thermal camera technologies only.

Furthermore, a skilled worker's understanding could cover the data used for AI-based learning and its generic mechanisms. We now know that AI can involve certain biases. For instance, it has been claimed that AI used as a risk management tool in profiling people involves indicators related to race and age, and identifies as risk those who have never committed a serious crime [15]. A worker should therefore understand that the predictions (and the functioning that results out of these predictions) are, indeed, predictions and not a certain truth. Hence, work system user interfaces should also support this kind of understanding with their design.

Computer-Human Communication

Computer-human communication refers to both the ways in which the AI system communicates its functioning, intentions, capabilities, and limitations to the user and also to the possibilities of the AI to understand human communication. Many of the ways to communicate the state of the AI in modern intelligent systems are far too complicated to be understood by non-expert users (e.g., log-type textual representations that include all the previous command actions of the process). To compensate this problem, for example, simplifications and clear visualizations are needed. We see that, for instance, explicit information visualization techniques, multimodal output user interfaces and interaction technologies that are natural for humans are in a key role here. For example, modern multimodal output user interfaces, such as subtle ambient sound feedback or augmented reality may be useful in some situations.

Vice versa, the communication of humans understood by the computer is an important human-computer interaction question. Natural ways of humans to communicate include, for example, voice or gesture input. However, regarding input communication methods from human to the computer it should not be forgotten that often the traditional solutions, like mouse and a keyboard, are actually rather efficient ways of commanding computers. Often, in the longer term fancy input systems may become tiring, tedious and frustrating especially in routine tasks.

Regarding more implicit human to computer communication issues, for example, Medina-Mora et al. [16] present The Coordinator tool, which allows creating and managing reports of conversations based on the universal vocabulary of speech acts. The goal of this tool is to enable a structure of interactions that is effective for coordination within work organizations [17]. Related to the possibilities of AI, the Coordinator type of approach might be beneficial in trying to understand how computers could be able to know from implicit information what humans are doing (e.g., praising vs. insulting) or aiming at when we, for example, utter something on a certain (e.g., cheerful vs. aggressive) tone of voice.

Appropriate Trust

Appropriate trust in this context refers to how the worker can trust the AI, based for example, on gained knowledge that the AI system has been developed using a sufficient amount of relevant data, or that the system has learned the required skills without becoming biased. According to Lee and See [18], trust can be defined as the "*attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability*". In this paper's context, we see that the 'agent' is AI, which is used by human beings for a variety of different work-related purposes.

In case of ML, to calibrate the trust in AI to an appropriate level (see [18]) the user has to have a clear idea of the capabilities of the used algorithms and also what kind of data has been used in the machine learning process. This would allow mitigating the possible problematic effects of overtrust or distrust in the results of the AI.

In case of overtrust, for example, accidents may happen in safety-critical environments as the worker trust the system in situations it should not be trusted. In a distrust situation, possible inefficiencies from the functioning of the human-AI team operation perspective may occur as the human does not trust the system and tries to do everything manually by herself. We also see that here, intuitive visualizations with possible simplifications of the ideas of how the AI algorithms work may help in calibrating the trust to an appropriate level. In this way, the AI-based system in question can be made more acceptable and successful among the workers using the system.

2.5 Artificial Intelligence Awareness and Affecting Matters

Our proposed concept of artificial intelligence awareness is related to all of the above-mentioned three types of theoretical human-AI interaction issues. AIA in work environments can be defined based on the previous definitions of SA and AA as *the worker's perception of the current decision made by the AI, her comprehension of this decision and her estimate of the decision(s) by AI in the future*.

In contrast to theoretical issues, on the practical level AIA is very much based on the ways for the worker to gain understanding about the AI's functioning. This understanding is affected by concrete matters, such as (1) the AI system's user interfaces, (2) the provided AI-specific training of the work organization, (3) the worker's general knowledge of the principles of computer systems and AI, (4), momentary high level of cognitive workload of the worker, and (5) the worker's subjectively experienced level of complexity of the AI system. Next, each of these factors will be discussed shortly in detail.

Firstly, if the system's user interfaces are badly designed and the usability of the system meant to provide a view to the functioning of the AI is poor, the workers will be able to follow the AI's functioning less. In the worst case, the system does not provide a possibility to follow the functioning of the AI at all. This may ultimately result in human overtrust in the AI system, as the workers have no other choice than to trust the system even in situations where it was not originally designed to cope with. Especially in exceptional situations such as AI-related faults, it is essential to provide information in the user interface about where the fault originates and what are the possible options for next steps.

Secondly, the training provided by the work organization is in a crucial role. Both the increase of theoretical knowledge and practical skills development related to the AI system is essential in training. Theoretical training may focus, for example, on the functioning principles of the AI and the limitations of the system. The training should therefore also consider situations in which the AI may make wrong decisions, the reasons behind these decisions and what to do when this type of a situation happens. Practical skills can be trained, for example, in simulator environments where different scenarios are practiced in hands-on situations. In addition, the AIA of the worker in different simulated situations may be evaluated with various human factors oriented methods, such as interviews and surveys.

Thirdly, the worker's general knowledge of the principles of computer systems and AI is relevant. Even though the worker does not necessarily have to have a background education in, say, computer science, in the future, the understanding of the functioning of algorithms and intelligent systems becomes increasingly important in many work domains. Basic understanding of different logic operations and Boolean algebra may help in deciphering the basic functioning of computer logic. In some cases, similar logic symbols are used even in the user interfaces, operating procedures and manuals of complex intelligent systems, which makes understanding them even more relevant.

Fourthly, momentary high level of cognitive workload of the worker may affect the level of AIA in specific situations. The worker is less likely to follow the functioning of the AI if other tasks cause too much cognitive workload. Therefore, smart and adaptive solutions are required to take into account the user's current task so that AI-related information is not given in situations where the user is not able to focus on the given information because of being busy with other relevant tasks.

Finally, a high level of subjectively experienced complexity of an AI system makes the development and maintenance of AIA harder. The objective structure and couplings of the AI system work as a basis for the subjective experience of the complexity of the system. However, also, for example, the views of colleagues affect subjectively experienced complexity of the system as well. In a teamwork setting, the experience of subjective complexity can also be lowered by joint sense making among the team regarding the AI system and its functioning.

With the influence of the above-mentioned factors, along with many others as well, the worker forms a mental model about the AI system. This model works as the basis for creating AI awareness in different work tasks conducted with the system. However, the mental model does not necessarily have to include details about the AI system's functioning, because a general-level understanding of the system's functioning is often enough to form an understanding about is the system is working correctly and the end-result credible. Ultimately, a clear overview mental model of the system helps in developing and maintaining an artificial intelligence awareness that forms the basis of safe and efficient work activity.

3 Taxonomy of Situation, Automation and Artificial Intelligence Awareness

We suggest that the awareness-related phenomena presented in the previous chapter enclose each other in the following way: AA encloses AIA, while SA encloses both AA and AIA. To illustrate this theoretical taxonomy, we present AIA inside of AA and AA inside of SA in Fig. 1. The stages of awareness of all the three concepts in the figure are based on the three-level SA model by Endsley [5]. However, instead of the linear cognitive information processing approach behind Endsley's original SA model, the circular form of this illustration refers to the formation of SA, AA and AIA as a continuous process, along the lines of Ulric Neisser's [19] idea of action-perception cycles in human cognitive activity. This view of SA is also similar to the situated cognition perspective, which emphasizes how the current awareness of a situation effects the process of acquiring and interpreting new awareness in an ongoing cycle [20].

The different shades of grey used in the circles of Fig. 1 do not have any other function than just to more clearly separate the circles from each other. However, the thickness of the circles in Fig. 1 indicates the broadness of the awareness in question: SA can be seen as the broadest awareness, as it includes also AA and AIA inside of it. Naturally, there is a lot of interaction between these different levels of awareness and in practice, the formation of a certain level of awareness is as clearly separated in reality.

The presented model also bears similarities to the semiotic theory of Charles Sanders Peirce [21]. We see that in Fig. 1's awareness circles, the perception level refers to the sign, the comprehension level refers to the object, and the future estimate refers to the interpretant found in Peirce's triadic relation model [21]. The interpretant can also work as a new sign for something else and the semiosis may continue from there.

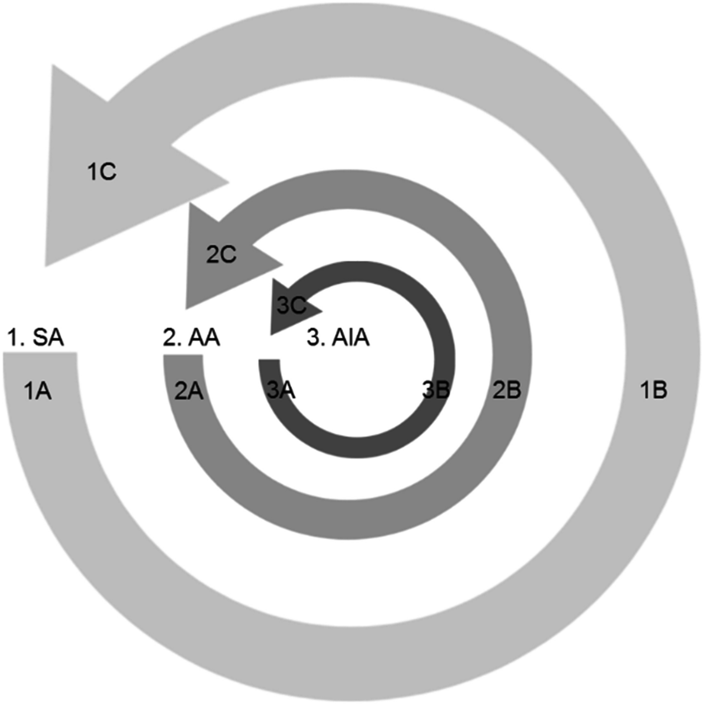

Fig. 1. The Awareness Circles of SA, AA and AIA. The Figure is meant to reflect the relationship between 1. Situation Awareness, 2. Automation Awareness, and 3. AI Awareness. Explanations for the used codes are, 1A: *Perception of the current situation*, 1B: *Comprehension of the current situation*, 1C: *Estimate of the future situation*; 2A: *Perception of the current status of the automation*, 2B: *Comprehension of the current status of the automation*, 2C: *Estimate of the future status of the automation*; 3A: *Perception of the current AI-based decision(s) by the system*, 3B: *Comprehension of the current AI-based decision(s) of the system and their basis*, 3C: *Estimate of the system's AI-based decision(s) in the future and their basis*.

Theory-wise, this model opens up opportunities for conceptual discussions regarding the nature of human cognition and awareness. We see that instead of the linear information-processing model that is based on cognitive psychology, also cyclical models in which human awareness is considered to be formed in the interaction with one's environment are worth investigating. As suggested above, for example, Neisser's ecological psychology [19], Suchman's situated cognition thinking [20], and Peirce's pragmatism [21] may provide very relevant views to the concepts of situation, automation and artificial intelligence awareness.

4 Discussion and Conclusions

It is evident that the increasing the level of automation in work environments has many effects on work activity. For example, in highly automated environments, it is no longer enough for the workers to be sufficiently aware of the situation of the work-related process (i.e., to maintain a good SA), but they also need to follow the functioning of the automated systems related to this process in order to achieve a good automation awareness. Due to AI's important role in future automated systems, we suggest that also "AI awareness" is a key concept to be considered when studying and designing future socio-technical work environments, which rely on AI technologies.

Similar problems that have already nowadays been identified with automation in work environments (see e.g., [22]) can potentially be avoided by considering how to support the workers' AIA through, for example, design and organizational practices. This support may include, for instance, the appropriate design of the intelligent system's user interfaces and the provided training related to the AI system. In this way, better worker understanding and interaction with and also appropriate trust in AI may be possible with intelligent work systems.

In addition to appropriate trust, key AIA-related concepts that are relevant here are system transparency and computer-human communication. While system transparency refers to how transparent the functioning of the AI is, computer-human communication refers to both the way in which the AI system communicates its functioning, intentions, capabilities, and limitations to the user and to the possibilities of the AI to understand human communication.

Clearly, this paper is just an initial small step in this endeavor and presents only some preliminary thoughts as a discussion opening. Both theory and practice should be developed to consider AIA more holistically. A lot more research is needed, for example, on how automation and AI affect work activity in different situations and how worker AA and AIA could be supported to mitigate possible human out-of-the-loop problems with future systems. Undoubtedly, practical case studies both in naturalistic and experimental settings are needed to validate the concepts and design. Furthermore, guidelines for the design of AI systems and their associated training from the perspective of supporting human AIA are needed. We hope this paper serves as a good beginning for research and development to consider the importance of AIA with future intelligent work systems.

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An Initial Generic Assessment Framework for the Consideration of Risk in the Implementation of Autonomous Systems

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Abstract. This paper considers some of the issues around autonomous systems and the different types of risk involved in their implementation. These risks are both barriers to the implementation of a successful autonomous system and risks that are consequences of the use of such systems. The different levels of automation, and different approaches to categorizing these levels, as presented in a variety of frameworks, are summarized and discussed.

The paper presents an initial generic assessment structure, with the aim of providing a useful construct for the design and development of acceptable autonomous systems that are intended to replace elements of the human cognitive process, specifically in situations involving decision-making. It introduces the concept of the "logos chasm": the gap between achievable autonomous systems and those which currently only exist in the realm of science fiction; and discusses possible reasons for its existence.

Keywords: Autonomous systems · Automation risks
Automation frameworks

1 Introduction

There has been a considerable amount of work looking at defining a useful framework or model for the consideration of autonomous systems. Much of this work has been domain specific, such as those being applied to cars or Unmanned Aerial Vehicle Systems (UAS). These frameworks are generally concerned with the extent of the automation within the system: i.e. how much of the task is performed by the automation and how much by a human operator. However, when actually implementing an autonomous system, there is another critical concern: the capability of the technology.

This paper presents an initial structure for combining these two aspects, allowing an assessment of whether the current state of automation technology will support the envisaged level of autonomy, together with an initial consideration of the level of risk associated with implementing that level of automation in that circumstance. This structure is intended to be applicable across any domain and to function as an early contribution to a design or development project; effectively grounding it in reality rather than science fiction. The structure also allows for the potential for technological advances, providing some degree of "future-proofing".

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The proposed assessment structure is used as a mechanism for discussing some of the wider issues around autonomous systems, considering the impactors on their implementation and use and some possible reasons for risks and limitations. It concentrates on systems with a fixed level of autonomy rather than those implementing dynamic adjustable autonomy (where the human is in control of the level of autonomy at any one point) or adaptable autonomy (when the computer decides upon the appropriate level of autonomy), however at the point of any single decision the system will have a single level of autonomy implemented.

2 Background

System autonomy is the capabilities that enables a particular system to be self-determining, or within designed limits, self-governing. Automation is the mechanism or set of mechanisms that support an autonomous, or self-governing system.

A number of models of autonomy exist, which present different levels of system autonomy ranging from no autonomy, i.e. a completely manual system directed by a human operator to a completely autonomous system, i.e. the human is completely out of the loop. This section provides an overview of a few of these, illustrating the different approaches adopted. An example of a simple model is the 4 layers proposed by Endsley [1].

At the other end of the continuum, versions of 10 levels of automation are presented, for example, in Sheridan's Model of Autonomy [2] (Table 2).

A different approach, such as that presented by Sheridan [2] and Parasuraman [3] is to describe the extent of the autonomy in terms of the level of supervisory control provided by a human operator, which is summarised in Table 3 below.

Other models consider autonomy at the level of functions within a system, such as NASA's Function Specific Level of Autonomy Tool (FLOAAT) [4], which also categorises the levels against the OODA (Observe, Orient, Decide, Act) loop [5] (Table 4).

These models are just a small selection of those that have been developed to illustrate a flavour of their similarities and differences.

Taking the gamut of the models, they could be classified as covering four main dimensions:

- the level of completeness of the autonomy
- the categorisation of the level of control by the human
- the relationship to the cognitive processes covered
- the relationship to the type of task being undertaken.

2.1 Relevance to Human-Computer Interaction (HCI)

The world today is characterised by increasing automation and digitization. Systems are becoming distributed and interconnected, with invisible and complex processes. Humans working and living in these environments are confronted with new challenges and are sometimes blamed for the failure of these systems. It is important to realise that building reliable and robust complex human-machine or socio-technical systems requires going beyond blaming the human and attempting to replace them with full-blown automation, leaving only a residual role for humans added as an afterthought when complete automation is impossible. Instead, "we need to develop our designs from the outset to take advantage of some of the wonderful flexibilities and capabilities of human beings" [6]. This has led to the development of a more human-centred approach to automation. This approach acknowledges an increasing awareness of the importance of human skills and judgment in making such systems work and the role of the interfaces in ensuring that the human is fully aware of the current situation and able to either take over, or trust in the automation; depending on the level of automation.

As an example, the automobile industry is focusing on pushing technology towards fully automated driving as fast as possible. This inevitably leads to a technology focus, neglecting aspects of the user experience, acceptance and trust. To fully take advantage of automobile interaction, whatever the level, requires further human-computer interaction research to understand how to best support drivers and passengers. Kun et al. [7] propose a research agenda for automotive user interfaces (UIs) in the age of automated driving.

The automobile industry is not the only area where artificial intelligence is giving increasing levels of autonomy. Artificial intelligence already has some level of autonomy over filtering our spam [8], deciding what we see on social media [9], providing legal advice [10], predicting future crimes [11] and delivering health care.

Health care is the current domain looking to exploit artificial intelligence and facilitate increasing autonomy. While it is hard to find examples of fully autonomous systems delivering treatment to patients, most progress has been made with insulin pumps [12]. However advances have also been made in automating cancer diagnosis (e.g. Platania et al. 2017 [13]).

3 Overview of Proposed Autonomy Assessment Structure

The preceding section shows that there are different taxonomies for describing the intent and capability levels of autonomy, but each one tends to approach the question from a single perspective: some of them then go on to assess aspects of risk.

The assessment structure presented here approaches the question from two different perspectives, with the aim of assessing the level of risk to the success of the implementation of an autonomous system in terms of its automation components. The approach is summarised as:

- Description of intent
- Description of capability
- Type of operational context
- What capability is needed for this intent
- What level of risk is implied by the combination of the selected level of intent and the capability of the technology to deliver it.

The assessment structure contains the following elements:

1. What the automation is intended to provide in terms of the level of control to be applied to the system
2. The capability of the technology in terms of:
   a. the extent of the inputs: a simple system will only use one or two, a more complex system can theoretically take in any amount or type of input
   b. the degree of freedom in the decision outcome: from the simplest "if these criteria are met, this action will be performed (only one outcome), through to multiple options of output, to any output
   c. the complexity of the problem-solving element.
3. The operational context in which the automation will be implemented:
   a. Passive: where the environment does not change in a way that requires the automation to adapt
   b. Active: where the environment changes, typically as a result of the actions of other actors within the environment who have their own intent(s)
   c. Reactive: where the actions of other actors within the environment are actively attempting to affect the outcome of the automation (typically this would be a military environment)
4. A gross assessment of risk, taking into consideration the risk associated with:
   a. the allocation of control
   b. the type of task
   c. the certainty of the information feeding the automation

4 Discussion of Problem Space

Taking a conceptual leap that this structure could be populated and could provide a useful framework, then the consequences and insights that this may bring can be considered. The following subsections look at each aspect in turn. They include the tables generated to form the assessment structure: these tables were generated during a project looking at the implementation of automated support to decision-making in a time-critical, safety-critical, complex environment. As such, the narrative descriptions may be more applicable to some domains than others: these tables are provided as examples of the assessment approach under consideration.

4.1 Statement of Intent

Looking at the intent of the automation in terms of what aspects are controlled by the system and what are controlled by the human, the following table presents a possible structure for generating a detailed description of the intent for the autonomous system. It is structured against an automation description loosely based on the Autonomy Levels developed by the Society of Automotive Engineers (SAE) [14], supplemented and adapted to make it applicable to autonomous systems across a variety of domains, not just automotive.

The result of completing this assessment table effectively forms a description of the allocation and/or supervision of tasks or types of tasks that the entire system (human and automation) intends to perform (Table 5).

4.2 Capability of Technology

Taking the statement of intent generated by the use of the first assessment table, the extent of the intended automation can then be considered. A modified OODA loop was considered to be a useful structure for this; presented in Table 6 below.

Using this framework to try to identify examples of technology that satisfy those technological requirements, it becomes evident (reasonably quickly) that for levels A to C there are existing examples to build upon: for example, a satnav could be categorised as Level B Advice and an automated system for reverse parking a car could be categorised as Level B Act. However, D and E have no tangible current examples outside of science fiction.

4.3 Risk Assessment

Risks to the successful implementation of autonomous systems can be associated with:

- the allocation of control and the interaction between the human and the automation
- the type of task and the operational context
- the uncertainty of information being used to feed the automation.

A set of risk assessment profiles have been constructed to represent each of these types of risk for each logical combination of intent and technology capability: there are nineteen of these logical combinations, leading to a total of 57 risk assessment profiles. The data within these profiles has been derived from currently available research in this domain together with human factors best practice. They are structured to allow new research findings to be included as and when identified. Some of the profiles are currently only sparsely populated.

The objective of this risk assessment process is to provide useful guidance for the implementation of an appropriate level of automation. The profiles allow a quick identification of when a proposed intent combined with a proposed technology level would be “high risk”: a simple example would be that a high level of uncertainty of input data would indicate a high risk if used for a highly automated system and therefore would imply the need for a human presence within the implementation of the system.

The aspects of risk covered by these profiles are reasonably well understood and are founded in current research. However, in the examples assessed it has been determined that there is a tendency that as the domain becomes more uncertain, the complexity of the solution increases, which increases the risk of insufficient time for a human to interact with the system. This leads to a new category of risk, which is related to the relation between the increasing complexity of automation and its interface to humans: defined as the “logos chasm”.

Table 1. Taxonomy proposed by Endsley (1987)

Level of autonomy	Description	Explanation
Level 1	Decision support	Human acts upon system recommendations
Level 2	Conceptual Artificial Intelligence (AI)	The system acts autonomously however, the consent of the operator is required to carry out actions
Level 3	Monitored AI	The system acts autonomously unless vetoed by the human
Level 4	Fully autonomous with no operation interaction	The system excludes the human from the loop-Fully autonomous case

Table 2. Sheridan's model of autonomy

Level of autonomy	Explanation
Level 0	The computer offers no assistance: human must take all decisions and action
Level 1	The computer acquires the data from the process, and registers them without analysis (1* new level)
Level 2	The computer offers a complete set of decision/action alternatives, human decides and acts
Level 3	The computer narrows the selection down to a few alternatives, human decides and acts
Level 4	The computer suggests one alternative, human acts
Level 5	The computer executes one alternative if the human approves, or
Level 6	The computer allows the human a restricted time to veto before automatic execution, or
Level 7	The computer executes automatically, then necessarily informs the human,
Level 8	The computer executes automatically, informs the human only if asked, or
Level 9	The computer executes automatically, informs the human only if it, the computer, decides to
Level 10	The computer decides everything, acts autonomously, ignoring the human

4.4 The Replacement of Human Cognition with Automation

As mentioned above, technology has (to date) failed to produce any examples of higher level autonomy. These higher levels tend to have a component of decision making, which requires a cognitive process.

One approach to examining this problem is to compare the detailed capability of technology to the cognitive processes it is trying to replace. Bloom's taxonomy [15], although conceived as a guide and tool for education, provides a useful structure for comparison.

Table 3. Summary Levels of Supervisory Control for Adjustable Autonomy

Level	Description
Manual Control	The UAS is responsible for gathering and displaying unfiltered, unprioritized information for the human. The human still is the prime monitor for all information, responsible for filtering, prioritizing, and assessing the data)
Consent Based Autonomy	The UAS gathers, filters, and prioritizes information displayed to the human, in time for human–operator to provide consent or to intervene
Executive Autonomous Operations	UAS observes and monitors all systems and commands and acts autonomously, informing the human operator after the fact, displaying information only if asked, ignoring the human

Most representations of Bloom's taxonomy present it as a two-dimensional matrix with the dimensions of cognitive process and knowledge. The cognitive process dimension consists of:

- Create - Put elements together to form a coherent whole; reorganise into a new pattern or structure
- Evaluate - Make judgments based on criteria and standards
- Analyse - Break material into constituent parts and determine how parts relate to one another and to an overall structure or purpose
- Apply - Carry out or use a procedure in a given situation
- Understand - Construct meaning from instructional messages, including oral, written and graphic communication
- Remember - Retrieve relevant knowledge from long-term memory

and the knowledge dimension consists of:

1. Metacognitive - Knowledge of cognition in general as well as awareness and knowledge of one's own cognition
2. Procedural - How to do something, methods of enquiry, and criteria for using skills, algorithms, techniques and methods
3. Conceptual - The interrelationships among the basic elements within a larger structure that enable them to function together
4. Factual - The basic elements that must be known to be acquainted with a discipline or solve problems within it

When considering computational technology the limitations of a Turing machine [16] must be understood. A Turing machine can be defined as "a mathematical model of a hypothetical computing machine which can use a predefined set of rules to determine a result from a set of input variables".

Although computer scientists are looking at a variety of hyper-computing solutions: i.e. computing solutions that extend past the confines of a Turing machine; it is true to say that currently, all computers have a Turing machine restriction. Until hyper-computing becomes available, automation can only represent a logical rule-based system. In attempting to create more completely autonomous systems, this means that the logic of the system becomes increasingly complex to try to compensate for the lack of both metacognition and creative imagination.

Table 4. NASA's 5-pt Scale and Definition of the Levels of Autonomy (from Proud and Hart 2005)

Level	Observe	Orient	Decide	Act
1	The data is monitored on the ground without assistance from onboard	The calculations are performed on the ground without assistance from onboard	The decision is made on the ground without assistance from onboard	The task is executed by ground support without assistance from onboard
2	The majority of the monitoring will be performed by ground support with available assistance onboard	The majority of the calculations will be performed by ground support with available assistance onboard	The decision will be made by ground support with available assistance onboard	The task is executed by ground support with available assistance onboard
3	The data is monitored both onboard and on the ground	The calculations are performed both onboard and on the ground	The decision is made both onboard and on the ground and the final decision is negotiated between them	The task is executed with both onboard and ground support
4	The majority of the monitoring will be performed onboard with available assistance from ground support	The majority of the calculations will be performed onboard with available assistance from ground support	The decision will be performed onboard with available assistance from ground support	
5	The data is monitored onboard without assistance from ground support	The calculations are performed onboard without assistance from ground support	The decision is made onboard without assistance from ground support	The task is executed onboard without assistance from ground support

Without going in to the detailed mathematical proofs of this, it can be shown that a Turing machine cannot solve the create level of cognitive processing or access the metacognitive level of knowledge. To put it a different way, it is possible to envisage a logical set of rules and process flows that satisfy the bottom five cognitive and bottom four knowledge dimensions of Bloom's taxonomy. This apparent separation between the Turing logic (logos) and the creative human processes (imagination) has reverberations of Jung's concept of "logos" and "imagination" [17]: which he then equated to conscious thought and subconscious thought. Taking this analogy to its extreme, current computing capabilities only utilise conscious thought, it is well-established that during the decision-making process, humans frequently utilise both conscious and subconscious thought.

Table 5. Statement of intent

Level	Name	Narrative definition
0	No Automation	The human will perform all of the dynamic operational tasks
1	Assistance	A single assistance system will utilise information about the environment to perform a mode-specific task: the human will perform all remaining aspects of the dynamic task
2	Partial Automation	One or more assistance systems will utilise a range of information about the environment to perform mode-specific tasks: the human will perform all remaining aspects of the dynamic task
3a	Conditional Automation	A mode-specific automated system will perform aspects of the dynamic task with the expectation that the human will respond appropriately to a request to intervene
3b	Conditional High Automation	A mode-specific automated system will perform all aspects of the dynamic task with the expectation that the human will respond appropriately to a request to intervene
4	High Automation	A mode-specific automated system will perform all aspects of the dynamic task, even if a human does not respond appropriately to a request to intervene
5	Full Automation	An automated system will perform all aspects of the dynamic task

This realisation goes a considerable way towards explaining why there are no examples of current technology at levels D and E as noted above. It may also imply that until hyper-computing becomes available, that boundary cannot be crossed (the logos chasm).[1]

4.5 Consequences for Autonomous Systems

When considering autonomous systems, there are three dimensions to explore:

- The quality of interaction over the task split between human and machine: this leads to discussions on the quality of a human decision versus a machine decision, which in turn implies the need for an understanding of the difference between machine logos and human logos and imagination. The question is, is there a notion of machine intelligence (which is all logos) which could be equally as good as (but different to) human intelligence?
- The time dependency of task split between human and machine: given that real life tasks happen in a time-constrained situation, and that machines are capable of computational calculations from sensors faster than humans can process the data, at what point does the fallback that humans can override the system become invalid? This identifies the point at which the human does not have the capability to react

[1] Extensive fuzzy logic engines can solve the "end problem", but only by virtue of the fuzzy logic's definition assuming that the fuzzy logic will always resolve.

Table 6. Extent of the intent of the automation

	Type	Definition		
A	**Observe**	Monitors conditions and provides information in respect to them	**Advice**	Limited set of Inputs and single (or binary) output
	Observe & React	Monitors conditions and reacts when a condition (or Limited set of conditions) are met	**Act**	
B	**Orient**	Applies the monitored information to the situation	**Advice**	Limited set of Inputs and outputs direct logic - “Proveable” logic has “perfect/optimised” solution
	Orient & Perform Action	Applies the monitored information in relation to the situation to perform a pre-specified activity when a condition (or set of conditions) are met	**Act**	
C	**Decide-Select**	Applies the monitored information in relation to the situation to make a decision about the parameters of an activity: which activity, when or where	**Advice**	Defined set of Inputs and outputs direct logic - can “not Proveable” logic Does not have a “perfect/optimised” solution
	Select/Act feedback loop	Applies the monitored information in relation to the situation, makes a decision about an activity (which activity, when or where) and performs that activity	**Act**	
D	**Decide - Solve**	Resolves multiple consequences and benefits	**Advice**	Defined set outputs but any inputs Resolves consequences and benefits and selects actions with acceptable levels of risk across multiple dimensions
	Solve/Act feedback loop	Applies the resolution of the multiple consequences and benefits by actioning - actioning the best options from it output set	**Act**	
E	**Decide - Solve**	Resolves multiple consequences and benefits	**Advice**	Any Inputs and Any outputs Resolves consequences and benefits and selects actions with acceptable levels of risk across multiple dimensions
	Solve/Act feedback loop	Applies the resolution of the multiple consequences and benefits by actioning: - the positive steps - the mitigations that reduce the likelihood of negative effects - the mitigations that increases the likelihood of the process staying in the optimum range	**Act**	

within the time constraints of the task and be able to undertake a comparably good "calculation" and generate a decision.

- The potential benefits of task split between human and machine: given that some cognitive tasks span areas of creative thinking and metacognition, how can the task be broken apart in order to allow the human to contribute in those ways, while gaining the benefit of the machine doing the computational calculations faster than the human can?

An additional cross-cutting aspect is that many real life situations are "open loop": i.e. once a decision has been made, it is impossible to tell if it was in fact the optimum decision as, unlike in a laboratory experiment, the outcomes of different decisions can be compared.

It seems sensible to utilise the unique abilities of both the human and the automation to their most beneficial extent within the entirety of the system. However, for automated systems that are trying to replicate decision processes in complex environments, this raises some critical questions, such as:

1. for a system with a large number of sensors and a large number of logical outcomes (decisions that could be made, given the information provided by the sensors) and a complex set of rules, how can it be organised so that an individual can judge the decision made (or recommended) by the automation?
2. accepting that computers are both more accurate and faster than humans at processing data (given the appropriate ruleset) how can it be arranged for an individual to be able to monitor the logical process followed by the computer to the extent that they can identify cases where they should override it?

The logical consequences of these questions are at one extreme, the human always has to accept the autonomous system's decision and never overrule it, and at the other extreme, the autonomous system has to be limited by the ability of the human to judge its decisions.

This logical barrier (referred to as the logos chasm) can be considered in three different ways:

- in terms of a barrier to intent
- in terms of a barrier to implementation
- in terms of a barrier to replacing human cognitive processes.

The logos chasm is effectively the gap between what is currently achievable in terms of the implementation of autonomous systems and what requires hyper-computing for its solution.

This does not mean that automation that sits inside this logical chasm should not be put into place; what this construct means is that when it is recognised that automation is sitting within that chasm space, mechanisms must be put into place to mitigate for the consequences.

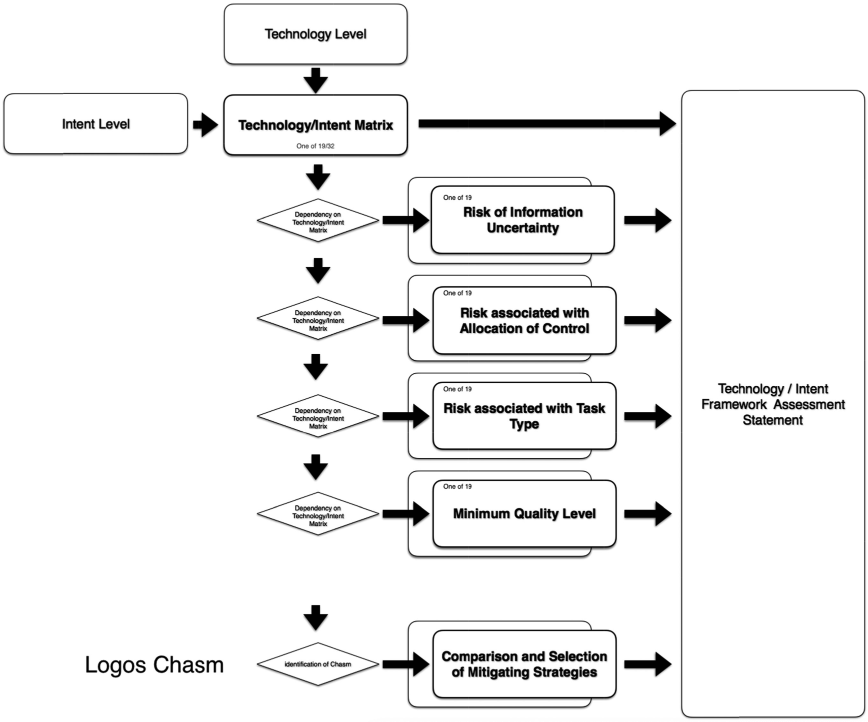

Fig. 1. Illustration of Overall Structure

5 Summary and Conclusions

Examining the multitude of papers that consider automation frameworks from different points of view, they relate autonomy to advice that roughly falls into the categories of:

- the allocation of control and the interaction between the human and the automation
- the type of task
- the uncertainty of information being used.

However no one framework seems to explicitly cover them all. They intuitively include the issues but do not always state why these are issues and when they are going to trigger, or relate them to the capabilities of the technology.

Additionally, they do not explicitly distinguish when autonomy steps into this chasm space, and therefore do not explicitly relate any mitigations or advice to the understanding that this chasm is currently unbridgeable and has the known ramifications identified above.

The framework discussed in this paper is intended to compensate for some of the inadequacies of individual approaches to the implementation of autonomous systems by providing an overall structure that includes both an assessment of the associated risks and an assessment of the barriers to successful implementation of the system (Fig. 1).

Although there are currently some concepts related to mitigating the logos chasm, these concepts have not been extensively investigated. Therefore future work is planned to attempt to identify and validate strategies that will mitigate the consequences of this chasm space.

It is hoped that this identification of the logos chasm and the multi-facetted risk assessment approach presented in this paper will provide a useful construct for implementing acceptable autonomous systems.

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A Methodology to Involve Domain Experts and Machine Learning Techniques in the Design of Human-Centered Algorithms

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Abstract. Machine learning techniques are increasingly applied in Decision Support Systems. The selection processes underlying a conclusion often become black-boxed. Thus, the decision flow is not always comprehensible by developers or end users. It is unclear what the priorities are and whether all of the relevant information is used. In order to achieve human interpretability of the created algorithms, it is recommended to include domain experts in the modelling phase. Their knowledge is elicited through a combination of machine learning and social science techniques. The idea is not new, but it remains a challenge to extract and apply the experts' experience without overburdening them. The current paper describes a methodology set to unravel, define and categorize the implicit and explicit domain knowledge in a less intense way by making use of co-creation to design human-centered algorithms, when little data is available. The methodology is applied to a case in the health domain, targeting a rheumatology triage problem. The domain knowledge is obtained through dialogue, by alternating workshops and data science exercises.

Keywords: Human-centered algorithms · Decision Support Systems
Knowledge elicitation methods · Knowledge engineering

1 Introduction

Decision Support Systems (DSSs), a set of manual or computer-based interactive tools made to support complex decision-making and problem solving, have demonstrated applicability in a multitude of realms [1–4]. Ideally, DSSs are built through a collaboration between data scientists, who build the models on historical data, and domain experts, who communicate their proficiency in order to discern the relative importance of the data features, and to tune the model parameters [5]. Collecting expert knowledge and skills entails obtaining access to both the explicit and tacit knowledge they apply in decision-making. This necessity is underscored by precedents such as the case in which a DSS was created for a hospital in order to detect patients with sepsis. The involved physician expected the system to work on the limited set of explicit parameters he used during his consultations. However, data scientists failed to build an effective model.

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Subsequently, the physician was asked to classify patients solely on data given to the model. This led to poor results which convinced him that the model required previously unexpressed parameters. Yet, the collection of relevant tacit knowledge is cumbersome and time-consuming, as experts are often unaware that they even possess it, or instinctively apply it. This makes it remarkably difficult for them to verbalize the information, and for others to collect it [6]. Furthermore, the sharing of tacit knowledge is influenced by the level of trust between the two parties [7]. These factors have led scholars of information technology systems to refer to the practice as the 'knowledge acquisition bottleneck' in system development [8]. Recent papers in the research field have addressed the statistical model development or the co-creation interface design of the DSS. However, a detailed description of the applied co-creation method for acquiring the underlying rules for a DSS is missing in literature, although being recognized as a strenuous task [9–11].

The current paper presents a co-creation method that aims to facilitate the troublesome task of substantiating the experts' tacit and explicit domain knowledge by visualizing it in a graph, easily interpretable by the data scientist. An efficient procedure is proposed that requires limited investment from the domain experts. In a next step, the data scientist uses the created graph to structure the data and fine-tune the data-driven developed model. The proposed method thus makes the singular modeling decisions explicit. This eventually allows the domain expert to reflect not only on the outcomes of the applied DSS, but also on the process and choices leading to the offered recommendations, hence rendering the underpinning algorithms interpretable by humans. This is of importance as granting insight into the reasoning behind an automated decision has been known to enhance the trust and uptake of such systems [12]. An additional benefit of the involvement of domain experts is that they can act as a gateway to larger historical, annotated data sets.

The remainder of the paper is structured as follows: the first section provides an overview of the applicability of DSSs and how domain experts are traditionally involved in algorithmic design. Next, we propose the interdisciplinary method of domain expert involvement for contributing their knowledge, during which we present how it was applied in order to address a triage problem in the field of rheumatology. The paper concludes with a review of the advantages and limitations of our approach and how expert knowledge can be used to create open and interpretive DSSs, while refraining from overburdening the involved expert.

2 Related Work

2.1 Decision Support Systems

Human judgement and decision-making are often suboptimal, especially in situations where the amount of information required to attain the best solution is substantial and the outcome is expected to be precise [13]. DSSs help out by structuring the cognitive process latent to the decision-making, and by granting educated access to the various required information sources [13]. Entering the fourth decade since their inception, DSS applicability has been demonstrated in a multitude of realms, such as business, engineering and the military [1–4, 14]. As decision-making in healthcare is growing in complexity, DSSs have also been developed specifically for clinical settings [4, 11]. Notwithstanding their suitability for multiple domains and the recent fast-paced research developments in the DSS domain, their actual adoption rate remains low. One of the causes mentioned is the lack of adequate interpretability [15]. The tools made for this purpose should be amenable to verification testing, which means that developers and end users should be able to assure that the DSS is based on correct assumptions and that it operates conform to accepted domain expertise [15].

2.2 Knowledge Acquisition for DSS

Many intelligent DSS implementations are based on expert systems, or knowledge-based systems [9, 16–19]. Their foundation is established through different knowledge acquisition techniques, such as computer modeling, case based reasoning, observations and co-creation methods [10]. The next two sections provide an overview of the machine learning and social science techniques that facilitate the process, how they can benefit from each other and the challenges they continue to encounter.

Machine Learning Techniques (ML). Computing power becomes increasingly potent through advancements in data science and machine learning. This allows for the automatic inference of the required decision rules from historical data through white-box or black-box machine learning. White-box techniques, such as decision tree induction and classification rule mining, are able to give an explanation and, as previously indicated, are applicable for expert decision support within critical domains [20]. However, their predictive performance tends to be lower than that of black-box techniques, such as artificial neural networks. The latter approaches are often able to learn features automatically with higher predictive performance, but they cannot provide an explanation for their predictions [20].

A number of challenges with the application of machine learning techniques for knowledge acquisition persist. First, a prerequisite of both white-box and black-box machine learning techniques to result in sound algorithms is access to a considerable amount of historical training data, which is not always easy to obtain. Second, it has to be noted that high predictive accuracy and consistency on historical data sets do not necessarily lead to the development of proper predictive systems, as the performance can be poor when having to deal with novel, unknown or uncertain cases [21]. Moreover, integral black-box methods have as a consequence the inaccessibility of knowledge and procedure on which decisions are based and are thus incomprehensible to their developers or eventual users. When the results of a DSS are not up to par, their designers are thus unable to know which parameters should be altered or deleted altogether. Furthermore, the application domain experts and end users of these tools cannot convey decisions on blind faith, when they are unable to explain them [12]. These considerations led us to further examine how machine learning for knowledge acquisition can be supported by input from social science techniques.

Social Science Techniques. Already in 1987, it was acknowledged by Keen that the DSS field is located at the intersection of human judgement and the power of computer technology [2]. Current social science techniques of knowledge collection for DSSs are often a combination of literature review and quantitative and qualitative data collection, such as surveys and interviews [18]. The benefits of these methods are: (1) gaining access to applied decision rules that do not necessarily come forth from the historical data; (2) the explicit account of parameters enhances the interpretability at the modeling phase, which leads to greater interpretability at run-time; and lastly, (3) the involved domain experts might act as a gateway to historical (training) data. However, it is not difficult to understand why knowledge acquisition is still often considered a bottleneck in the development of DSSs. The unwillingness to share due to mistrust, and the unavailability of experts with sufficient time are well-known obstacles [5]. Furthermore, the externalization of the tacit knowledge that domain experts gather through experience, and apply in a subconscious manner, remains a challenge as it is often a non-organized part of the experts' intuition [5, 9, 17, 22]. To this end, the use of metaphors and narratives is prescribed in order to facilitate this externalization. However, the exact course of action is not specified [9]. Moreover, literature mentions how tacit knowledge is often only revealed during observations when a prototype of the DSS is already available [22].

The methodology disclosed in the current paper seeks to overcome these drawbacks by providing an efficient means to capture tacit knowledge before a prototype is developed. It is part of a larger evolution investigating how machine learning and social science techniques can complement each other for knowledge acquisition in the development of DSSs [10]. The method consists of a succession of generative workshops with explicit probing and project techniques, designed to obtain latent and tacit knowledge [23]. Involvement of domain experts in this manner has been recognized to reduce the chance of overlooking crucial data [18]. More specifically, this paper aims to address the general lack of an explicit presentation of the detailed protocol used for knowledge acquisition in DSS design in literature [10].

3 A Methodology for Knowledge Acquisition for DSS Design

The present paper proposes a methodology for the materialization of expert knowledge through a succession of qualitative workshops. The method is particularly applicable towards the development of the knowledge base in a variety of domains for which the decision-making process is susceptible to automated support. Each step of the protocol is rigorously described with an immediate illustration of how it is implemented in a health use case, regarding the support of triage in the field of rheumatology. Figure 1 provides an overview of the protocol.

3.1 Step 1: Mapping of Context and Motivation for DSS Development

The need for a DSS can be propagated in different ways: the research team can observe the benefits themselves and take it up in subsequent explorations with relevant experts (top-down), or domain experts can voice their concerns and contact the research team with their request (bottom-up). In both cases, it cannot be assumed that the researchers fully understand the context, frustrations and motivations in the specific domain.

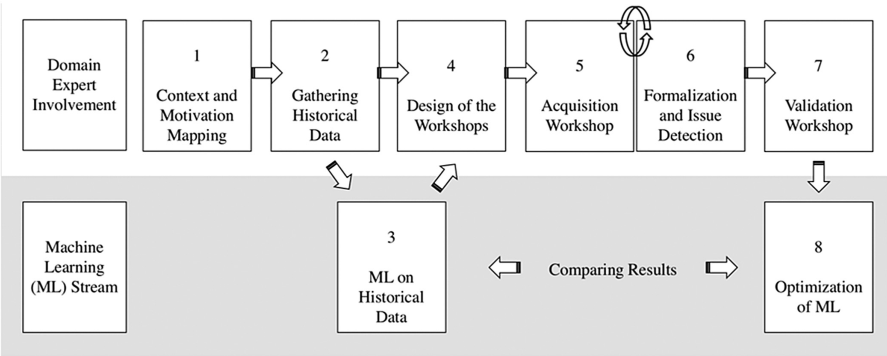

Fig. 1. Overview of the developed methodology

After an introductory meeting with domain experts, a preliminary literature review and context mapping is performed. However, an exhaustive understanding is unattainable, and can even be counterproductive for the course of the development process, as it undermines the need for detailed descriptions from experts. Nevertheless, a basic understanding is imperative in order to decide upon (1) the minimum number of workshops, (2) the required domain expertise and characteristics of the attending participants, (3) the number of participants in each workshop and, (4) the mix of participants in each workshop. The participants should have different experiences and should preferably not be part of the same team, as this would result in shared implicit knowledge that would not be clearly articulated.

Application in the Rheumatology Use Case. A rheumatologist who witnessed the potential utility of a DSS contacted the research team and briefly explained his motivation and the context in which he operates as follows.

Rheumatologists in Flanders, Belgium have to cope with an ever-increasing workload. This is due to the growing number of patients per expert, as a result of an aging population and a decrease in active rheumatologists, as the older generation is retiring and new doctors specializing in the field are scarce. The rheumatologist had strong beliefs that a digital triage system, supporting General Practitioners (GPs) in their diagnosis, could remove some of the burden from the medical specialist, if able to reduce the number of misguided patient referrals. As a first step, he enables a number of GPs to fill in a digital checklist for patients who were suspected of suffering from rheumatism. Data for 127 patients was collected. As a second step, the rheumatologist went through the data to determine if the specific patients were eligible to get an urgent appointment. Although successful, the post-analysis by the professional was too labor-intensive to be practical in a real-life setting.

In a first meeting with the research team, it was established that the logical step forward was to extract the knowledge rheumatologists applied in evaluating such digital checklists. It was decided that three workshops would be conducted: one with rheumatologists affiliated with a university, one with private rheumatologists, and one with general practitioners. The objective of the workshops was to identify the patients who were eligible for referral according to each party involved, which rules they apply in their diagnosis, and which data sources should be accessible. A fourth workshop, containing a mix of the different participants, would subsequently be conducted in order to validate the extracted knowledge.

3.2 Step 2: Gathering Historical Data and Explicit Knowledge

The inclusion of domain experts from early on in the creation of a DSS, before a prototype is conceived, is a valuable asset as they can act as a gateway to annotated historical data. During the initial meeting, it is discussed if they know or are in the possession of annotated data. Moreover, the experts can refer to easily collectable, explicit knowledge they apply in the course of the decision-making process. This consists of the decision rules and data sources experts can effortlessly identify when inquired about the information they base their day-to-day judgements upon. These are in subsequent steps used for both the creation of a baseline DSS and the further development of the co-creation workshops.

Application in the Rheumatology Use Case. As the rheumatologist declared in the initial meeting that he was already in possession of a digital checklist and referral data for 127 patients, the research team inquired for an anonymized version of this labeled training data. This file was based on the already-existing screening sheet with patient data and the evaluation of the expert on whether they were urgently to be referred to a rheumatologist.

3.3 Step 3: Preparation and Application of the Labeled Training Data in Machine Learning (ML)

The information on knowledge application that was gathered in the second step allowed for the creation of a baseline DSS. The objective was to discover how successful the DSS is when created by purely using different data-mining algorithms on the available historical annotated data. Gathered training data is often not directly useable to its full extent as input for machine learning, e.g. due to inconsistent input of parameters such as variable data formats, open text fields that allow unstructured input and missing values. Therefore, an initial data cleaning is often required. Even when the results of this initial ML exercise are not convincing, the examination of the data and the creation of a baseline DSS remain important: not only does this give a baseline performance level by which future enhancements through the adoption of expert knowledge can be measured, but it also serves as an incentive for the domain experts to accept that an interdisciplinary approach, such as the one presented in this protocol, is beneficial.

Application in the Rheumatology Use Case. Based on the anonymized patient data file provided by the rheumatologist, a baseline DSS was built. The expert emphasized the need for an interpretable DSS which meant that it needed to be capable of giving an explanation regarding which process had led to its conclusions. This was required to gain the trust of the domain experts, i.e., the rheumatologists and GPs, in the designed system. The physicians will only be comfortable to use the DSS and follow its recommendation, if they fully understand how the model works. Moreover, it allows the rheumatologist to understand why the patient was referred, so that the urgency of the case can be assessed in deciding upon an appointment date. Therefore, white-box machine learning algorithms were put forward to design the DSS. The most well-known white-box algorithms are decision tree induction and rule learning [24, 25]. Based on its wide successful adoption in practice, the See5 toolkit was used for the rheumatology case [26–28]. It uses the C5.0 algorithm to manufacture decision trees or collections of if-then rules. Several classifiers (either decision trees or rule sets) are generated rather than just one. When a new case is to be classified, each classifier votes for its predicted class and the votes are counted to determine the final class.

As a first step, the data file provided by the rheumatologist needed to be cleaned. This was performed based on the input gathered during the initial meeting with the expert. As a result, 215 different, sometimes overlapping, items on the checklist were derived as input for the DSS. These consisted, for example, of an indication of all the joints and whether they were swollen or painful to the patient, the medical history of the patient, his/her medication usage, results of laboratory tests and medical imaging, etc. An initial filtering of unimportant items, e.g., administrative features, was performed to reach a set of 188 items. See5 generated DSS algorithms with an error rate ranging between 29.36% and 53.8%, when using two separate disjoint datasets for training and evaluation, and an error rate between 7.1% and 14.19% when the complete set was used for training and validation. This was clearly due to the fact that the set of 188 items per case was too large compared to the number of available cases, i.e. 127 patients. Therefore, unconvincing results were obtained, even when trained and executed on the same set. Additional domain knowledge was required in order to reduce the number of items.

3.4 Step 4: Design of the Co-creation Workshops

As an intermediate step, the social scientists involved perform an investigation on probing material and adapting generative techniques aimed at extracting domain expertise. Through a set of workshops, the implicit knowledge the domain experts possessed is extracted and tested. The challenge lies in allowing the participants to share their experiences and intermittently ask them pertinent questions as a non-specialist in the field. This inquiry by an inexperienced party may determine the participants to tell their stories in a precise manner. Different tools can be used to help convey the descriptions, such as text, narration and visualizations. Each workshop has its specific set-up and lasts for a maximum of two hours. Two different types of workshops can be distinguished: a first set where the knowledge of the experts is gathered and systematized (acquisition workshops), and a second set in which the resulting flowcharts are validated (validation workshop). In the following sections we will elaborate on these, as well as the sequence of different exercises that constitute each session. In general, a preparatory step is required in order to discuss and structure the workshop format. In general, they should contain the different elements enumerated in the following sections. The material used can vary according to the different object of expertise. The specific workshops that are discussed below were designed in close collaboration with the data scientist.

3.5 Step 5: Acquisition Workshops

First Section: Introduction. In the first part of the Acquisition Workshops (AWs), the structure and objectives are introduced to the participants. This component does not differ from that of other interpretative social science research methods. The essential steps required are:

- The organizers present themselves, as well as their roles in the workshop as presented in Table 1.

Table 1. The different roles of the organizers during the workshop

Expertise	Roles	Applied reasoning
Data scientist	Architect of the DSS Schematizes the articulated knowledge of the domain expert	Deduction
Social scientist #1	Facilitator of the workshops Inquires until all relevant knowledge surfaces	Induction
Social scientist #2	Note taker Brings attention to missing information	N/A

- The project is shortly presented as well as the contribution of the current workshop to its goal.
- The structure and objectives of the session is explained.
- If the session is being recorded, the participants are notified of this, as well as of what will happen with the recordings.
- An informed consent is provided and signed by all participants. This document describes the aims of the session, what will happen with its results and the possible risks for the participants.
- The different participants and organizers present themselves and their background.

Second Section: Experience Case Description. Each participant is asked to write down in a few lines a specific case from their experience, for which the decision-making process was intriguing or peculiar. Every expert subsequently shares the case with the other participants. The objective is to steer the discussion away from an abstract level towards more practical and experience-based examples. After each attendant discloses their case to the group, one of them is selected through a short discussion led by the social scientists. This example will lead the rest of the expert consultation, as a common ground on which the participants can share their implicit knowledge. The particularity of the case can for example be attained by pursuing cases where the decision was difficult to make, a bad decision was eventually made or the urgency of the case was underestimated. Past experience has shown that looking for extreme examples contributes to a more animated discussion.

Application in the Rheumatology Use Case. The rheumatologists were asked to write down three different patient cases: a patient that was wrongfully referred to them, a patient that was referred too late, and a patient that was correctly and timely referred. In the alternate workshop, the general practitioners were asked to write down one case in which they had difficulty in deciding if the patient should see a rheumatologist. Afterwards the participants presented their cases to the group with an emphasis on the particularity of each case. After a short discussion, the most thought-provoking patient case was selected, which would be used throughout the workshop.

Third Section: Playing the Omnipotent DSS. In this phase, the experts have to work together and take up the role of an all-knowing and powerful DSS. This fictional system has access to every conceivable information source. The objective of this exercise is to define what information and knowledge are crucial to be considered and in what order it should be requested by the system. The questions that should be repetitively asked by the social scientist facilitating the process are:

- What knowledge do you need (next) to make an educated decision?
- Where do you get this information from?
- Why do you feel this information is pertinent?
- Can you give examples of the knowledge? How do they relate to one another?
- Does everyone agree with this?

Simultaneously, the data scientist takes on the role of the system architect who visualizes the thought processes on large papers. The different information components indicated by the participants are compartmentalized, related to each other and given an hierarchy based on importance. Imperative to this process is a mutual recognition and reciprocal communication flow between facilitator and DSS architect. The facilitator aims to assist the DSS architect by abstracting from the situational and working towards a consensus. When saturation is achieved as no new information components are distinguished, the exercise enters a new phase. The other experience cases, described by the participants but not yet used, are run through the designed omnipotent DSS. This allows to question the structure, components and sequence as provided by the DSS architect.

Application in the Rheumatology Use Case. In the use case, the facilitator sketched the situation as follows: a patient arrived at a general practitioner, being supported by a DSS. Together the participants had to take up the role of this DSS and decide on whether the patient needed to be immediately referred to a rheumatologist. They had to indicate their information needs during the different stages of the patient visit. The rheumatologist or GP that presented the case needed to provide the information required by her/his colleagues. After each request for information, the facilitator enquired about its importance and at what time the DSS may need this particular piece of information. During this process, the data scientist schematized the whole process. If something was not possible to schematize or a conflict appeared on the existing schema, this was mentioned. In case something was missed, the note-taker brought this to the attention of both the facilitator and the data scientist. After each discussion, the facilitator asked what the follow-up question would be that the system needed in order to make a meaningful referral. This process was repeated until the participants, and thus the DSS, had gathered all of the information they needed.

Fourth Section: Synthesis and Evaluation. The process of the workshop is reviewed in a joint effort with the participants. This starts with a recapitulation of the explicit knowledge available at the start of the session and how this is supplemented by the tacit knowledge that became available. At this moment, an inquiry is made of the information and procedures that are still lacking. Some time is also devoted to the evaluation of the process itself: do the contributors feel that they got to voice their concerns and that their participation was worthwhile?

Application in the Rheumatology Use Case. This final part of the AW started with running through the diagram of different patient cases from the start, in order to see whether all required information needs had materialized. Once everything was included, the original digital screening sheet was brought to the table in order to help identify the differences with the new diagram and to look for an explanation for these differences. Afterwards some time was devoted to the evaluation of the workshops.

3.6 Step 6: Formalization and Issue Detection

After each acquisition workshop, the resulting flowcharts are formalized and structured, with extra input from the transcripts of the note-taker, as some information may have been overlooked during the session itself.

After the finalization of all AWs, the data scientist compares the different flowcharts and integrates them into one consolidated diagram, containing all the different concepts and flows that had been previously indicated (See Fig. 2). Ambiguities and experienced missing links that should be taken into account in the validation workshop (VW) are noted down in the course of this process.

3.7 Step 7: Validation Workshop

Objective of the Validation Workshop. The objective of the validation workshop (VW) is to run through the integrated flowchart and to take away any existing ambiguity that still resides over the priority and necessity of the different questions that the DSS needs to take into account. It also re-evaluates the information sources it needs to address in order to formulate a successful outcome. If the AWs were conducted with different types of stakeholders, a sub-selection with equal representation of each party needs to be present in the VW. The different steps that are undertaken in the VW are summarized below.

Application in the Rheumatology Use Case. The participants of the VW were two rheumatologists and two general practitioners.

First Section: Introduction. The intent and procedure of the workshop is introduced in this section. This process is similar to the introduction of the AW.

Second Section: Prioritization of Components. The result of the AWs is an integrated flowchart, which lists the main information components that are necessary to formulate an informed decision. As preparation for the VW, the different components are listed. In this first part of the workshop, the participants are asked to go through the

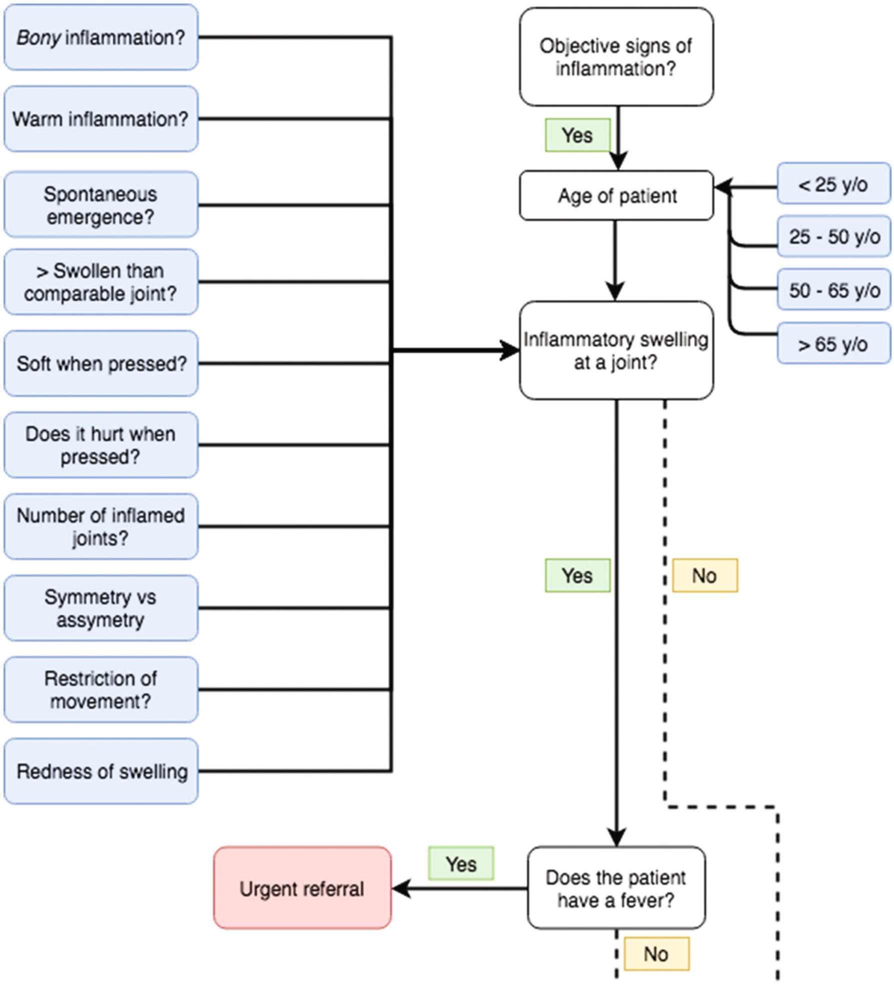

Fig. 2. Part of the integrated diagram of the rheumatology case.

list individually and give a priority rating (Low/Neutral/High) to each of the information needs. This exercise is repeated until all components have been rated. The sheets of the different responders are gathered, processed and integrated by the data scientist and note-taker. The result of this process is presented to participants and discussed in group until a consensus about the priority level of each of the sub-questions is reached.

Application in the Rheumatology Use Case. In the rheumatology case, it became apparent that two main information needs existed: inquiries about pain and swollen joints. These main components contained several sub-components which were listed on two different files that were shared with the participants. All participants went through these questions individually and ranked them according to their importance (Low/Neutral/High). Afterwards, the results of this exercise were discussed publicly. This exercise resulted in the deletion of some of the sub-questions.

Third Section: Experience Case Description and Playing the Omnipotent DSS. Similar to the AW, the stakeholders are asked to describe a case for which the decision-making process was peculiar. These cases are then used to jointly run through the integrated flowchart, making use of the priority levels that were obtained during the previous exercise. In an ideal situation, the use of the flowchart should guide the participants towards the right conclusion for each of the cases. If this is not the case, the possible reasons for the drawbacks are explored until a new consensus is found.

Application in the Rheumatology Use Case. In the rheumatology case, the participants were asked to write down an experience case. Similar to the AWs, the rheumatologist had to describe a case that was wrongfully or tardily referred to them. The attending GPs had to describe a difficult case to diagnose. One of them was chosen to run through the integrated flowchart. New pitfalls in the flowchart were discovered and discussed in the group.

Fourth Section: Synthesis and Evaluation. The validation workshop ends similar to the acquisition workshops, with an overview of the results and an open discussion about the followed procedure.

3.8 Step 8: Optimized Machine Learning Based on Expert Involvement

Not all data engineering enhancements done in step 3 resulted in better performance of the DSS. Therefore, it is of utmost importance to apply the correct re-engineering principles in the correct situation, something which can be achieved with the application of domain expertise. The presented protocol allows for this information to be extracted, shared and correctly applied. Based on the expert knowledge, data engineering principles can be applied to reduce the number of items into more practical input features in order to achieve a more accurate result. Afterwards, the new results are compared with the baseline DSS created in step 3.

Application in the Rheumatology Use Case. First, some continuously valued items (e.g. blood pressure values) were converted into value portioned ones, based on boundaries indicated during the workshops. Second, labeled data that was never mentioned during the workshops was discarded (e.g. the medication history). Third, some items were too detailed, according to the domain experts, and these could be clustered into a single input item. An example here is the localization of joints that could be clustered into six categories: left/right hand, left/right foot and left/right side of the body. Different weights were also attached to the components (e.g. morning stiffness was given a higher importance). Similarly, misclassification costs were given a weight. Under-diagnosis was for instance deemed much worse than over-diagnosis. However, it has to be noted that some of the parameters that were deemed important by the domain experts were not included in the labeled data set. This resulted in the newly developed DSS not having access to all of the required information.

The previously discussed baseline DSS for the rheumatology case achieved error rates between 29,36% and 53,8%. After expert involvement, a best-case DSS was achieved with an error percentage of 22.8%. As mentioned, the DSS is a combination of various decision trees or rule sets that achieve the final result through majority voting. Through a manual check-up off all these trees and sets, it was possible to find a DSS algorithm which performed 100% correct. However, it has to be kept in mind that this was achieved with only a limited dataset at hand and that the inclusion of more diverse data would probably lead to errors in that particular DSS algorithm as well.

4 Discussion

Since the inception of DSSs, the importance of domain expert inclusion in the constitution of a knowledge base has been underwritten [2]. However, to our knowledge, there is a lack of information regarding the specifics of co-creation protocols guiding knowledge acquisition [10]. In general, the externalization of tacit knowledge is said to be enabled by the application of narratives or metaphors, but a description of an approved method is missing [9].

The current paper addresses these issues by clearly presenting a methodology to unravel, define and categorize the implicit and explicit domain knowledge, through an alternation of co-creation workshops. The objective is to enable the discovery of underlying skills and know-how as they are provided through dialogue by professionals in the field. This interpretability at the modeling phase is more likely to create interpretability at use time in comparison to black-box machine learning methods. Unlike previous attempts, the proposed methodology captures the domain knowledge before a prototype of the DSS is developed. This allows experts to exert a higher influence on the design choices.

The methodology was applied in a health case targeting a triage problem in the domain of rheumatology. The preliminary results have been encouraging as both the tacit and explicit knowledge of domain experts could be extracted and formalized. However, it should be stated that it is impossible to know if all relevant tacit knowledge was extracted during the succession of workshops. During the workshops, no mistrust towards the researchers was noticed. The participants stayed engaged throughout the process as long as it did not last longer than the envisioned two hours. Although some participants showed some initial reserve, this changed throughout their involvement in the group discussions and as they witnessed the rules materialize in the drawings of the data scientist. The results strengthen the authors' conviction that the use of narration through the experience case description exercise as well as the simultaneous diagram creation can be used to extract knowledge, also in other domains than DSS creation, e.g. organizational information sharing.

The domain expert involvement guided the subsequent data engineering. An initial comparison of the baseline DSS with the one created after the involvement of the domain expert had some promising results. However, due to the data set's small size, as only data on 127 patients was present, and because not all required information was available in the initial labeled training set, the study requires more future validation.

This method is only one example; we would like to stimulate the community to develop other ways of involving the domain expert in knowledge capture processes in a pragmatic and efficient way.

Further validations of the applied methodology in alternative application domains are necessary. Additional research is also required in order to see how the aim of interpretability at run-time can be implemented so that the end-user receives insight into why specific decisions are made on their behalf. Moreover, if such a system is used by more people, it might become beneficial to add a feedback loop where users can indicate themselves which parameters should hold more weight in the decision-making process, so that the knowledge base on which the system operates is adapted to new findings.

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A Framework for Understanding Human Factors Issues in Border Control Automation

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Abstract. New security threats and increasing traveler flows as well as needs to enhance facilitation and security in EU external cross-border traffic have accelerated the use of novel technologies in border control. Especially at airports, automated border control, more commonly known as e-gates, have been taken widely into use. With e-gates, travelers perform border check as self-service, and the role of the border guards is to monitor or possibly also assist travelers passing the border. The introduction of automated systems significantly reshapes current ways of conducting border control from the border guard's perspective, and automation thus requires new skills from them. Understanding the effects of automation on the work tasks and work performance of border guards requires thorough examination. This paper introduces key Human Factors issues affecting border guard and border control system performance. The results are based on literature review and field studies conducted in different border control points within six European countries. The paper presents a Human Factors framework for understanding the complex nature of the border control and different factors influencing to both border control process and border guard performance within it.

Keywords: EU · Schengen area · Automated border control
Border digitalization · Human factors · Human factors framework

1 Introduction

To improve the effectiveness of EU border control in the context of growing passenger flows, cross border threats and budget restrictions, new socio-technical models are being envisioned with high reliance on automatic technical systems, such as e-gates. During the last years, especially largest airports in EU member states have introduced automated border control (ABC) for border checks. In 2017, ABC systems were extensively used at airports in 16 EU member states, and they are expanding to other type of borders as well [1]. Implementations in airport terminals research has been made to enlarge the systems to other border types, including road, sea and rail [2]. This technological change has been driven on the one hand continuously increasing passenger flows [3] and demands on

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performing border checks effectively, efficiently and with high security as well as serving travelers better by seamless travel and trade experiences [4]. European border and coast guard agency, Frontex, defines the main objective of automating the border control to reconcile traveler facilitation and security [5].

Border control environment is a complex and demanding environment to automate and develop solutions, as all systems must fulfil the challenging and somewhat contrary aims. As a precondition all systems must be effective in enforcing the law related to the border control, they should be as unobtrusive to the flow of travelers and goods as possible, additionally they should respect the rights of an individual and finally they should be cost-effective with regard to the use of both public and private resources [2].

The Schengen Borders Code [6] sets the framework for the various border control measures, which are implemented at the external border control points (BCPs) of the Schengen area. This regulation provides the framework under which the automated, self-service border control concepts operate. Smart Borders Package and the establishment of the EU Entry-Exit System represent the next significant evolution in border control [7]. The proposed changes include additional biometrics verification, replacement of manual stamping of passports by automation and the possibility for third country national, TCN citizens to use automated, self-service border checks systems. Thus, it is expected that the use of automated systems, such as ABC-gates with document and biometrics scanners will increase in border control.

Automated border control (ABC) is an automated system, which performs the same tasks as in the manual border control with a high degree of automation [5]:

(1) checks that the traveler trying to cross the border is carrying a genuine and valid travel document,
(2) verifies biometrically that this travel document belongs to the traveler trying to cross the border,
(3) checks that the traveler is eligible for the system and entitled/authorized to cross the border,
(4) allows/denies passage according to a predefined logic, sometimes requiring the intervention of the border guard operating the system
(5) guarantees the security in the overall process, meaning that only a traveler who has been cleared is allowed to cross the border and that travelers who have been rejected are properly handled

A border guard supervises the system and controls multiple self-service gates. The work shifts from checking travelers individually to monitoring a system outcome and exceptions indicated by the system or acting upon border guard's assessment. Table 1 describes the roles and tasks of border guards in manual process and in automated border control process [5, 6]. Border guard's tasks in the automated process are divided depending on the guard's role, whether the guard is monitoring or assisting traveler on using automates. The highlighted cells presents those manual tasks that automated border control is set to replace.

Table 1. Border guard roles and tasks in manual and automated border control process

FIRST LINE BORDER CHECKS		
Manual process	**ABC process**	
First line border guard	*Operator*	*Assisting personnel*
verify presented travel document(s) and other required documents verify traveler identity	monitor the user interface of the application and react upon any notifications given by it	handle exceptions and assist operator
verify conditions governing entry verify documents authorizing residence and pursuit of professional activity	manage exceptions and makes decisions about them	conduct brief interviews and redirect travelers to second line check if found necessary escort travelers to second line checks when needed
consult relevant databases providing information for example on stolen, misappropriated, lost or invalid documents	communicate with the assisting personnel for the handling of exceptions at the e-Gates	monitor and profile travelers queuing in the ABC line and using the e-Gate
monitor and profile travelers queuing to the control desk	monitor and profile travelers queuing in the ABC line and use e-Gates to look for suspicious behavior in travelers	conduct first line border checks in case of ABC system failure
communicate with second-line checks if needed	communicate with second-line checks if needed	provide on-the-spot assistance to travelers

The automation of work will have consequences on human performance [8], and implementing new technology is likely to cause reactions among employees. This is mainly because new systems alter the ways in which employees perform their work. In addition, related work processes and tasks as well as the working environment are likely to change. Furthermore, employees may be unsure of the overall impacts that automation will have on their work. Automation can have both positive and negative effects on human performance. The latter effect may arise, because introducing automation changes the type and extent of feedback that operators receive, as well as the nature and structure of tasks people perform [9]. Attitudes that are shaped by the reliability or accuracy of the automation will influence an employee's willingness to use automation [10]. Moreover, the probability of potential use of automation is influenced by various factors, such as trust in automation, self-confidence in manual performance, perceived risk, and fatigue [11]. In addition to performance, automation may have effects on human factors like situation awareness, workload, motivation, stress and trust [12, 13].

Multiple studies present models, which investigates human factors in different contexts where technology is used to assist employees in their work tasks [e.g. 13–15]. Some human factors models have also been standardized by standardization organizations [16]. However, these models are quite narrow leaving many important aspects uncovered. This paper introduces a Border Control Human Factors Framework (BCHFF) to understand the complex and dynamic nature of border control environment, where multiple factors influence the employee and the system performance. The development of the framework is based on literature review and field studies in six EU countries. The created framework aims at forming a comprehensive model to visualize underlying human factors in border control and interrelations between them. The framework helps to understand the border control context and how work performance is influenced by automation. The objective is to facilitate the development of systems that are both efficient and user-friendly to operate.

2 Human Factors in Front of Border Digitalisation

Human factors and ergonomics (HFE) focuses on systems in which humans interact with their environment [17]. The ISO 6385 standard [18] as well as the International Ergonomics Association [19] defines that ergonomics addresses the interactions between the humans and other components of a system, such as other humans, machines, products, services, environments and tools, as appropriate. The Health and Safety Executive, HSE [20] defines human factors as “referring to environmental, organizational and job factors, and human and individual characteristics, which influence behavior at work in a way that can affect health and safety”. Thus, human factors is concerned with (1) what people are being asked to do (the task and its characteristics), (2) who is doing it (the individual and their competence) and (3) where they are working (the organization and its attributes). In addition, the wider societal context has an influence on all these three areas.

The ISO 26800 standard provides an integrated ergonomic framework and defines a human-machine system model, which deals with the interactions in the system between the human and other parts [16]. In the model, the human and the machine are integral parts of the system, and they exist within a spatial environment, which in turn exists within a physical and an organizational environments. In addition, the social, legal and cultural environments influence the functioning of the system. Kraemer et al. [14] present a macro ergonomic conceptual framework for human and organizational factors in dynamic security system environment that highlight the “social dimension” effects on the system performance. The framework categorizes human and organizational factors into five categories: organization, operational environment, individual or operator, tasks and workload, and tools and technologies. The framework contends that a high performing decision support system design and implementation needs a strong notion of both, the social and technical components. Situation awareness, workload, boredom and monotony, motivation and stress, and trust will be the key human factors issues for the future monitoring work, like the air traffic control [13]. Especially issues of stress, trust, and boredom will become more significant because the automation will change the role of the controller from active, “hands-on” controller to relatively passive monitor.

HFE aims to optimize the performance of both the human and physical components of the system. The focus is to improve performance and well-being through system design and by enhancing the integration of humans into the system. Disregarding HFE in system design may result in sub-optimal end-products with quality and efficiency defects, not forgetting adverse effects on employee well-being and health [17].

The introduction of automated systems will change the work of border guards, and automation thus requires new skills from employees. Usability of the used technology, operational environment and border guard's personal profile are important factors that influence to the work performance [15]. In addition interaction with travelers transforms primarily into supervision of travelers using the e-gates. Nevertheless, the need for human oversight will not disappear, and in the future, border guards are expected to operate more like customs officers – performing risk-assessment and spotting of anomalies rather than frontline passport-checkers [21]. Border guards appreciate the technical tools like document and fingerprint readers because they make them feel more confident about deciding the travelers' eligibility to cross the border [22]. However, even though the technology is considered useful, border guards want to keep the control in their own hands [22].

3 Creating a Border Control Human Factors Framework (BCHFF)

3.1 Methods

To understand the complex nature of the border control context, it is vital to study the context from a comprehensive viewpoint: organization, work environment and work tasks as well as used technologies and tools. Understanding human factors of border guards' work involves gathering information about their tasks and their competences. The research and development work was based on real work analysis and co-creation with relevant stakeholders. Thus, the data was gathered both by literature review and by field research.

The field research was performed in border locations that had different experiences and perspectives to automated border control. These studies included interviews with different actors involved in the border control and observations of border guards' performing their daily operations related to border check process. The focus of the semi-structured interviews was to gather human factors information of border control work. Therefore the interviews included themes of organization, BG's activities and tasks, performance, training, soft skills, technology use, evolution of the work and ethical issues. The interviews were fulfilled with observations always when it was possible in the real work conditions.

The field studies were conducted at six European countries and at different border control points: sea, air and rail. Altogether, the study was completed in 19 locations and four border types and over 110 border authority or stakeholder interviews and border guard observations were conducted. All locations implement automated border control solutions functioning alongside with manual border control process and all border guards worked on both manual and automated lines. The amount of the e-Gates, ABC processes and topologies as well as exception handling varied somewhat in different border control points. In addition, amount of travelers and traveler profile differ in each border control point.

3.2 Data Analysis

The studies have indicated that in real settings the work is rarely performed as theoretically planned [23]. In real conditions, the employee has to adapt to the external constraints like technological and environmental challenges as well as internal factors like workload and motivation that may affect to the work performance. The data analysis was grounded on analyzing the real work of border guards aiming to prescribe the tasks border guards actually conduct during the border control. In addition, the organizational and technological issues were analyzed.

The literature review focused on the border related technologies and how they will affect the border guards' work and their operational environment from the perspective of human factors. Based on the literature review preliminary human factors issues that are influenced by the new technology and automation of border control were recognized. This knowledge was used while planning the field studies, observations and interviews with different stakeholders.

All the data gathered from the field studies were integrated in an Excel sheet. The data was grouped into the categories accordingly to the themes used in interviews for further content analysis (e.g. ABC-system, technology, training, working environment, interaction with travelers, ethics and legislation). The qualitative data analysis was performed by profile and categories. Based on the field studies the challenges that border guards have while performing their work tasks were recognized. The factors behind the challenges and their influence to work performance were identified as well as border guards' means to cope with identified challenges. In addition, the aim was to find what kind of good practices can be discovered and how these can be used in other border control contexts as well. Location-specific information is withdrawn from the analysis in order to respect the research permissions made with border organizations.

The gathered data was the starting point for the first model created to define the performance of the border control. This model highlights that the efficacy of performance of border checks with automated system takes into account three main dimensions: speed, security and fairness [24]. This means that the border control has a good performance if the border check is (1) fast, (2) above a good security threshold and (3) with an optimal fairness.

The focus of the speed-security-fairness model was mainly on performance of the border control. Apart from the border control performance, there is performance of single border guard, which is affected by different external and internal factors. The speed-security-fairness model was extended with the main human factors issues that affect to the BG's work performance. These were recognized based on the field studies and literature review. In addition, the environmental factors/layers that contribute to the performance were identified. The border control human factors framework (BCHFF) that combines the models of a general system to the single border guard was created. Performance criteria was also updated accordingly to emphasize the effect of human factors in the overall.

4 HF Framework to Model Interaction Between Border Guards and Automated Border Check

The border control human factors framework (presented in Fig. 1) aims to combine and categorize different factors to form a general and comprehensive model to visualize the most important factors affecting to border guards' work performance and interrelations of them. The framework is an expanded description of the human-machine-environment system model presented in ISO 26800 [16] and frameworks created for monitoring work [13, 14].

The framework describes different background variables, the environmental layers and functional actors, which together form the overall environment where border guards operate and where the border check takes place. All these factors contribute to the system performance and to border guards' ability to perform their work efficiently as well as general well-being of employees. In addition, these factors affect travelers profile, flow and behavior.

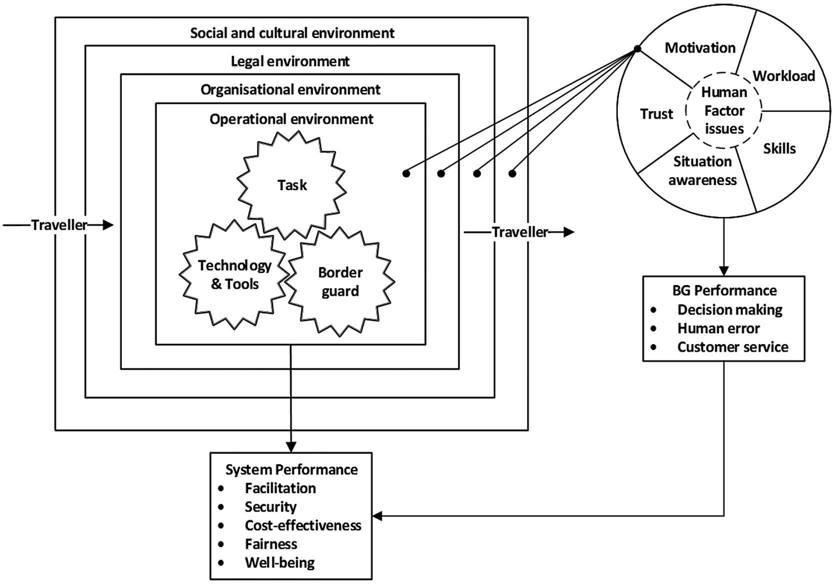

Fig. 1. Border control human factors framework (BCHFF)

The main human factors issues of border guard, which were identified based on the field studies are motivation, workload, trust, situation awareness and skills. These issues may have impairing or strengthening effects on **border guard's performance**. Border guard's performance deals with the quality and quantity of human errors, quality of decision-making process and quality of customer service (customer feedback). In order to support good border guard performance, it is important to prevent or minimize issues that have impairing effects on border guard's human factors and facilitate the positive ones.

System performance is an outcome of all the factors and interplay and balance between them. In addition, the border guard's performance influences greatly to the system, in this case border control, performance. Overall border control performance can be evaluated through facilitation, security, cost-effectiveness and fairness of the process as well as general well-being of employees.

Social and cultural environment describes the people, their attitudes, knowledge explosion and public opinion. The cultural environment deals with values, beliefs, norms and accepted behavioral patterns. Social and cultural environments differs from one country to another and it is important to understand how it will affect to border control and border guards' work as well as impacts on travelers' ability, decisions and willingness of using self-service systems. This environment is permanent in nature and the border organization must adapt to it. **Legal environment**, border control legislation and national regulation influences and guides border organizations. The Schengen border code and national laws regulate the border processes in Schengen area. In general, the border checks follow the same procedures across the different member states and in border checkpoints and border types. The legal environment can change but usually changes take time. Legislation defines the border control process and what elements of it can be automated. For instance, in Schengen area current regulation does not allow processing all traveler types automatically, but some tasks needs to perform by human. **Organizational environment** includes organizational culture and structure, and management. It is affected by social and cultural factors and depends on national regulations and rules, but these are applied to the practice by organization. Border control is organized in different ways within the member states of the Schengen area. Usually it is managed by one administrative organization. Most of border control authorities in Europe are police organizations but in a few countries border control is managed by a military organization. In addition, border control processes and topologies as well as shift planning have some variations in different border control points. **Operational environment** includes both physical (e.g. border crossing point) and spatial (e.g. work station) environments. At each border types there are some characteristics that must be taken into account when considering the human factors of border guard work. The characteristics are related to conditions at the border, other stakeholders involved, environmental conditions, surrounding technology, fixed or moving construction, means of transportation when crossing the border, traveler flows and travelers profile in general. In addition, the implementation and configuration of border control point have an impact on the border control process.

The border check process consists of the three core functional components: **border guard**, **tasks** and (technical) **tools**. In automated border control, the technology has more visible role, but there is always a border guard monitoring the process. The cogwheels illustrates the close interaction of all these three core components and the importance of their compatibility.

Tasks refer to the border guards' tasks and activities at first line border check. Tasks can include different tasks depending on the type of the border and defined process on the border control point as well as BG's role (performing manual control, monitoring traveler, assisting traveler).

Technology and tools means all the technological tools and devices that border guards have at their use while performing border check. This includes technology used at manual check as well as automated border control technology: e-gates, pre-enrolment kiosks and monitoring and surveillance equipment. In addition, other non-technical equipment such as magnifying glass can be included in this category.

Border guard's individual characteristics and features (physical characteristics, perceptions, personality, behavior, skills, motives, and needs) have significant role to the work performance. Personal features lay the foundation for all activities and performance, these features defines how person acts in certain situation, how one interacts with travelers and is able to cope with challenging situation and stressors. In addition, travelers' behavior and experiences of border control and technology influence greatly to border guard's work.

Human Factors Issues are the factors that have impact on border guards' performance and are shaped as an outcome of all background and environmental variables together. The influence of these issues on performance can be positive, neutral or negative depending on the situation. The key human factors issues identified to influence the border guards work performance are motivation, workload, trust, situation awareness and skills.

Motivation describes why individual acts or does something. Motivation in work is defined as the set of internal and external forces that initiate work-related behavior, and determine its form, direction, intensity and duration [25]. The values such as job satisfaction, professional development and nature of the work were mentioned as factors that inspire and motivate BGs in their work [26]. While considering the increased automation in BG's work it should be reflected that the BGs still desire the opportunity to feel themselves competent while performing monitoring tasks.

Workload consists of both external and internal loads. External load (also work stress) can be understood as an external conditions and demands, which influence on a person's physical and/or mental internal load. Internal load (or work strain) is an individual response to the external load. Individual characteristics and personal features influence how the effects are experienced and how the one is able to cope with them. Mismatch between demands and capabilities cause suboptimal workload, which can mean either over-load or underload. Unbalanced mental workload may cause monotony, reduced vigilance, fatigue and satiation, which often result in increased number of errors, pro-longed processing time, diverted attention and reduced alertness [27]. In the future, the amount of technology and tools as well as automation will increase in border control work and it will increase BG's monitoring work. Automation can decrease BG's workload in some task as well as increase it in other tasks.

Trust is a new human factor introduced by automation which importance increases when more and more tasks are shifted to automated systems [13]. Trust on technology is seen one of the most important factor in acceptance and adoption of automation [28]. In the framework trust refers to trust on technology, organization and colleagues. Balance in trust is crucial for human-automation reliance; both over-reliance and mistrust are harmful and may lead to misuse and disuse of automation [29]. Overreliance refers to the situation where operator trusts too much on the system, which as a consequence may limit the detection of warnings and lead to misunderstanding of the system functionalities. Mistrust may lead the situations where warning signals of the system are ignored or underestimated. The balance between overreliance and mistrust of technology in BG's work is essential in case of border control automation; the border guard has to be able to rely to decisions made by the technology but they still want to have the control by themselves [22].

Situation awareness refers to the perception of elements in an environment, within a volume of space and time, and comprehension of their meaning and projection of their status in the near future and to integrate this knowledge onto person's current activities [30]. Numerous factors may affect a person's ability to fully comprehend and suitably respond to the challenges posed by the environment in which he/she is operating. The level of automation will affect to the situation awareness and especially the automation of decision-making functions has been found out to reduce operator's situation awareness on the system and work environment. Automation may enhance situational awareness in two main ways: first, by easing the user's workload and, secondly, by assisting the user with the collection and processing the information [28, 31]. On the other hand, the interaction with software tools, electronic displays and database systems may create problems for the work of border guards. Difficulties may arise, for example, from border guards having to deal with unprecedented amounts of information coming from multiple sources as well as from their need to make decisions with help of the technology.

Skills refer to border guard's personal abilities and skills as well professional knowledge gained through experience and training provided by the organization. Both soft and technical skills should be considered. Good versatile skills support performance and smooth communication with travelers, poor or lack of skills instead may in turn have adverse effects on performance (e.g. language skills, social skill, ability to use technology efficiently etc.) Job satisfaction is also linked to the adequacy of the skills/expertise of the operators to their jobs. Introduction of new technology and automatic systems for border control will change the nature of BG's basic skills. It may also introduce new kind of skills and knowledge needs.

5 Discussion

The presented border control human factors framework is intended to be used in identifying the challenges and opportunities resulting from the automation of the border control process. After these are identified, the recommendations and requirements to enhance the system and employee performance as well as finding the optimal task-allocation between human and technology in work automation could be conducted. The important question is that by knowing the human factors issues that affects to BG's work performance how to support border guard's work and decrease the possible disadvantages of the automation such that the balance between efficiency and well-being remains.

Automated border control systems have transformed the role of border guards from active controllers to ones monitoring the system. According to filed studies, the evolution of job and new work tasks increases the border guards' motivation. However, border guards' still desire the opportunity to feel themselves competent while performing monitoring tasks. Involvement in decision-making, problem solving, social nature of work, meaningfulness of own role and societal responsibility were mentioned as important factors for motivation and job satisfaction.

Border check process is demanding task and requires continuous vigilance from border guard. Decrement in vigilance over time is recognized by studies that concluded that people are only able to maintain an initial level of vigilance for a short period before it slowly decreases [32, 33]. In addition to the workload, the boredom is closely related to vigilance, attention management, and task performance [34]. Workload influences to the vigilance and according to the field studies the workload and strain in border check varies a lot due to e.g. border type, time of the year and amount of travelers crossing the border. Organization can support border guards in maintaining their vigilance by reducing the workload and boredom by planning the work shifts to ensure adequate time in monitoring as well as amount of breaks and diversifying the tasks that border guards perform in a shift.

Trust on technology is seen one of the most important factors in technology acceptance and adoption [28]. Automation should be designed to be both technically competent and matched to the task and easily understood and transparent in its operation [35]. Border guards seem to have high trust on automated border control technology since the technology provides them support in the most challenging tasks [22]. However, the field studies revealed that the border guards think that they have important role in border checks since they are more capable of performing some tasks than technology.

Employee satisfaction and engagement contribute to employee's performance [36]. Job satisfaction and engagement have also great influence into turnover rate. According to field studies, the organization and management play an important role in border guard engagement. Regular training seems to contribute positively to job satisfaction through the possibility to enhance personal expertise as well as in maintaining the skills needed to perform the work. This is also pointed out by Frontex, which recommend that initial and follow-up training will be required so that officers can operate the system successfully and contribute to its enhancements [5]. In addition, participants in field studies highlighted that it is important to understand the meaning of border guard's work and societal role as a whole. They assumed that by understanding the work in a bigger context it might be easier to perform different kind of tasks associated to border guards. In order to maintain the motivation of border guards, it is important that they are able to use their skills while performing their work as well as maintaining their competence.

Usability of technology as well as border guards' experience of using the technology plays an important role in automation. To enhance efficient performance of border control the technology has to provide border guards a suitable, efficient and easy to use tool to perform their monitoring and controlling work [15]. Thus, it is essential not to forget interaction design of humans and automated systems focusing on engaging user experiences in work environment [37]. In the field studies, it was generally argued that automation has lightened and eased BG's work. The automation performs tasks that are often considered challenging and can especially lighten the workload during peak hours.

6 Conclusion

Due to the demands on performing border control effectively, efficiently and with high security the amount of automation and technology for border checks is increasing. The introduction of automated systems significantly reshapes current ways of conducting border checks from the border guard's perspective, and automation thus requires new skills from them. Understanding the effects of automation on the work tasks and work performance of border guards requires thorough examination.

This paper has examined those key human factors issues that automation of border control will have and that influence on border control and border guard performance. By gathering information and experiences from the border control stakeholders from different countries and border crossing points, we have gained a deep understanding of the complex nature of the border control environment. Based on this data we have identified key human factors issues that affect to border control as well as border guard performance. The purpose of this paper is to provide greater understanding of the complexity of the border control context and to identify those human factors that can be used to guide technology development in order to provide such solutions for border control that will enhance both system and employee performance.

The paper presents the human factors framework for border control. The framework combines and describes the different background and functional factors that together form the overall environment where border guards operate and where the border check takes place. All these factors contribute to the system performance and to border guards' ability to perform their work efficiently as well as to general well-being of employees.

The next steps with the framework are validation and formulating the understanding how the framework will support in creating the recommendation for automation of border control.

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Research Methods – What Is Best for Developing and Evaluating Human Computer Interaction and Interactive Artistic Installations?

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Abstract. Research in human computer interaction (HCI) covers both technological and human behavioral concerns. As a consequence, the contributions made in HCI research tend to be aware to either engineering or the social sciences. In HCI the purpose of practical research contributions is to reveal unknown insights about human behavior and its relationship to technology. Practical research methods normally used in HCI include formal experiments, field experiments, field studies, interviews, focus groups, surveys, usability tests, case studies, diary studies, ethnography, contextual inquiry, experience sampling, and automated data collection. In this paper, we report on our experience using developing and evaluation methods to assess artifacts. Four defined outputs (projects) were examples of the different methods application to gather information about user's wants, habits, practices, concerns and preferences. An interactive artistic installation, Sea Grains – an immersive poetics in interactive artistic experience, is another example of the use of research methods for development and evaluation of artifacts. The goal was to build an understanding of the attitudes and satisfaction of the people who might interact with those artifacts. Conversely, we intend to present a framework design to be applied on the design for interactive applications, to promote better user's experiences.

Keywords: Human computer interaction · Mixed methods
Human work interaction design · Interactive artistic installations
Framework for interactive artistic installation's evaluation

1 Introduction

Practical research methods normally used in HCI include formal experiments, field experiments, field studies, interviews, focus groups, surveys, usability tests, case studies, diary studies, ethnography, contextual inquiry, experience sampling, and automated data collection.

This paper reports authors' experience using the evaluation methods focus groups, surveys and interviews and how they were adopted to develop artifacts: either interface's design or information and technological systems. Conversely, the use of research

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methods on interactive experience with an interactive artistic installation is presented. What makes the challenge greater for interactive art installations is that they often deal with evaluation of easier perceptions. Inflexible usability evaluation methods may fall short of measuring the successful or unsuccessful outcome of an interactive activity that is supposed to have an artistic effect on the participant. It is not easy to adapt HCI methods to an artistic context [1]. Instead methods inspired by HCI for understanding usability issues that might be part of the experience of interacting with an art piece should be used.

In this paper it is considered that HCI can support with the methods for evaluation at the development phase and mixed methods should be used along the whole design process to evaluate the easier perceptions.

The paper is structured as follows: Sect. 2 – describes the considered research methods for evaluation, which comprises the methods in HCI, user centered design and mixed methods. Finally, research methods for interactive artistic installations are listed. Section 3 – presents a summary about the developed artifacts and the methods applied in those artifacts. Section 4 - contains the results and discussion highlighting human work interaction design approach and a framework for interactive artistic installations' evaluation. Lastly, some tips are presented on the conclusion.

2 The Use of Research Methods for Evaluation

This section presents the concepts and approaches used by the author to get and analyze data obtained from the development of artifacts and artistic installations. The focus was on user-centered design, focus groups, surveys, interviews, observation, prototyping and other methods used in artistic installations. Despite considering that participatory design (PD) is a research method it is out of the scope of this paper to deeply considering it. Authors can inform that PD was handled since all the stakeholders were involved during the design process as active participants. The methods used in HCI and in interactive artistic installations are presented.

2.1 Methods in HCI

Human computer-interaction (HCI) focuses on the investigation about relationships between computer technology, human activity, and society. Various methods and tools are being applied within organizations to improve the understanding of user task requirements to support the design process and evaluation. HCI is a multidisciplinary field, which justifies the use of all the social sciences evaluation methods, as well as, some engineering and medical research methods.

Qualitative methods of research permitted to get data related with user's motivations, expectations, and behaviors. Questions are asked, notes registered. "we tend to project our own rationalizations and beliefs onto the actions and beliefs of others" [2].

The use of different research methods on the development of artifacts, services and systems that improve people's lives, and that in particularly, engage and amuse people, i.e. that give positive experiences on people are reported. During the design process: design, creation, and evaluation developers/artists use different research methods. Authors focus on user centered design approach method and on mixed methods.

2.1.1 User Centered Design

There are some techniques, described by design research, which explains how to add context and insight to the design process. These techniques are known as user research. The design research included the careful analysis of findings, turning them this way and that, looking for patterns [3]. The tools of design research are both quantitative and qualitative methods. However, most design research is qualitative, not quantitative.

User centered design is a multidisciplinary design approach based on the active participation of users to improve the understanding of user and task requirements, and the iteration of design and evaluation [4, 5]. The user centered design methods most used are: field study, user requirements, iterative design, usability evaluation, task analysis, focus groups, formal heuristics evaluation, user interviews, prototype without user testing, surveys, informal expert review, card sorting, participatory design [6].

Figure 1 provides an overview of user-centered design techniques [7]. The research activities are task-based audience segmentation, personas, scenarios, use cases, storyboards, wireframes, interaction design concept (…) and prototype.

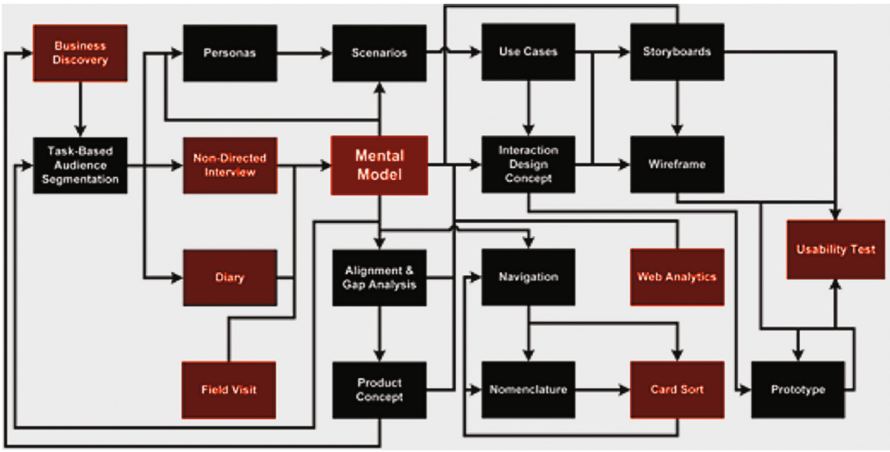

Fig. 1. User centered design techniques [7]

The design team is responsible for the analysis of user research. The projecting analysis techniques include the design of personas, mental models, storyboards, etc.

Various methods and tools are being used within organizations to improve the understanding of user task requirements to support the design process and evaluation.

One of the key characteristics of Interaction Design process is the need to focus on users [8]. User involvement from an early phase of design process is beneficial because it can increase user acceptance of a product. Within interaction design perspective, observation of users will help the designers to focus on users and their needs.

Design techniques have been used to obtain information about the subjects and their environment: Users' background or experiences and the specificities of the user and/or environment [7].

Prototyping is a method common to HCI and to user-centered design to elicit information from users. One example of prototype usage is the technology probe - a high-end prototype that is used in its real intended environment over an extended period of time. Technology probe had been used to successfully collect data about user experience in the real world setting and as a tool to test the engineering aspect of a product [9].

2.1.2 Mixed Methods

The use of mixed methods research applied to human computer interaction field is generally used when we consider both quantitative and qualitative techniques [10]. Mixed research deals with compatibility and pragmatism [11]. The idea is that quantitative and qualitative methods are compatible and pragmatism meaning "researchers should use the approach or mixture of approaches that works the best in a real world situation".

Qualitative research is more subjective, based on smaller, targeted sample sizes, and is concerned more with how and why questions [12]. Quantitative research, on the other hand, is often about large, random, statistically significant sample sizes and is designed to answer what questions. The quantitative methods permitted to obtain numerical data concerning, for example, in general, the number of prospective users for our applications, the number of those that were used with similar applications, the tendency of use, etc. Both qualitative and quantitative research, in combination, provided a better understanding of the research problem. Although, mixed methods research is generally concerned with the combination of quantitative and qualitative methods, authors present the paradigm of mixing almost qualitative methods. The methods may be a mix of qualitative methods [13]. Table 1 presents examples of mixed research methods used in HCI and in user-centered design approach.

Table 1. Research methods

HCI	User centered design
Formal Experiments	Field study
Field experiments	User requirements
Field studies	Iterative design
Interviews	Usability evaluation
Focus groups	Task analysis
Surveys	Focus groups
Usability tests	Formal heuristics evaluation
Case studies	User interviews
Diary studies	Prototype
Ethnography	Surveys
Contextual inquiry	Informal expert review
Experience sampling	Card sorting
Automated data collection	Participatory design

There are other research methods used to evaluate artifacts: Delphi technique (is a focus group method that is usually used to gain consensus on a particular issue and is used for gathering data from participants within their domain of expertise), nominal group technique, which prevents the discussion being dominated by one person whilst at the same time encourage passive members to engage and speak out [14]. Performance ethnography is a descriptor for per formative methods. It must be seen as stories to open space between analysis and action [15].

Another research method found in literature is narrative thinking – the narrative thinking (NT) process organizes thoughts temporally. NT is a distinct way of understanding, which came from the work of feminist researches where participant voices and marginalized stories are included [14]. Barone [16] Elbaz [17], Clandinin and Connelly [18] among others, used this narrative form of meaning making. Narrative work is a methodological bridge between thematic and arts-based research.

2.2 Research Methods in Interactive Artistic Installations

Interactive artistic installations overlap with other data collection methods such as photography and digital approaches. Installations can be static and situated pieces or can be other forms when participants become part of the installation. An interesting method for participants' interaction is Collage. Collage is a method that requests participants to reflect and communicate based on, for example, the juxtaposition of different materials such as pictures, artifacts, natural objects, words, phrases, textiles, sounds and stories [19]. This method allows constructing meaning about the research questions and the process, the participants and other themes.

Collage portraits in qualitative research and analysis [20]. Portraiture is a method of documentation, analysis, and narrative development that uses a variety of mediums including photography [21], poetry [22, 23], jazz [24], performance [25] and visual art [26–28]. The goal of Gerstenblatt [20] was to encourage a range of linguistic and non-linguistic representations to articulate authentic lived experiences.

Heinrich [29] used a circular method (or cybernetic) process, consisting of firstly theory formation as a discursive process that questions and re-describes already existing theories on beauty, and secondly the validation of her theoretical findings by means of observation and analysis of interactive artifacts by various artists as well as own artistic experiences.

Reflective writing method makes part of field notes, which involves record of behaviors and events. It comprises date, time, location and details of what or who is being observed.

Digital storytelling refers to a two to five-minute audio-visual clip combining photographs, voice-over narration, and other audio [30] among other fields it is applied for an arts-based research method [31].

Table 2 summarizes the main methods used, according to literature, for interactive artistic installation evaluation.

Table 2. Research methods in interactive artistic installations

Methods	Other medium
Collage portraits	Photography, poetry, jazz, performance, visual art
Circular method	Theory formation, validation of theoretical findings (observation)
Reflective writing method	Field notes, record of behaviors and events
Digital story telling	Combination of photographs, voice-over narration, other audio

3 The Developed Artifacts

In this paper four examples of digital application's development using mixed methods are described. 1. A Framework for e-government, 2. Frameworks used by Information Technologies Companies, 3. User centered healthcare design project, and 4. Learning Tool for Musicians [32]. Complementarily, an interactive artistic installation is described [33].

The description of each output is, from now on referred as project. The main goal of project 1 was to understand how information systems of different social centers for the elderly were aggregated. And how to improve the quality of operations and services, as well as, the interaction process of the collection, requirements and information system aligned with those of the social centers for elderly.

The goal of project 2 was to study the impact of frameworks use in Information Technologies companies.

The goal of project 3 was the quality improvement of information flow and the design of interactive application.

For project 4 the concern was to develop a technological application for musicians that solve some of the encountered problems on other available systems.

The methods applied on the developed projects were focus groups, surveys and interviews for conducting user research, since they are suitable for answering questions about what, why or how to fix a problem and they are methods to collect data to enrich different interface and systems design and development. These methods permitted categorizing attitudes and providing a view of what people think about the interface/application in development.

Focus groups are a method to explore opinions about a specific product and topics. They were used on the application for musicians (project 4) and on the project about the elderly center (project 1). In the field of human computer interaction, they are used to explore user perspectives on systems and their usability. However, focus groups tend to be less useful for usability purposes, for a variety of reasons, but it provides a top-of-mind view of what people think about a brand or product concept in a group setting. This method was a prevailing tool for the systems development; nevertheless it was not the only source of information to get data about the user behavior and to discover what they wanted from the systems.

Surveys represent one of the most common types of quantitative research. Survey sampling is particularly useful when the population of interest is very large or dispersed across a large geographic area. Survey research is widely used in human-computer interaction (HCI) to measure users' attitudes and collect product feedback. Online surveys was conducted to gather feedback about a learning tool proposal (project 4) and to measure user's satisfaction about framework's use. In survey research, the researcher selects a sample of respondents from a population and directs a standardized questionnaire to them. Questionnaires and surveys are complementary tools: A questionnaire is a research tool that uses questions in the gathering of information from different respondents while a survey is the systematic collection of information from different individuals. Also, a questionnaire is a survey tool while a survey is the process of using questionnaires to gather information. A survey is broad while a questionnaire is a specific type of gathering information. The questionnaire, or survey, can be a written document that is completed by the person being surveyed, an online questionnaire, a face-to-face interview, or a telephone interview. On the experiments carried out the goals of the conducted surveys were the measurement and categorization of attitudes or the collection of self-reported data that could help track or discover important issues to address on the application or interface development.

Interviews permitted, by asking questions that explore a wide range of concerns about a problem, to give interviewees the freedom to provide detailed responses. Interviews were used in almost any phase of the project, from initial exploration to requirements gathering, evaluation of prototypes, and summative evaluation of completed interfaces/systems. Interviews were applied in all the projects. In some case, interviews followed the survey to complement the gathered data. When the interviews were concluded a new phase arose, the data transcription and analysis. From that moment, different codes were defined to give rise to several categories. This analysis process was made with other spreadsheet and from there charts and diagrams were constructed. In one of the projects (musical learning instrument) additional questions complemented those included on the survey.

SandBox is an interactive artistic installation that, by means of poetic immersion, (re) presents life stories, scenarios or simply moments lived from the representation of that place: the sea [33]. In this work a combination of several qualitative methods was used: questionnaires, interviews and observation. Questionnaires and interviews were used before the prototype development phase, and along the interaction process between the whole interactions and the interactive installation. The interviews allowed to explore several problems we had and to get users' information, which was used, on the installation.

The presented methods were used either for conducting the design process or for the artifact's evaluation. The next section contains an explanation about this subject.

4 Results and Discussion

This section presents the author criticism about the research methods used on the artifacts design and artistic installation. Human work interaction design framework is introduced as a kind of research method to be considered on HCI. Conversely, authors propose the use of mixed methods approach as, according to literature, the more complete one to evaluate a diversity of artifacts.

4.1 Human Work Interaction Design

HWID includes the study of how to understand, conceptualize, and design for the complex and emergent contexts in which HCI and work are entangled. HWID aims to increase the benefit derived from elements from both interaction design and work analysis knowledge, such as work analysis, prototyping, organizational change, computer-supported cooperative work, human-computer interaction, and participatory design, by interrelating them and capitalizing on their individual concepts and empirical instruments [34, 35].

Secondly, it aims to develop a new and harmonized interdisciplinary framework for trans-mediated and smart workplaces that addresses the core challenge: how do you take a balanced and holistic design approach to improve the work experience in the organization? It aims to engage with and learn from partners' research in different work domains when identifying key attributes in the effective trans-mediation of pervasive and smart technologies from one work domain to another. Figure 2 shows the HWID framework used for data gathering and analysis for the developed artifacts.

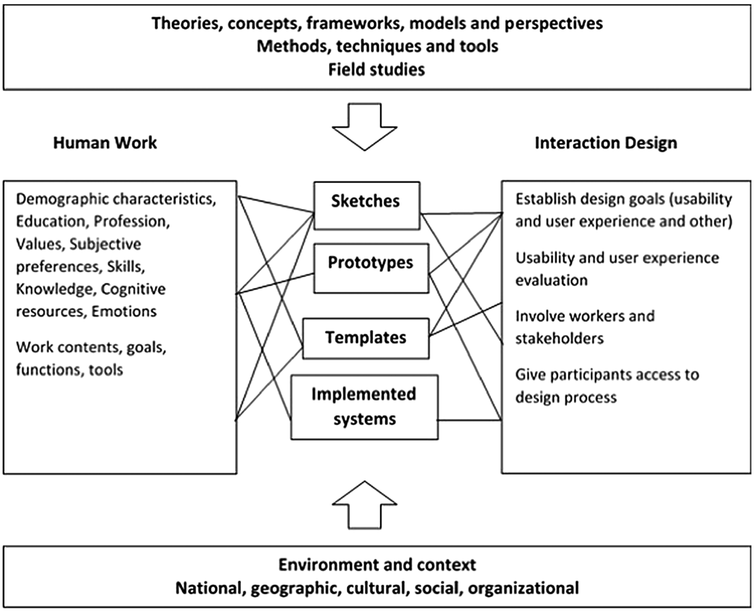

Fig. 2. HWID framework [34]

Human work analysis is traditionally focused on user goals, user requirements, task and procedures, human factors, cognitive and physical processes, and contexts (organizational, social, and cultural). Today, generic designs are applied to use-situations with very different purposes, as the same social software or games are used for both work and leisure situations. Thus, design shifts from design of a technology to design of various use situations encompassing the same technological design. There are other frameworks and tools to design and evaluate artifacts. For example, Norman model of interaction [36] provides a framework for examining interaction. The model concentrates on user's view of the interface. The model is also known as model of human action. It identifies processes involved in action, but does not specify how they take place. It is a useful tool for thinking and analysis.

Authors consider that this model and the overall approach are interesting to apply on the development of artifacts. It contains the guidelines to obtain and to analyze data. This framework was used on the artifacts examples described in this paper.

4.2 Framework for Interactive Artistic Installation's Evaluation

Evaluation, in some sense, of an interactive system in action is the only way to understand its full dimensions [37]. The main feature an artist wants to evaluate is a range of aspects of the interactive artistic installation and its exhibition including the audience experience of the work and their involvement in research.

Authors propose the use of mixed methods for interactive artistic evaluation. These methods are the same used for data gathering and development of which the questionnaire survey format is the most common. Evaluation is done mainly through general questionnaires, which helps to provide feedback for the artist to measure success in terms of audience attendance and general attitudes. Several forms can be used: log-data, video footages, interviews, and questionnaires for example. This data allows to identify the factors that raised the engagement and to understand how participants appropriated the interactive artistic installation, as well as, how they behave.

The proposed framework to evaluate the interactions and acceptance of an interactive artistic installation is presented on Fig. 3.

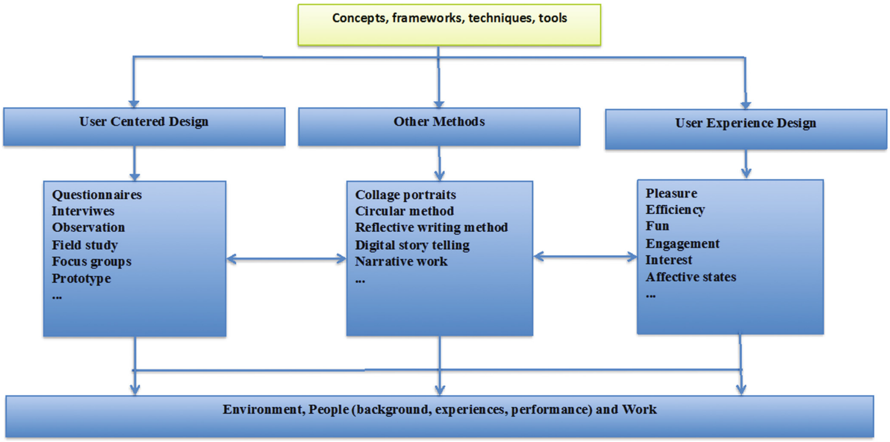

Fig. 3. Framework for interactive artistic installation

The framework contains the main information about context and environment from HWID framework and the mixed methods from HCI, user-centered design, interactive artistic installations methods and from user experience design approach.

The main aspects of the user experiences are: pleasure, engagement, fun, interest, and other affective states revealed by the user. These aspects can be observed in several ways or evaluated by mixed methods. However, the user's role is very important: if he/she interact or not with an installation providing us a feedback to start the affective reaction's analysis.

4.3 Critical Appraisal

The choice for the best method to use in HCI or, specifically, in the development of artistic installations, is a tough decision with different implications.

The discussion along the paper about research methods was presented in distinctive levels: different research methods used in HCI were described, according to literature; then, within this bracket a specific approach of design was explained together with the methods, normally applied to evaluate outputs; moreover, examples of developed artifacts were settled to reach the point that the same or different methods, for example, qualitative ones, can be applied independently of the artifact either to develop or evaluate it; finally, other methods for design were presented.

To clarify this endless discussion, it is necessary to focus on the following arguments: first of all, it is important to decide when to choose a method; is it to be used for helping the design process or for the output evaluation (user using the artifact)? Then, the following question must be answered: why is evaluation needed in HCI, or specifically in digital art? Starting from the end, author considers that evaluation produces information about user reaction to design (positive or negative emotions), validation and alternatives in design ideas. Also, evaluation makes part of the iterative design process.

In this discussion the focus is on the design stage and the designer and developer. The design stage comprises several moments: before, during and after the outcome. On the first stage, developers are focused on the context and requirements; on the second stage, the goal is to evaluate the choices of design ideas, the representations and the user reactions to design; the final stage is the moment for the revisions and to test the user performance. The evaluation serves as a critique either for the developer or for the user. When the focus is merely on a digital artistic artifact, side by side with the design process, the user/audience interaction is a very important source of information. The practice is similar to other forms of research but it requires thinking about how to design and implement the technologies involved and research about understanding how audiences respond to the interactive experience. The degree of audience engagement with the interactive installation is an essential clue to register, not merely by how long people look at an artifact, but how they sustain the interaction and the level of engagement: the overall behavior. To register this data, observation method is the main one to be used, although it can be combined with other methods in order to obtain substantial information.

The choice for a correct and unique method does not exist. The reason is because each method offers possible opportunities, not available by other means and also, each method has weaknesses and strengths. So, mixed methods research is the suggested solution since it comprises different and complementary methods. However, the focus about what and why to evaluate must be defined. Moreover, within the mixed methods approach and after considering the user-defined profile, the choice must contemplate those that permit to include tools inherent to the design for all.

5 Conclusion

Author considers that the suitable approach for interactive artistic installations should be a mixed method approach to evaluate the easier perceptions.

HCI can support with the methods for evaluation at the beginning, during and after the developed output.

The interactive artistic installation's area is under development and there still is a lack of common practices, considering research evaluation methods compared to areas that deal with more traditional HCI. The main reason is probably on the dichotomy between objectivity and subjectivity. In artistic installations field the experiences are fundamentally subjective. They are evaluated as they are installed in real world situations – implicating that evaluation is carried out when user receives the implemented installation. Evaluation in the field should be inspired by HCI for understanding usability issues that might be part of the experience of interacting with an artistic installation.

HWID framework can help to sustain the theories applied and to organize the design structure of the interactive artistic installations. Both mixed methods in HCI and the HWID framework can be combined on the proposed framework for interactive artistic installations evaluation. This framework is under construction. Authors are testing it among artists and technologists who are developing artifacts.

The presented examples of research methods given in this paper are examples being adopted by the author but they are by no means exhaustive. They are intended only as examples, which begin to demonstrate a growing confidence in the use of different research methods in HCI in general, and in specific in interactive artistic installations.

In summary, the best method to use depends, firstly, on what the developers want to get. Design with or design for users/audience. If they want an interactive artistic installation centered on the user, which means that the user is involved from the beginning of the design process. Or if the goal is to register the affects, i.e., the audience experience with the work. The chosen method must help to answer the question settled at the beginning of the design process.

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Theorizing About Socio-Technical Approaches to HCI

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Abstract. In this paper, we theorize about Socio-Technical approaches to HCI. The Socio-Technical tradition indicates that looking at design only or mainly from a technical design side is insufficient to design systems for work and workers; instead the social and the technical need to be co-designed and contingent on characteristics of the context, the organisation, and its historical development. However, it also argued that this tradition does not provide enough handles for the design of interactive technologies for users. We present Socio-Technical HCI as a distinct field of knowledge outlining the Socio-Technical traditions where it is rooted, and illustrate these with three different conceptual frameworks that have been used to support the design, development, and evaluation of interactive systems. These frameworks are Cognitive Work Analysis, Human-Work Interaction Design, and Technological Frames. These frameworks are compared and analysed in terms of what are a balanced and comprehensive way to in address socio-technical, contextual, and design issues in HCI. It is argued why Human-Work Interaction Design is best placed to address these issues.

Keywords: Socio-technical · Human-Computer Interaction
Human Work Interaction Design · Cognitive Work Analysis
Technological frames

1 Introduction

The study of Human-Computer Interaction (HCI) has historically drawn on Socio-Technical (ST) traditions on attempt to provide an understanding of users' actions, which goes beyond cognitive and individual experience phenomena to incorporate the social, cultural and contextual character of interactive systems design, development, evaluation and use. For instance, ethnographic methods with a sociotechnical perspective have been used in HCI to understand the work of end-users actions performed collaboratively with other people in a field setting. This implies that user activity is seen as a social and organisational experience. In this context, ST and HCI are interlinked in such a way to form a distinct field of knowledge, namely Socio-Technical

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HCI (ST-HCI). In this paper, we offer an overview of ST-HCI the ST traditions where it is rooted and illustrate these with three different conceptual frameworks that have been used to support the design, development and evaluation of interactive systems. These frameworks are Cognitive Work Analysis (CWA), Human-Work Interaction Design (HWID), and Technological Frames (TF). Compared to Activity Theory or Actor Network Theory, we believe the frameworks we have chosen offer practical ways to address contemporary design issues such as designing automation [1] from a ST-HCI HCI perspective. For example, HCI authors find that activity theory has some shortcomings when analysing dynamics over time [2]. Going beyond HCI, while actor network theory does explain how actors develop networks by translation and thus innovate technology [3], how this is to be applied in HCI design is not clear. Other promising social theory for studying ST-HCI is Social Representation theory that explicitly addresses the temporal experience of meaning making [4] In social representation theory, work engagement should carefully be anchored in, e.g., stabilised into, an existing HCI design goal such as user experience, and then objectified through a series of research studies and practical design projects that would gradually lead to established HCI design goals. However, HWID, CW and TF have the advantage, compared to the above theories, that they are already narrowly focused on interaction design and well-known HCI methods for empirical socio-technical analysis.

The paper first provides an overview of ST traditions and then presents series of key questions ST-HCI should be able to answer. This is followed by a presentation of instances of ST-HCI in the form of brief case studies featuring CWA, HWID and TF. These case studies are then discussed in terms of the key questions introduced earlier. From this we go onto a discussion of what each perspective provides to ST-HCI and the distinct characteristics of this field of knowledge. Based on this discussion, the paper concludes with recommendations about the most suitable ST-HCI approach.

2 Socio-Technical Traditions

ST traditions and approaches stem from two different scientific traditions: one that emerged from organisational studies conducted by the Tavistock Institute of Human Relations in London in the late 40s and 50, [e.g. 5, 6], and one that emerged from a group of authors concerned with the social shaping of technology [e.g. 7, 8]. Socio-Technical systems theory key principles were originally proposed by Trist and Bamforth [6] and are aimed at increasing both productivity and worker satisfaction through joint optimisation of the social and technical components of organisations. These principles recognise the need to empower workers in decision making and focus on whole tasks as main units of analysis beyond any spatial-temporal boundaries. The main tenet of Socio-Technical systems theory is that introduction of technology innovation without the consideration of organisation's existing structures and division of labour can lead to a decrease in productivity and worker satisfaction. Job enrichment, as opposed to job enlargement, is claimed as the immediate benefit for workers. These principles were later developed by Mumford [9] through her ETHICS methodology for the design of information systems, where the participation of workers, as users, in decision making is a basic condition for satisfaction and usefulness.

Unfortunately, despite ST approaches emphasis on user involvement and decision making in organisational work contexts, no clear handles have been provided by authors like Mumford [9] and Cherns [5] to interactive system designers trying to make their systems not only more usable, but also more useful and satisfying from a user experience perspective. Dillon [10] defines this gap very well by pointing out that 'Criteria for effectiveness, efficiency and satisfaction must be derived from the social not the individual context of use' and calls for ST approaches to be operationalised at the level where user interactions are designed.

Authors in the Sociology of Technology are ontologically concerned with Socio-Technical phenomena [7, 8, 11, 12]. They converge on the fact that the character of technology is situated, interpretatively flexible and socially shaped and shaping. They usually produce concepts and theories aimed at making sense of Socio-Technical change and diffusion. For instance, the concept of technological frames by Bijker [13], tries to capture the interpretive frames and social dynamics that influence the social construction of technology. Actor network theory (ANT) proposed by Latour, [14], presents an approach to understanding Socio-Technical phenomena through the agency of networks of human and non-human actors. A key concept in ANT is that of translation [3], as it explains to understand how technology innovation is the consequence of the successful re-alignment of actors willing to sustain and develop the corresponding network. In ANT networks are inherently Socio-Technical since human and non-human actors can have mediating roles depending on their situation in the network. Technological frames and ANT are good examples of how theories can be used to make sense of technology design and use.

The key difference between the two ST traditions discussed above is an epistemological one which can be summarized into a constructive-critical dimension: knowledge in ST systems theory is aimed at problem resolution in the design of work systems (constructive), while knowledge in the Sociology of Technology is aimed at a rich understanding of Socio-Technical change (critical). ST-HCI inherits from Socio-Technical this epistemological double aim of design and understanding but adapting it to HCI.

3 Questions to Ask Socio-Technical Traditions from an HCI Perspective

There are questions to ask to the ST traditions from an HCI perspective. The key characteristic of almost all ST research variants, even those close to systems thinking traditions or to Marxist inspired system development approaches, is that ST challenges a purely technical perspective.

Here HCI may (1) ask exactly which interpretation of all the variants of ST is useful for HCI research and practice, which has indeed a specific technical perspective on the interactions with computers. While the starting point is typically some (new) technology, ST research does not focus on technology per se, but on social issues on four different levels: the interaction level (HCI, UX, Interface), the individual level (job satisfaction, job design, automation), the organizational level (decentralization, decision making, business models, strategy) and/or societal level (unemployment, privacy, wealth distribution) [15].

So, HCI may ask, (2) how can HCI researchers take into account several levels of the social while still focusing on the interaction design? Though some variants of ST may offer more practical guidance as to "how to develop systems, how to manage implementation or how to identify exciting IT inventions/innovations", other ST variants, despite being offered prominent positions such as CHI keynotes have not yet been shown to support the actual design of HCI.

So thirdly, HCI may ask (3) how to conceptualize the computer/interaction and give recommendations for design? Obviously, design is highly contextual, "design becomes a set of routines that emerge in context" [16]. ST has to some degree acknowledged the importance of context, e.g., by modifying US based textbooks on Management of IT to match the local context [15].

However, HCI may ask (4) how should context be taken into account? A forceful argument is that changes in economic paradigms enforce new contexts for HCI: from the usability of industrial economy, the user experience of the experience economy, the social media and open platforms of the knowledge economy, and most recently, the ethical issues and emphatic livings labs of the transformation economy [17].

In the next section we demonstrate how ST-HCI approaches sitting in different epistemologies should help answering these four questions.

4 Epistemologies that Allow Us to Explore Socio-Technical HCI Perspectives

Our aim with ST-HCI is to articulate epistemologies that provide researchers with a flexible standpoint in their approach to HCI design. According to Guba [18], theorising from a relativist ontology and epistemology, as in in the case of ST-HCI, recognises that the production of theories will never be exhaustive or absolute, and that knowledge is possible only through interaction of the inquirer and the inquired. ST-HCI researchers recognise the need for these interactions and see knowledge as a continuous co-construction, where researchers, developers, designers, managers and users can be the subjects and objects of inquiry. ST-HCI epistemological positions fundamentally serve two different types of purposes.

On one hand ST-HCI can enable an understanding of ST change, – drawing on theories in the Sociology of Technology such as Actor Network Theory or Technological Frames, which is discussed later in this paper. ST-HCI can facilitate the integration of concepts and perspectives that enable the identification of scripts and power relations inscribed in work systems, and, by implication, with the interpretive and experiential dimensions of workers' engagement. While this knowledge is not directly instrumental to support design decisions, it is a legitimate way to make sense of ST change in the context of the workplace as a complex network of human and non-human actors.

On the other hand, ST-HCI can also help to solve ST design practical problems – in the spirit of the Tavistock tradition. This means that visualising relations between the work domain, interaction design and work systems can lead to an iterative set of contingent tools and rules with explicit implications for design decisions for workers' utility, usability and user experience goals. In this case, the knowledge produced is not aimed at understanding the social and political nuances shaping ST change as an organic process but aimed at solving practical interaction design problems in the context of ST systems. In the following sections we present 3 different instances of ST-HCI conceptual frameworks.

4.1 Cognitive Work Analysis

ST traditions share a general concern: provide knowledge that can be used to create systems that 'fit' with users and their context. However, while interaction design offers handles to support design decisions for user interfaces, methods in work analysis provide structural and/or contextual models of actors and information flows, not necessarily concerned with interface design. As a response to these limitations in work analysis, Vicente [19] developed CWA as a framework to model complex Socio-Technical work systems. Within this framework, Ecological Interface Design (EID) emerges as set of analysis methods to support decision making in the processing and presentation of information according to end-users and their role as actors in the work system. CWA and EID fall clearly within a functionalist paradigm as per Hirschheim's paradigm of information systems development [20].

We illustrate the use of CWA in a case study used to support design considerations for the Smart University system [21]. This technique is driven by a framework that supports and structures the analysis needed when designing a flexible and adaptive system. The framework focuses on analysing the limitations and constraints on workers behaviour; and mapping these constraints is the design of the system that will support the workers.

The CWA framework comprises five different phases; work domain analysis, control task (or activity) analysis, strategies analysis, social organisation and co-operation analysis, and worker competencies analysis. Using CWA has two distinct advantages. First, CWA is a multi-dimensional analysis that incorporates the physical and the social environment to provide a rich description. Secondly, CWA can be paired with Ecological Interface Design (EID) [22] to generate designs for new information systems. EID has shown success in the design of analytic information displays in power plant displays [23]; social systems [24], healthcare decision support [25] and community building [26]. For these reasons, CWA is a viable approach in cyber physical systems such as those supporting smart work environments. We now illustrate CWA briefly with a scenario focused on smart universities:

> A lecturer, who offers weekly online exercises has the intention to help his/her students to prepare for an exam. But she is not sure if the currently available exercises are helpful enough for this purpose. Therefore, he/she would like to know if those students who practice with her online exercises on a weekly basis are better in the final exam than students who do not use them. A Learning Analytics toolkit could help him/her to do research on this hypothesis by automatically collecting, analyzing, and visualizing the right data in an appropriate way. The smart university platform should allow for interactive configuration in such a way that its users could easily analyze and interpret available data based on individual interests. We present this scenario through the lens of the different phases of CWA.

Work Domain Analysis (WDA) provides an overview model of the work environment with a view to understanding what kinds of information should be included in the user interface and how this should be presented. The learning analytics toolkit is part of a ST system whose main goal is maximising learning outcomes and the learning experience for students. Table 1 presents an Abstraction Hierarchy (AH) typically used for WDA [25]. This is made of five levels, which are now described in terms of the learning analytics scenario:

Table 1. Work domain analysis for learning analytics scenario

WDA: supporting exam preparation	
Physical form	for student (type, program, year of admission, status, performance level); for learning material (type, date available); for evaluation material (type, date of evaluation, grades achieved), for lecturer (level, name, availability); for student record system (type, data available, dates accessed)
Physical function	Student, VLE, Lecturer, university student record system, material to be learned, evaluation material
Generalized function	Student accessing material, lecturer creating and uploading new material, contributing to discussion board, monitoring and evaluation of student's progress
Abstract function	Balance the ratio of evaluation to learning
Functional Purpose	Maximize learning outcomes, Maximize student experience

Since education is a core goal of this scenario, learning needs to be present in the functional purpose and generalized function levels. The scenario indicates that there is a concern that weekly exercises might improve learning, as evaluated through exam results, or might not be helpful. This is why we have chosen to describe at the abstract function level that there must be a balance between evaluation and learning, e.g. you cannot evaluate 100% of the time, but you also need to evaluate at some level. The functional purpose is to find the sweet spot where learning outcomes and student experience are maximised at optimum levels.

WDA will allow us to identify the analytics data needed for designing components of the system. For instance, a key goal derived from this WDA is to enable the instructor to move that sweet spot between evaluation and learning to maximize outcomes and experience. Those are the drivers, i.e. decisions to be made with the analytic system.

Control Task Analysis is done to determine what tasks are being carried within the system and under what conditions. In this learning analytics scenario, control task analysis (ConTA), based Rasmussen's decision ladder [26], the analysis would look like in Fig. 1. Is there uncertainty and ambiguity on the possible goal state? Quite possibly, if the instructor is following a new evaluation approach for students, she may move into knowledge-based behavior trying to figure out what is wrong. Analytics could play a role here. Instructors can then 'define a task', i.e. choose to modify their instruction approach. This implies setting a new 'procedure', more or less exercises in this case, which would then be 'executed'.

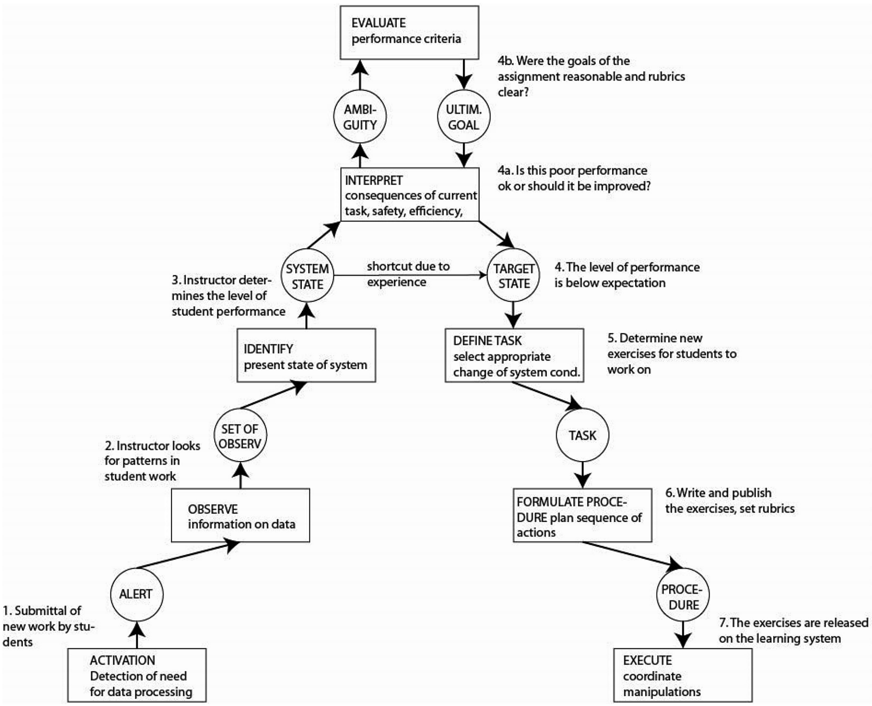

Fig. 1. Decision ladder for learning analytics scenario.

Strategies, Social and Worker Competencies are also critical. This level of analysis can facilitate the discussion of different teaching strategies (traditional, flipped, blended learning). This could also reveal different evaluation strategies (short quick frequent evaluations, longer midterm/final, or project based evaluation).

The identification and description of social competencies could represent values and intentional constraints being conveyed by the institution. It could also consider the culture and cooperation of the students in this. As a worker, the instructor must have competency in teaching, the material being taught, and the use of the smart learning system. Skills, rules and knowledge is the base for all of these.

Looking at this scenario through the CWA approach supports the HCI decisions on which usability and user experience goals that should drive the interaction design of the different interface components of the smart university sociotechnical system. The CWA of the learning analytics scenario clearly points to importance of effectiveness and utility [27] as main usability goals driving the design of the user interface of the lecturer trying to establish the optimum level of exercises that should be set for students to meet learning goals in a satisfactory way.

In terms of design guidelines feedback and mapping become core objectives in the presentation of the student performance data. Good user interface design meeting these goals and principles will support the overall functional purpose of the learning analytics systems, i.e. Maximize learning outcomes, Maximize student experience.

4.2 Human Work Interaction Design

The problem with CWA and its derivative method, EID, is that they are framed with a mainly functional paradigmatic view of information systems and this limits a more relativistic approach to study of user engagement in the context of work systems. However, sharing with CWA theoretical roots in cognitive engineering research at Risø National laboratory in Denmark [28], an alternative approach called Human Work Interaction Design emerged around 2005 [29]. HWID as a framework is sitting in a social-relativistic paradigm [20], and can thus contribute to the design of systems supporting work satisfaction and positive organisational ST HCI design goals. Below we outline the current version on the HWID framework, see also Fig. 2.

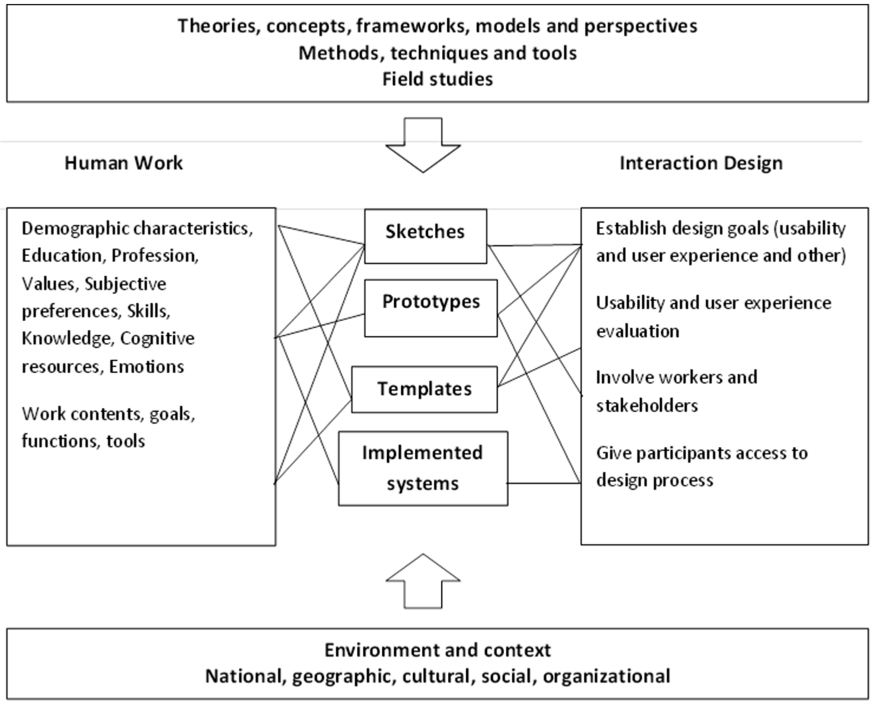

Fig. 2. The HWID framework by Clemmensen [30]

HWID studies how to understand, conceptualize, and design for the complex and emergent contexts in which information and communication technologies (ICT) and work are entangled. Several aspects influence the way humans work and the work itself. For humans, language, culture, education, skills, knowledge, emotions and cognitive abilities contribute to define the profile of users and their approach to individual and collaborative work. For work, its goals, functions, available tools and content contribute to delineate its characteristics and challenges.

The HWID leans heavily on the HCI and human factors traditions specific interpretation of the *social* and the *technical* elements of the ST system. In contrast, the *social* in ST has been described as a broad 'concern with the human workers job satisfaction in a broad sense', and the *technical* in ST has been described as in general 'the IT system' [6, 15].

In contrast to ST's general concern with the human workers' job satisfaction in a broad sense, in HWID the *social* is analysed as end-users' work tasks performed through IT systems within a given work domain. The focus is on the user's experience of tasks (procedures) and the IT artefact environmental constraints as a work domain. Hierarchical Task Analysis [31] and Work Domain Analysis [32] are among the methods that can be used to analyse the goal-directed tasks, and map the work environmental constraints and opportunities for behaviour. In addition, there is a strong tradition in HCI for studying work with ethnographic methods [33] and from Socio-Technical perspectives, e.g., [34]. These approaches focus on work as end-user actions performed together with other people in a field setting, that is, the user's experience of using systems are social and organizational experiences. User experience, usability and interaction design are influenced by these approaches and techniques for analysing and interpreting the human work, which eventually manifests in the design of technological products, systems and applications.

In contrast to ST's general focus on 'the IT system', the *technical* in HWID focus either on interaction designs as such, i.e., user interfaces, or focus at interaction design methods and techniques, i.e., think aloud usability evaluation, sketches, prototypes, and more. Interaction design is presented in textbooks as an approach consisting of conceptual models, scenarios, task analysis, persona, think-aloud evaluation, and other user-centred techniques [27, 35]. In addition to being user-oriented, textbook approaches to interaction design also focus on the use of prototypes, storyboards and sketches, which interaction designers see as products or sources of inspiration in the design process rather than the interaction design itself. For example, sketches, such as free-hand drawings or low-fidelity prototypes, have been studied for their role in design and have been found to stimulate reflection, particularly in the early stages of design [36]. When moving from analysis to design, that is, from conceptual models to physical design, interaction design relies heavily on iterative usability and UX testing of prototypes with users of the future product. A large number of techniques for user requirement elicitation and user tests are available for use in interaction design [27]. In many of these techniques, communication between stakeholders about user requirements is supported by the use of prototypes, mock-ups, and sketches.

We now present an example articulating HWID as a form of ST-HCI. Barricelli et al. report from a long terms case study of an interdisciplinary collaboration between several domain experts in the frame of archaeological projects. Since 2001, different independent interactive systems have been co-designed, developed, and tested on the field, in the frame of the "Tarquinia Project" carried out since 1982 in the ancient Tarchna, one of the foremost Etruscan cities, by the Università degli Studi di Milano. This project concerns the involvement of domain experts, the main characteristics and challenges of the archaeological practice, and how to design and apply technology to support the work and user experience of archaeologists as they engage with their tools and tasks.

Barricelli et al. [37] apply a semiotic approach to the archaeological domain and put in practice a participatory action design research method. Barricelli et al. [37] argue that the archaeological application domain is characterized by strong social and organizational factors, and thus a framework like HWID is needed to ensure a successful theory-based introduction of technology and interactive systems. They argue that the framework does not force a technology/design perspective on the case but allows the interaction of work and the ID to evolve. They applied their favourite theoretical and methodological tools and adapt these to the case, all within the overall framework which provided a holistic gestalt for a set of very diverse approaches, ranging from User Centered Design (UCD) to technical design.

They followed five stages: (1) analysis of the domain with open problems identifications; (2) detection of opportunities and open challenges to be addressed with a participatory approach; (3) actual design with the use of prototypes and recurrent usability evaluations; (4) measurement of impact evaluation with the active involvement of the members of the interdisciplinary team on the field; (5) generalization of the outcomes in a model that reflects the expertise that the researchers developed in the domain.

The case study documents the interactions between the ‘human work’ and ‘interaction design’ streams in the HWID framework. For the ‘human work’ stream, typical archaeologist methods and tools are referenced: non-intrusive (e.g., analysis of aerial photography for landscape alterations, use of ground-penetrating radar to find buried anomalies, and the systematic, controlled collection of materials from surface contexts) and intrusive (e.g., shovel testing, test units, and excavation blocks, each with different range). Archaeologists analyse and interpret these remains in relation to how and why cultures evolved over time. For the ‘interaction design’ stream several methods and tools are referenced: technological approaches, e.g., mobile or web applications, supporting data collection on site, 3D modelling, processing, and visualization technology support modelling, e.g. create replicas of how the soil layer looked and the position of artefacts and structures. The case study highlights the crucial value of the user experience of archaeologists in interacting with data platforms ensuring a correct management of the cultural objects contained in the original sources.

The HWID framework may help formulate findings in relation to how environment and context: strongly influenced the archaeological practice, e.g., the distributed nature of the work (on excavation site, in storage rooms, in laboratories, in universities), the interdisciplinary work with the involvement of experts from different domains, and the international collaborations that highlighted the existence of experts’ sometimes radically different methods, use of different languages (not only in terms of spoken language but also visual notations) and remote interaction (most of the time asynchronous and written).

The overall objective of the research reported in this case study is how to facilitate and perform the co-design of a cloud of services aimed at integrating all the tools into a bigger framework to support the work practice and user experience of archaeologists in a more pervasive and engaging way. What is learned from this case study is that all four main elements of the HWID framework: theory, context, work, interaction design, are all related to the overall goal of work engagement as both a process and an outcome of design: involving and supporting domain experts in the design of their own practice and tools. While HWID is clearly in Social Relativistic epistemology as per Hirschheim's taxonomy [20], ST-HCI can also engage with more radical structuralist stances. The next section presents an example drawing on concepts from the sociology of technology.

4.3 Technological Frames

This section presents a framework based on the concept of Technological Frames (TF) [13, 34, 38], which enables the identification and understanding of the symbolic, material and political dynamics that shape the co-configuration of people, culture and technology in social groups. A TF is constituted by people's interpretive frames and practices that lead to the attribution of meaning to technology. TF give a sociotechnical account of the social shaping of technology and the technology shaping of society and, it is argued, of the process of technical and knowledge communication that go with these processes.

The concept that an important gap exists between producers and users, which can make information systems irrelevant for their intended users is well established and is congruent with Suchman's work [39]. TF provide a means of explicating and analyzing the situation so that interpretive frames and practices of the different stakeholders in a system can be understood and modified or mitigated. Moreover, it is recognized how these frames and practices are subject to political and power relations.

TF analysis is underpinned by the assumption that the usefulness of technology is shaped by the socio-cultural conditions of its stakeholders. This idea is a core element of the Social Construction of Technology approach (SCOT) [7] and is central to the research reported here. SCOT focuses on how diverse meanings are attributed to technology and the interpretive flexibility of technology. In this context, technology is not only defined in the sense of tangible artifacts, but also in terms of knowledge and methods, which makes the TF perspective relevant to the field of technical and knowledge communication.

Usually, the different elements of TF are identified by analysing qualitative data in the form of field notes, documents, observation logs and interviews. However, the creation of categories of analysis can also be based on assumptions and previous experience with the groups studied. The example analysis provided here is based on data gathered in the first visit of the VESEL project team to Kenya as well as some assumptions from the researchers based on their experience of introducing technology in similar contexts. The VESEL project (Village E-Science for Life) brought together British and Kenyan universities to define the most urgent information requirements for a rural farming community and to design the appropriate technologies to meet these needs. The TF elicited from these data are not static and change over the development lifecycle. This is done by an iterative cycle of production and evaluation of sociotechnical scenarios by the producers and, ideally, users of the technology – for more information on this process see Hansen [40].

In order to study TF elements, Bijker [13] would identify the goals and problems that a particular social group had with respect to a particular technology. Table 2 summarizes goals and problems of producers and users with respect to the technology designed in the VESEL project [41]. The Table presented here is not a full-blown analysis but a proof-of-concept exercise to illustrate the value of TF. Elements from the TF of the members of the VESEL team (producers) are compared with those of the farming communities (users).

Table 2. An illustration: technological frames in the VESEL project.

Technological frames in VESEL	
Producers	Users
Goal	
Create effective ICT systems using sensor networks to improve quality of life of rural farming communities. Enabling access to new markets	Improve the quality of their farming knowledge and market network. Improve their productivity and profitability with the least effort
Problems	
Keep to fund holders budget in terms of cost, time scale and resources Need to be innovative	Having suitable ICT tools to support their work
Elements of Interpretation	
Universality of Technology Technical Centredness User awareness in terms of expectations	History of village, perception of socio-political boundaries, established expectations of tools and technology, perception of foreigners No or little previous experience with Technology Rumours of other groups with access to PC
Elements of Practice	
Development practices which are incongruent Limited contact with Users Problem Locus Construction: VESEL tools will improve Kenyan farmers' practices, which are problematic in certain areas	Local Working Practices: interaction protocols for knowledge transfer among villagers, tool mediation Subscription to Technology vs. workarounds: substitution vs. accommodation/integration? Problem Locus Construction: what is wrong with what we do? Why do we need these tools?

The table shows that the Elements of Interpretation and Practice between producers and users are different. This is not surprising as they come from different technological and cultural backgrounds. Producers had to constantly review their assumptions about the universal usefulness and validity of technical artefacts and locate them in the context of these communities. Initial meetings in the VESEL team highlighted the technical centred perspective of some developers, which did not question the situated usefulness and relevance of the scientific content and functions being implemented in the system. The application of TF facilitated the reflective analysis of the language and discursive and political practices surrounding technology of all the groups involved in VESEL, which had a direct impact on the design of metaphors in the user interfaces of the systems being designed – for further description of this impact see [42].

4.4 Summary

In summary, in Table 3 we revisit the questions that we posed in Sect. 3.

Table 3. Differences between CWA, HWID, TF

	CWA	HWID	TF
1. Exactly which interpretation of all the variants of ST is useful for HCI research and practice?	CWA including EID has proven useful to expert work analysists (Vicente 1999r) to help dig deep into a work domain	HWID has proven useful for enabling dialogues between work analysis and interaction designers across various contexts	TF has proven useful to focus on the social construction of technology within organizations
2. How can HCI researchers take into account several levels of the social while still focusing on the interaction design?	One of the five proposed phases of CWA - work domain analysis (WDA) – offers a five level analysis of the work domain that feed into later stages of ecological interaction design	Interaction design (ID) on the individual user/employee level is seen as mutually shaping organizational and work (HW) analysis level issues in a process that also take into account the wider context	Interpretive technological frames (TF) and practices of the different stakeholders in a system – rather than social levels - are understood and modified or mitigated
3. How to conceptualize the computer/interaction and give recommendations for design?	The WDA analysis within CWA helps identify major usability and UX goals for design based on the work domain and work tasks	Relations between work (HW) and interaction design (ID) happens through and is expressed in design artefacts	TF's interpretive flexibility of HCI designs lead to recommendations about tangible artifacts and knowledge and methods for technical and knowledge communication
4. How should context be taken into account?	Context is understood and modelled in CWA at different levels, including physical description of a work domain	What is the relevant HWID context is determined by the temporal unfolding of relations between individual interaction designs and organizational work issues and processes	The context for TF is always an organizational context, and not the wider societal or technological context

5 Discussion

HCI like ST challenges a purely technical perspective on computer design and use. The three ST-HCI frameworks that we have presented in this paper all take into account the social aspects and at the same time conceptualize technology. They all offer a way to theorise about HCI in ways pointed Clemmensen et al. [2]: on one hand we are the first level of meta-theoreticians where we are comparing different socio-technical theoretical traditions and analyze its features, principles and problematic aspects; by focusing on concrete conceptual frameworks within each of them, we are also at the second level where we assess and extend CWA, TF and HWID as an analytical tools to support the design of socio-technically aware interactive systems. They are all candidates for a socio-technical foundation for HCI that goes beyond cognitive and individual experience phenomena to incorporate the social, cultural and other contextual character of interactive systems design, development, evaluation and use. Much needed in the global HCI world of today. However, the three approaches are also different, and perhaps not equally suited for empowering the individual human in her interaction with computers within the wider context. In Table 3 and the following sections, we revisit the questions from Sect. 3 and use these to discuss the differences between the three frameworks, and which one to choose for HCI.

5.1 Differences Between CWA, HWID, TF

Which interpretation of the variants of ST is useful for HCI research and practice? HCI may ask exactly how each of the three frameworks are most useful to HCI research and practice and its traditional individualistic and technology deterministic view. While HCI traditionally focus on individual human-computer interaction and takes point of departure typically in some (new) technology, ST research does not focus on technology per se, but on social issues on different levels.

CWA including EID has proven useful to expert work analysists [43] to help dig deep into 'causal' or physical work domains, in contrast to 'intentional' work domains such as office work [24]. The analysis of control tasks and the work domain are but two of the methods that look at the wider social, physical and technological contexts of human technology use [44] Thus the positivist and functionalist epistemology of CWA is useful for HCI design in certain domains, mostly safety critical and complex work domains.

HWID has proven useful for enabling dialogues between work analysis and interaction designers across various contexts [45]. The relational epistemology of HWID and its explicit focus on the relations between interaction design and work analysis has enabled a dialogue about how to design for the individual within the wider contexts, i.e., how to keep the tradition of the psychology of HCI but embed the notion of usability into a globalized dialogue [46]. Hence HWID is useful for moving HCI incrementally towards a wider and more diverse understanding of the psychology of the user in digitalized work environments.

TF has proven useful to focus on the social construction of technology within organizations [34]. Usability is thus within TF constructed as a stakeholder perspective, e.g., librarians may themselves acts as usability experts evaluating digital library systems [47]. TF's view of usability and other HCI issues as socially constructed is clearly different from CWA's view of HCI issues as phenomena occurring in physical environments; in contrast HWID's view of HCI issues as relational issues does not take a strong position on the nature of HCI issues.

How can HCI researchers take into account several levels of the social while still focusing on the interaction design? Given that ST traditionally deals with several levels of human-technology interaction, of which HCI is only one: the interaction level (HCI, UX, Interface), how will the different frameworks for ST-HCI take into account also the other levels: the individual employee level (job satisfaction, job design, automation), the organizational level (decentralization, decision making, business models, strategy) and/or societal level (unemployment, privacy, wealth distribution)? How can HCI researchers take into account several levels of the social while still focusing on the interaction design?

In CWA, one of the five proposed phases is work domain analysis (WDA). It offers a context-independent five-level analysis of the work domain, see Table 1, which feed into later stages of ecological interaction design. Later development of CWA has led to new social dimensions of CWA such as 'team dimensions' [44]. The objective of Team WDA is to understand how work domain constraints influence a team on different levels. For example, team members may have shared objects or processes, team members may have objects or processes that are not shared, team members may have shared purposes, or team members may have different or conflicting purposes. However, CWA tends to model 'levels of physical reality' rather than 'levels of an organization' or levels of other social entities.

In HWID, Interaction design (ID) on the individual user/employee level is seen as mutually shaping organizational and work (HW) analysis level issues in a process that also take into account the wider context. The relational epistemology of HWID indicates that what is the appropriate level of HCI analysis and how to understand what is an HCI evaluation technique will change depending on the current relation between interaction design and work analysis and the current wider contexts. For example, 'contextual personas' in HWID are focused not on the usage of one system but on describing the whole context of work [48]. Thus a contextual persona could typically be using 20 software systems for solving various tasks at work. Thus in HWID personas are used not as positivist depictions of real target user groups, but as a reflexive tool to be used as trigger material when talking with users, which for example could be the diverse and multifaceted work of the business administrators, see [48].

In TF, the interpretive frames and practices of the different stakeholders in a system – rather than social levels - are understood and modified or mitigated. The constructivist-critical approach of TF emphasizes the social and political rather than the technical. For example, when different groups of users with differing HCI experience evaluate usability a TF analysis will reveal how the evaluation reports are shaped by the different technological frames of the evaluators, and how and at what stage these frames were translated between different groups [47]. In VESEL, it could be seen how farmers and researchers had different political agendas on the development of the technology to be deployed as depicted in their TFs [41]. TF thus tends to model, rather than the technical, mostly the social, organizational and political levels.

While CWA tends to model 'levels of physical reality' rather than 'levels of an organization', TF in contrast focus on the social, political and organizational levels. HWID takes a flexible approach and take into account various social and technical levels depending on what relations between work analysis and interaction design that is currently in focus.

How to conceptualize the computer and give recommendations for design? How do the three frameworks conceptualize the computer/interaction and give recommendations for design? The WDA analysis within CWA helps identify major usability and UX goals for design based on the work domain and work tasks. This could entail doing ecological interface design by mapping work domain information to a graphical representation through a skills, rules and knowledge taxonomy, with the aim to enable users to interact with the information in these three ways. For example, with this approach human–computer interfaces have been design for use in the petrochemical industry [49].

In HWID, relations between work (HW) and interaction design (ID) happens through and is expressed in design artefacts. HWID is thus to be thought of as a design research approach, where the designed IT artefacts are part of the resulting new knowledge production. For example, a mobile interface for illiterate users with weak motor skills may be produced as part of a HWID analysis that also provides insights into work domains, interaction designs, and socio-cultural contexts [46].

TF's interpretive flexibility of HCI designs lead to recommendations about tangible artifacts and knowledge and methods for technical and knowledge communication. For example, Khoo et al. [47] identified 'findability' as an important issue for one group of librarians, and furthermore, that not only did resource retrieval depend on 'metadata', but so did the wider perceptions of the usability of digital libraries in general. In the social constructivist spirit of TF, they argue that the findings are important not only to the design of the digital library and its evaluation, but also to the design of the roles of users and designers in such evaluation.

While the CWA conceptualize the computer/interaction with a skills, rules and knowledge taxonomy and give recommendations for design that are domain specific, TF co-constructs user roles and computer/interaction, and HWID take a design research approach in which the designed computer/interaction is part of the new produced HCI knowledge.

How should context be taken into account? How should context be taken into account? A forceful argument is that changes in economic paradigms enforce new contexts for HCI: from the usability of industrial economy, the user experience of the experience economy, the social media and open platforms of the knowledge economy, and most recently, the ethical issues and emphatic livings labs of the transformation economy.

In CWA, context is understood and modelled not as a separate entity, but at different levels, including physical description of a work domain. More recent approaches also include designing for intentional systems which needs to include analysis of how the environment is constrained by actors' intentions, values, and priorities of practice [24]. Thus, even in analysis of wider societal contexts, CWA remains sensitive to local, contextual details, which cannot be anticipated, by adopting a constraint-based approach.

What is the relevant HWID context is determined by the temporal unfolding of relations between individual interaction designs and organizational work issues and processes. Today, in the current trend of globalization of HCI, it is obvious that the diversity in national cultural contexts shape the ways that HCI designs emerge between work analysis and interaction design. For example, a study of supporting human collaborative works by monitoring everyday conversations made sense when the Japanese context with an increasing elderly population was explained; a study of designing a health-care worker-centred system for a chronic mental care hospital made sense when the Brazilian context of less economic resources was explained, etc. So in HWID, context matters.

In TF, the context is per definition an organizational context, and not the wider societal or technological context. For example, Khoo et al. (2012) argue that the usability evaluator carries out her analysis in the "context of her HCI technological frame" [47].

Context in CWA is taken into account as 'environment' and analysed by looking at the environmental constraints, while context in TF becomes a social psychological representation, and context in HWID is a relational issue, which has so far often been national cultural contexts.

5.2 Which of the Three Approaches to Choose for HCI?

Which of the three approaches to choose for HCI is not only a matter of personal taste, but may be seen as a holistic choice that is related to the wider development of social paradigms. One view of such paradigms is presented by Gardien et al. (2014) who sees the economy as going through four stages with the transformative, ethical oriented economy as the most recent. Without finalizing the discussion, it is possible to argue that CWA has it strengths in the industrial and experience economy, TF in the knowledge economy, and HWID is the most appropriate in today's design for ethical value exchange as it can allow to unfold the ethical dimensions of ST relations, see e.g. [50].

Furthermore, it may be more useful for HCI to take HWID's indifferent position towards the nature of reality, compared to CWAs' marriage to physical reality or TF's basis in social constructivism. HWID also has the advantage of a flexible approach and can accommodate various socio-technical levels of analysis; in contrast CWA has a fixed number of 'levels of physical reality' and TF only focus on social, political and organizational levels. For HCI, the design research approach of HWID appears more natural than the elaborate taxonomies of CWA or the continuous co-construction of users and technology in TF. The final argument for choosing HWID for ST-HCI is that it is the only framework that can handle the diversity of contexts that are important to HCI of today – CWA can handle physical 'environments' and TF social psychological representations, while context in HWID is a relational issue.

5.3 Using HWID to Do Empirical, Design-Oriented Studies

While it is beyond the scope and space to discuss method implications, as an ST HCI framework HWID should be understood within an interpretative paradigm. It supports bottom up case-specific theory building, supported by HWID framework. The use of grounded theory approaches supported by qualitative analysis software to do open and data tolerant analysis is recommended. At the same time, it is always important to consider the various kind of contexts for the HWID relations. Finally, best practice is to compile data displays that allows cross case comparing and discussion of the shapes of the holistic HWID gestalt.

As with contextual personas example indicated above [48], HWID provides clear handles to inform the design of digital artefacts and services by enabling a socio-technical dissection of design features and decisions in terms of it social and technical origins or implications. It does so by making otherwise invisible relations between the domains of work and design explicit and visible by theorizing them. The HWID framework supports designers in identifying socio-technical issues that are likely to make a functioning system useless once it is deployed in its organizational context of use. Another, more outwardly looking example is the HWID analysis of a mobile app to support fishers in Alibag, India, where it is illustrated how design decisions about visibility of the fish location did not take into account wider implications in the division of labour between large and small boats and the sustainability of fishing practices [50].

6 Conclusions

In this paper we have introduced the need for a socio-technical approach to HCI. Three different candidate frameworks have been presented, CWA, HWID TF, and compared in terms of how they address four questions: (1) which interpretation of all the variants of ST is useful for HCI research and practice, which has indeed a specific technical perspective on the interactions with computers? (2) how can HCI researchers take into account several levels of the social while still focusing on the interaction design? (3) how to conceptualize the computer/interaction and give recommendations for design? (4) how should context be taken into account? The analysis of how these questions are addressed by these frameworks highlighted the main following points. CWA is focusing on models of physical realities and is underpinned by organizational psychology and cognitive engineering. Its functionalist perspective makes it ideal as a tool for the future design of interaction in socio-technical systems. TF is focusing on socio-political meaning-making practices around technology and is underpinned by more critical perspectives on the sociology of technology. Its critical perspective makes it ideal to deconstruct technology in terms of the social and political meanings that have shaped it. HWID has the advantages of a relational epistemology which is much needed for doing HCI in the current global economy. This means that HWID both can be used to ‘look outward’ and make sense of existing socio-technical relations (like TF), and also be used to ‘look inward’ and inform design of future solutions (like CWA). HWID is therefore being the preferred ST HCI approach.

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A Worker-Centric Design and Evaluation Framework for Operator 4.0 Solutions that Support Work Well-Being

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Abstract. Future factory work is developing towards knowledge work, making it more demanding but also more enriched and flexible. The change described as Operator 4.0 has high potential to increase work well-being but it will require careful design of future factory tools and work practices focusing on the worker point of view. We introduce a design and evaluation framework that supports design, evaluation and impact assessment activities that target at Operator 4.0 solutions with a positive impact on work well-being.

Keywords: Work well-being · Design and evaluation framework Impact assessment

1 Introduction

The fourth industrial revolution, often referred to as Industry 4.0, is already on its way enabled by advanced digitalization, industrial internet and smart technologies such as Internet of Things (IoT). For manufacturing industry, this revolution is expected to provide shorter development periods, individualization in demand for the customers, flexibility, decentralization and resource efficiency [1, 2]. Industry 4.0 will also change factory floor work, making it significantly more demanding in terms of managing complexity, abstraction and problem solving [3, 4]. Employees are likely to act much more on their own initiative and organize their personal workflow. Flexible work organization models meet the growing need of employees to strike a better balance between work and private life as well as between personal development and continuing professional development [3].

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A central part in Industry 4.0 is the human-centricity of the Factories of the Future, described as development towards Operator 4.0 [5]. Operator 4.0 refers to smart and skilled operators of the future, who are assisted by automated systems that provide a sustainable relief of physical and mental stress and let the operators utilize and develop their creative, innovative and improvisational skills, without compromising production objectives [5].

Operator 4.0 factory work will be qualitatively enriched and flexible and will require new qualifications to master the digital technology invading to factories. Future factories should support current workers in learning new skills while tempting new workers who are already familiar with digital solutions. The advanced work environment and work tools are expected to enhance work well-being. Well-being is crucial for keeping qualified and experienced personnel in the company and, additionally, work well-being positively correlates with productivity [6]. Thus, work well-being serves both the employee and the employer.

New Operator 4.0 work tools and related new work practices have the potential to enhance productivity and work well-being but these positive impacts do not materialize automatically. How should the targeted impacts then guide the design process? It requires, at least, that the objective of the design is set accordingly and kept in focus throughout the design process. In the *Factory2Fit*[1] project, we aim to design Operator 4.0 solutions that directly support the workers themselves and enhance their possibilities to influence their work. The challenge in designing such solutions is to find ways to guide the design so that the main aim of worker wellbeing is affecting constantly and efficiently the design. This cannot be obtained by just emphasizing wellbeing in design as wellbeing is the result, not the means. In the design process, we need to focus on immediate implications of the design decisions from all relevant perspectives such as usability, user experience and safety. The design decisions then have wider impacts on worker well-being, and those impacts should be foreseen in the design. Thus, we need a design and evaluation approach that will focus both on immediate implications of the design and wider impacts on work wellbeing. To face this challenge, we have created a framework to support the design, evaluation and impact assessment activities throughout the project.

In the following, in Sect. 2, we first give an overview of related research. Then in Sect. 3, we introduce the basic structure of our design and evaluation framework. In Sects. 4 and 5, we describe the work well-being approach as well as the design and evaluation approach that we have chosen to the framework. Finally, in Sect. 6, we outline how we plan to use the framework in design, evaluation and impact assessment activities and present examples of using the framework. At the end, we present conclusions and our future work plans.

2 Related Research

In the literature, various frameworks for design and evaluation of work systems have been proposed. Activity theory can be used as a framework for analyzing and redesigning work [7]. Activity theory analyses work, roughly, from the perspectives of instruments,

[1] www.factory2fit.eu.

subject, rules, community, division of labor and object of work, and can be used for developing work in a systemic level [7]. A framework for design and evaluation of complex interventions to improve health was created by Campbell et al. [8]. Their framework is focused on addressing the additional problems resulting from the evaluation of complex interventions. The framework used in the study of Sluga et al. [9] provides a conceptual framework for collaborative product design and the related operations in manufacturing work systems. They created a conceptual model for collaboration and an ICT platform, which supports collaboration over the web. None of these models address the worker's satisfaction or well-being that are of main interest in our project.

Danna and Griffin [10] present an organizing framework that highlights the major elements of health and well-being in the workplace. They propose that the antecedents personality traits, occupational stress and the work setting influence work well-being and the worker's health in the workplace. Furthermore, the well-being at work determines individual (e.g., psychological consequences) as well as organizational consequences (e.g., productivity). There are about 1,300 articles citing the one of Danna and Griffin, but hardly any of them really use their framework. Some studies test or refer to some relationships that are part of the framework [11–18]. Examples are briefly outlined below.

When assessing the impact of healthy work organization intervention in a retail setting, DeJoy et al. [11] used the conception presented in the study of Danna and Griffin [10]. So an expanded view of organizational effectiveness was assumed, including both business performance and employee health and well-being. Wood and de Menezes [12] state, referring to Danna and Griffin [10], that the policies that increase employee well-being are essential, because, among other things, stress at work extends to general health [12]. Koopmann et al. [13] examined predictors of daily regulatory focus at work and the foci's impact on employee well-being at work and home, conceptualizing well-being as mood and psychosomatic health complaints, in accordance with the prior work of Danna and Griffin [10]. In the review of current state of research in employee well-being, Ilies et al. [14] refer to Danna and Griffin [10] in stating that happy workers are less often late and show up for more days of work. Nielsen et al. [15] reported having used the definition of well-being of Danna and Griffin [10], so that well-being is the state of employees' mental, physical, and general health, including also their experiences of satisfaction both at work and outside of it.

Only a few studies, found by the authors, have utilized the framework as such or with minor modifications, like in the present study. Dežmar-Krainz [16] has analyzed and assessed in a theoretical level how socially responsible orientation incorporated in human resource management can contribute to well-being of employees. In line with Danna and Griffin [10], Dežmar-Krainz acknowledges that home and workplace well-being often overlap. Furthermore, the original model [10] was only slightly changed by reformulating the concept of occupational stress (preferring the concept of psychosocial stress).

Nykänen et al. [17] combined the model of Danna and Griffin [10] and the framework of Newsham et al. [18] with the goal to develop a new user-friendly design model for intensive and intermediate care facilities in hospital context. The model by Newsham et al. [18] links the physical environment, through environmental satisfaction, to job satisfaction.

In the framework by Nykänen et al. [17], multitasking, job stress and burnout as well as indoor environmental satisfaction are regarded as mediating factors between antecedents (physical conditions and personality factors) and consequences, in this context well-being indicators (job satisfaction and work engagement). The usage of physical factors is a natural choice when indoor design is focused on, and multitasking reflects an elementary part of nurse's work. Nykänen et al. [17] were using their framework for evaluation purposes.

Although other frameworks exist besides the one of Danna and Griffin [10], none of them covered the concepts satisfaction and well-being in a similar way. Their framework included the design aspect and the characteristics of work-related aspects and company benefits as needed within our research. Furthermore, various authors have referred to Danna and Griffin's framework [10]. Thus, we decided to utilize the model of Danna and Griffin [10] as the fundamental basis and we decided to relate also to the model of Nykänen et al. [17]. The framework used in this study is described in the next section.

3 The Design and Evaluation Framework

When designing Operator 4.0 solutions, individual worker's point of view should be central in the design and evaluation activities. New work tools and related work practices should be designed so that they result in meaningful, motivating and engaging work tasks. Accordingly, the design outcomes should have a positive impact on work well-being and company benefits.

Our aim was to define a framework, which supports the (i) design and evaluation of the new Operator 4.0 tools and practices and the (ii) assessment of their impact on work well-being and company benefits. The design and evaluation framework that we suggest is presented in Fig. 1. The framework utilizes the framework of Danna and Griffin [10] by modifying its content to meet the design and evaluation needs of our project. In that sense, our study is similar with the studies of Dežmar-Krainz [16] and Nykänen et al. [17]. Conceptually, the framework by Nykänen et al. [17] is quite close to our approach. Similar to those approaches, in our framework, work well-being is affected by both non-work and job-related satisfaction. The novelty value of our approach is to use the same, theoretical framework for design, evaluation and impact assessment purposes. This provides a firm basis for practical decision making in designing the solutions to be developed in the project. Danna and Griffin [10] as well as Nykänen et al. [17] differentiate antecedents and consequences from the immediate implications of the intervention, i.e. the introduced new work tool or practice. In our framework, we use the term impacts instead of consequences to stress that design decisions might have impacts on work well-being and company benefits.

Antecedents include the work environment, work organization and worker characteristics. They describe the original context of use [19] where the intervention - in the form of new tools and new work practices - is implemented.

Immediate implications cover workers' experience with their work and work tools. Desired immediate implications can directly guide the design process, and be in the focus of evaluation activities. Well-designed tools that are acceptable and safe to use,

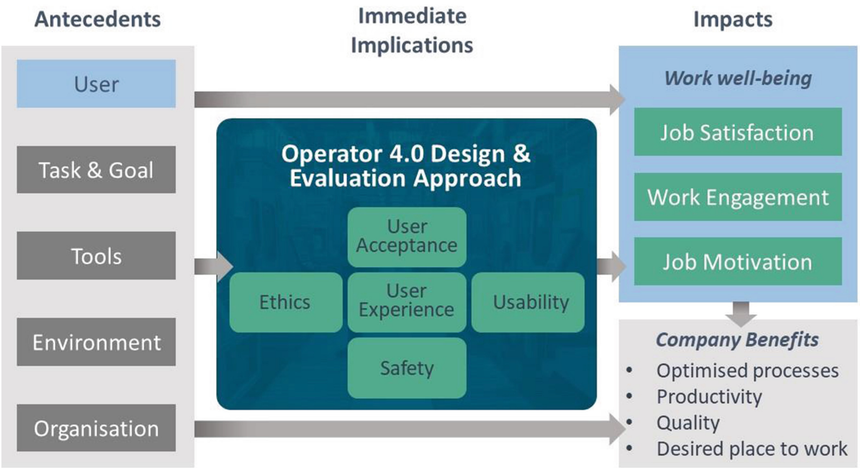

Fig. 1. The design and evaluation framework for Operator 4.0 solutions that support work well-being.

that provide high usability as well as positive user experience and that are ethically sound, will most likely have an positive impact on work well-being. We chose these perspectives to study immediate implications.

Impacts include work well-being and company benefits. For investigating the impacts of new Operator 4.0 tools on work well-being, we focus on the positive indicators of well-being: job satisfaction, work engagement and job motivation. Company benefits, based on the new work tool and work practice solutions, origin from the efficiency of the new solutions on work output directly and from the increased well-being at work. Expected company benefits include optimized processes, productivity, and quality. In addition, the developed solutions are expected to affect the company image so that the company becomes as a more desired place to work. Thus, the company benefits are the ones related to the core task or function of the company, often related to economic matters. Company benefits are also the impacts that the companies themselves find interesting and important.

As a whole, the new tools are evaluated during the design phase with a specific set of perspectives, focusing on the usage-centric qualities of the tool (located in the center of Fig. 1, Operator 4.0 Design & Evaluation approach). After the piloting of the new tools is performed, the users (workers in the factory in question) are asked for feedback from the same perspectives as used during the design, as well as from the well-being approach (Work well-being, in the upper right corner of Fig. 1). After the piloting it is also possible to evaluate or foresee the company-level benefits (the lower right corner of Fig. 1).

In this paper, we focus on the framework from two perspectives: (i) the design and evaluation approach and (ii) the approach to assess the impacts of the new tools and practices on work well-being. Together these constitute the part of the framework that supports designing Operator 4.0 solutions that might enhance work well-being. In the following, we will describe in detail these parts of the work well-being framework.

4 Work Well-Being

Work well-being is a concept affected by various phenomena. Thus, it can be a result of a combination of, for example, wellbeing due to an experience of meaningful life during leisure time, as well as finding the objective of work motivating (related to job motivation) and get satisfaction of performing work tasks (related to job satisfaction). The relative importance of each factor is individual so a straightforward formula cannot be created - for instance, for some, interesting work can balance unsatisfactory leisure time whereas others feel better at work only when happy at home. The concept of work well-being is, then, just the well-being as it realizes itself at work, irrespective of its reasons.

Job satisfaction and work engagement are considered to represent major components of work-related well-being [20]. Van Beek, Hu, Schaufeli, Taris, and Schreurs [21] have shown the relevance of motivation for explaining differences between work engagement and negative dimensions of well-being. Thus, job motivation represents an important mediating factor for well-being that also needs to be considered. Our work well-being approach includes these three factors: job satisfaction, work engagement and job motivation, which are described in more details in the following sub sections.

4.1 Job Satisfaction

Work is an important part of life in the western society and job satisfaction a vital factor reflecting work related attitudes and feelings. Job satisfaction, or the lack of it, is shown, for instance, in the willingness to go to work and the pride, or lack of it, when talking about it. Two common definitions of job satisfaction describe job satisfaction as "a pleasurable or positive emotional state resulting from the appraisal of one's job or job experiences" [22] p. 1300 and "the extent to which people like (satisfaction) or dislike (dissatisfaction) their jobs" [23] p. 2. Based on these definitions, job satisfaction reflects an overall attitude towards work in general, or in relation to different aspects of work, such as, colleagues, salary, the nature of work itself, supervision, or working conditions [23] p. 2. The extent to which work properties meet or exceed the personal expectations of employees determines the level of job satisfaction [22]. Satisfaction with the nature of work, including job challenge, autonomy, variety and scope, predicts best the overall job satisfaction [24].

Because work tools and related new work practices may have strong impact on job satisfaction, the implementation of new solutions for operator 4.0 should consider the individual expectations of the workers and thereby fostering the satisfaction at work. In addition, job satisfaction as a part of our framework, is an important premise for increasing job performance and is closely connected to other concepts such as work engagement.

4.2 Work Engagement

Work engagement is something that the employer does not require, as long as work is well done and employees stay at the company: For the worker him/herself, the level of engagement to work is important, indicating how interesting (s)he truly finds the work.

Maslach and Leiter [25] argue that work engagement refers to energy, involvement and professional efficacy of a worker. Schaufeli et al. [26] p. 74 define work engagement as "a positive, fulfilling, work-related state of mind, which is characterized by vigor, dedication and absorption". Schaufeli et al. [26] p. 74 characterize an engaged worker as feeling energetic while working, being willing to invest effort in one's work and persistent when facing difficulties. An engaged worker is also dedicated in one's work and such feelings as the feeling a sense of significance, enthusiasm, inspiration and pride are included in engagement. According to JD-R (job demands-resources) model of work engagement [27], both job resources and personal resources predict work engagement, having a positive impact on it especially when the job demands are high.

Work engagement has a positive impact on performance at work. When the workers are engaged and perform well, they are able to create and strengthen their resources, which creates a positive spiral. The measurement of work engagement is important to learn as it provides a rather stable reference to other work well-being related phenomena (job satisfaction and job motivation). The enhancement of work engagement, based on the introduction of the new tools, would be a strong signal about the positive impact the tools bring along.

4.3 Job Motivation

Job motivation is rather superficial as regards the relationship with work, compared to the more closely work-related concepts of job satisfaction and work engagement. A person may be motivated to work without finding pleasure in the work tasks, for instance, as long as the status of the work role is good enough or because of the social environment at work.

Porter and Lawler [28] divide job motivation into intrinsic and extrinsic motivation. If workers fulfil their tasks because they derive spontaneous satisfaction from performing the activity itself and are interested in their work, they are intrinsically motivated. Extrinsic motivation, in contrast, describes that workers' satisfaction comes not from their tasks, but rather from the consequences that go along with the fulfilment of the task, such as verbal or financial rewards. In Herzberg's motivation-hygiene theory [29], motivators involve factors determined by the job itself such as achievement and recognition. Besides that, hygiene factors are extrinsic to the job, such as interpersonal relations and salary. Hygiene factors prevent negative feelings and dissatisfaction; the existence of motivators determines satisfaction. According to Hackman and Oldham [30], the degree of motivation depends on whether (1) the work is experienced as personally meaningful, valuable and worthwhile, (2) employees perceive themselves as personally accountable and responsible for the work outcomes, and (3) employees are aware how well they perform in their work. High work engagement goes along with high intrinsic and extrinsic motivation [31]. Nie and colleagues [31] argued that intrinsic motivation has a positive influence on well-being and is positively correlated with job satisfaction whereas extrinsic motivation might have positive as well as negative effects.

In summary, extrinsic as well as intrinsic factors are important for fostering motivation at work. Therefore, job motivation within our design and evaluation framework refers to both intrinsic and extrinsic motivational aspects. Negative consequences of new operator 4.0 solutions should be avoided and individual preconditions should be established for positive effects of the work utilizing the new tools.

5 Approaches for Design and Evaluation

As pointed out earlier, we chose five complementary design and evaluation perspectives regarding the immediate implications:

1. Usability was included in the framework as it is traditionally a central viewpoint in human-centered design [19]. Usability studies focus on the appropriateness of the tools for work tasks. Systems usability [32] has extended the view to complex industrial systems where both tools and work practices are studied and developed, thus contributing to smooth work processes.
2. User experience (UX) has also become an essential viewpoint in human-centered design. User experience is widely used as a design driver in the design of consumer products but in industrial contexts, user experience driven design is still rare. UX extends the focus from mere usage of the tools to how the users feel while working, and wider how the new tools shape their image as professionals [33]. User experience driven design has potential especially in designing radically novel concepts.
3. User acceptance studies are widely used to support the uptake of new technical solutions at work places [34]. User acceptance studies aim to explain the reasons for people's attitudes towards work systems and tools as well as further adoption of the systems. The studies connect usage behavior to both user characteristics and attributes of the work tools.
4. Safety assessment is essential in industrial systems to prevent risking workers' health. Safety is typically addressed with expert assessment of safety risks and proposing mitigation measures. Safety should be assessed also from the worker point of view and then trust is an important concept.
5. Ethical assessment is important as the adoption of new technologies may raise concerns. For instance, Industry 4.0 solutions are often based on gathering data of the work environment and even the workers, and this may be ethically sensitive.

In the following, we will describe these five perspectives and analyze in more details what contribution each perspective brings to the framework.

5.1 Usability

Usability refers to "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use" [19]. The satisfaction with a new tool forms a precondition for its positive impact on work satisfaction.

In the context of complex socio-technical systems, a more holistic system-oriented approach to usability is called for. In the Systems Usability approach [32], understanding the appropriateness of the tools in industrial production processes begins by investigating the purpose and meaning of the tools in human use. In activity theory, one main principle is that of mediation. According to Vygotsky [35], tools and instruments mediate the relationship between the subject and the object of work (what is acted on). Based on the activity theory [7], the tool's mediating role can be elaborated by making distinction between the different functions of a tool: the instrumental, psychological and communicative functions [32]. The three functions can be scrutinized from three different types of activity, i.e., performance, way of acting and UX (see Fig. 2).

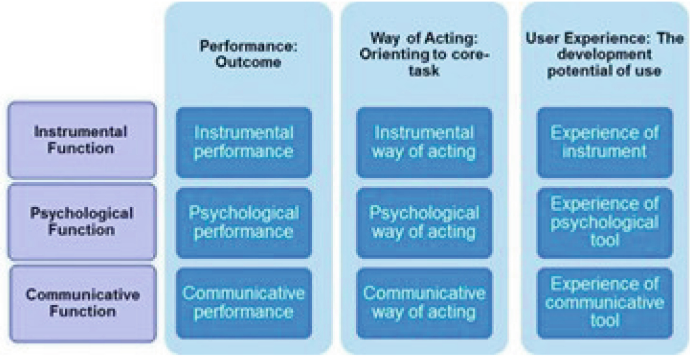

Fig. 2. Systems usability framework [32].

In the framework, systems usability brings in the viewpoint of the work practices: new work tools and new work practices need to be developed in parallel. Thus, design and evaluation should not only focus on the interaction with the new tools but actually working with the tools as well as adopting and developing new ways to work.

5.2 User Experience

Good user experience (UX) is the goal of most products and services intended for the consumer market. UX is also receiving increasing attention in the development of industrial systems. According to Hassenzahl [36], UX consists of both pragmatic and hedonic aspects of product use. UX at work is the way a person feels about using a product, service, or system in a work context, and how this shapes the image of oneself as a professional [33]. This definition connects UX to well-being, especially to work engagement.

Kaasinen et al. [37] propose UX goals to guide the design of industrial systems. UX goal setting integrates the viewpoints of different stakeholders, thus committing them to the defined UX goals and emphasizing user experience as a strategic design decision. In our design and evaluation framework, UX goals are defined as suggested by Kaasinen et al. [37], and used as suggested by Roto et al. [38]. High-level UX goals help to create and maintain UX mindset within the design team, thus keeping the focus on how users would feel at work while using the new tools. In the evaluation activities, UX goals can be utilized to study if the users actually have the intended experiences such as feeling of control. UX can also be evaluated more openly, aiming to identify widely the actual experiences.

5.3 User Acceptance

Technology acceptance models aim at studying how individual perceptions affect the intentions to use technology as well as the actual usage. Acceptance models mainly focus on explaining adoption behavior and often include behavioral intention. In the initial Technology Acceptance Model (TAM) [39], the aim is to explain the determinants of user acceptance of a wide range of end-user computing technologies. TAM points out that perceived ease of use and perceived usefulness affect the intention to use, which determines actual usage. TAM was designed to study information systems at work to predict whether the users will actually take a certain system into use in their jobs. The model provides a tool to study the impact of external variables on internal beliefs, attitudes and intentions.

Van der Laan, Heino and De Waard [40] define attitudinal acceptance as "pre-dispositions to respond, or tendencies in terms of "approach/avoidance" or "favorable/unfavorable" (p. 2) and describe two dimensions of "attitudinal" acceptance of technological innovations: satisfaction and usefulness.

Technology acceptance models provide solid frameworks to identify issues that may affect user acceptance of technical solutions in work. The original TAM has been extended to provide further aspects about the drivers and obstacles for adoption of technology. Especially for new information and communication technologies, the UTAUT2 model [34] that includes TAM as well as other theoretical frameworks (e.g., Theory of Planned Behaviour [41]), are used to assess drivers and barriers for acceptance of new technical solutions. In detail, performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, and habit are relevant factors influencing workers' intention to use the technology or solution as well as actual usage.

In the design and evaluation framework, user acceptance perspective supports designing tools that the users want to use, rather than tools that they have to use. User acceptance studies are especially important during the early phases of the design to identify factors that affect the acceptance. High acceptance of Operator 4.0 solutions is a precondition for positive impacts on work well-being.

5.4 Safety

Safety is related to physical and mental well-being and thus has a clear role in the framework. Safety design starts with generic safety requirements, which cover many kinds of machines and their typical risks. Safety requirements are an agreement of acceptable risk levels available in the form of various safety standards (e.g., [42]). Generic standards do not cover all safety aspects of all kinds of machinery. This is especially true for new developments. Therefore, risk assessment, which covers also new and unusual risks, needs to be performed by safety experts. In addition, the industrial user organization should perform risk assessment focusing on potential accidents. Risks are described with the severity and the probability of each risk [42]. Risk assessment methods focus on system operations and functions as well as human operation and tasks [43]. The possibility to avoid a hazard is often depending on the skills and awareness of the worker.

Safety risks may lead to hazards and may threat worker's health. The feeling of safety influences the worker's well-being. In the framework, we focus on the worker's point of view. We will study perceived safety, as it indicates the worker's own feeling of the safety of the work and the work environment.

5.5 Ethics

The adoption of new technologies can reveal ethical challenges. Especially when the new technology is used for measuring person related attributes, such as health in work context in our study, ethical matters become vital, from the sake of ethicality itself and also as it affects user acceptance. This raises the need to include ethics in the framework. Niemelä, Kaasinen and Ikonen [44] propose the Ethics by Design approach based on positive, forward-looking and proactive ethical thinking. Ethical points of view are considered in the early project phases, with the aim of creating a positive, ethical-solution-oriented mindset among project partners. The ethical approach should not just identify current or future problems but also actively design for and be inspired by achieving ethically sustainable solutions [45].

In the design and evaluation framework, we have adopted the Ethics by Design approach [44]. The focus is on creating ethically sound solutions rather than just identifying potential problems. Thus, we focus on ethical guidelines that guide the design and form a basis for evaluation activities.

5.6 Summary

The aim of the design and evaluation framework is to guide design and evaluation activities so that they support creating solutions that have positive impact on work well-being. The approaches of systems usability, user experience (UX), user acceptance, safety and ethics support this goal. Systems usability brings in the viewpoint of focusing not only on the interaction with work tools but also on the new work practices that are developed in parallel to the new work tools. User experience points out focusing on how people feel at work when using the new tools, and how this shapes their image of themselves as professionals. User acceptance focuses on users' willingness to adopt new tools and practices, and the underlying factors affecting adoption behavior. Safety assessment and ethical assessment are typically performed by experts. The framework emphasizes that they both also have the worker point of view that should be included. Do the users consider the solutions safe; can they trust the solutions? Do the workers judge the solutions as ethically sound? Is there something that they have doubts about?

Even if the five perspectives all bring in a specific, important viewpoint, they also include similar elements. Systems usability includes UX as one element but it does not include the idea of concrete UX goals. Ease of use element of user acceptance is very similar to performance outcome in systems usability. Feeling of safety, trust and ethical concerns are closely related to UX and user acceptance. These similarities should not be a problem in using the framework, as the aim is to integrate the perspectives so at all important aspects will be studied.

6 Utilizing the Framework

The aim of the design and evaluation framework is to support design and evaluation activities throughout the project. Now that we have defined the framework, our aim is to continue utilizing it in practice, analyze the experiences of use, and update the framework accordingly.

In the design activities, systems usability puts the focus of the design to new work practices and how the new tools could best support smooth ways to work. UX covers the design aspect of how people feel at work. Both systems usability and UX support early design phases where different stakeholders of the project build a common vision of the solutions to be defined. Drivers and obstacles for user acceptance should be identified early in the design to find solutions that will be accepted. Safety and ethics viewpoints emphasize the consideration of those aspects early in the design, and from the worker's point of view. In this way, they bring in a positive, forward-looking viewpoint that helps finding safe and ethically sustainable solutions.

The evaluation perspectives included in the framework are all using different methods. Integrating these methods is challenging but necessary to avoid having too many parallel evaluations that would be difficult to organize in practice. Furthermore, parallel evaluations might result in contradicting results, the implications of which would be difficult to interpret. The chosen perspectives should be integrated in evaluation so that we address all the necessary perspectives. Depending on the evaluation activity, the focus may be on higher-level issues or on details. Using similar questionnaires in all evaluation activities allows following the progress of the development work. These questionnaires can be extended by further items and complemented with interviews for individual evaluations to focus on selected issues. The interviews can be evaluation specific even if the evaluation themes follow the perspectives of the framework.

When Operator 4.0 tools are developed, at least as prototypes, they can be tested in real-life working contexts, where a more realistic impact assessment can be gained. In the impact assessment, measuring worker's well-being before and after the introduction of new tools and practices allows for direct comparisons. This gives us the opportunity to draw conclusions about the impact of the new work tools and practices on well-being. Impact assessment can be continued later on in actual use. We emphasize that impact assessment can also be part of the early phases of a project. Foreseen impacts, assessed by the workers themselves, other company representatives and external experts give valuable insight to the potential of the new solutions already during the design phase. From the participating companies' point of view, early feedback on foreseen impacts has been seen especially valuable, as it helps assessing which solutions are most promising regarding business benefits.

When performing evaluation, validated and widely used measures are beneficial as they are solid means producing clear results, easy to compare with the results of other studies using the same measures. However, the set of various perspectives is rather large in our project. Using validated questionnaires would mean hundreds of questions for each worker. Such a load cannot be set to the users. As we feel it to be important to include all the perspectives of the framework, a compact set of questions, with just a few questions for each perspective is needed. Thus, in practice, the questionnaires used and to be used in this project are tailored for this purpose. Of course, validated tests can still be used in some individual evaluations if needed for some specific goal. Furthermore, the questionnaires are complemented with solution specific questions. Using the common questionnaires allows comparing different solutions, while solution specific questions and complementary results of user interviews give detailed user feedback.

In the following, we describe our first experiences of using the framework in design and evaluation activities in the *Factory2Fit* project.

6.1 Overall Concept Design

The *Factory2Fit* project started with a series of co-design activities that involved all the project partners. First, factory workers of the project's pilot factories were interviewed and their work was observed. Then, a series of workshops were conducted in which the results of the factory worker studies were analyzed and discussed among project partners. Industrial partners, representing the pilot companies, presented their expectations related to the new tools and the foreseen impacts. In the workshops, a common vision for the project was gradually set, and the vision was complemented with descriptions of new concepts for work tools and related work practices. The common vision was based on how the future work should feel and based on the vision, two high-level UX goals were defined in the workshops: empowerment and engagement. UX experts analyzed these high-level goals and based on the results of the user studies and the design workshops, they proposed more detailed experience goals (Table 1). The experience goals will guide the design of the Operator 4.0 solutions, as they will be analyzed to identify design implications for each individual concept and tool.

Table 1. User experience goals in *Factory2Fit* project.

Empowerment	Engagement
Feeling of competence	Feeling of community
Confidence	Ownership
Self-respect	Self-expression
Feeling of achievement	Being appreciated
Feeling of control	Having an influence

To support ethics by design, we defined ethical guidelines (Table 2) based on the ethical guidelines for ambient intelligence by Ikonen, Kaasinen and Niemelä [46]. We chose five out of the six ethical themes (we left out "benefit for society" as it was felt too abstract in our case) and for each of the five ethical themes, we modified the original guideline so that it reflected what the guideline would concretely mean in Operator 4.0 solutions in factory environments. In the design phase, the guidelines form a checklist, with which the design team can assess proposed solutions.

Table 2. Ethical guidelines in *Factory2Fit project*.

Ethical theme	Guideline
Privacy	Operators should be able to control access to their personal data
Autonomy	Operators should be able to choose their own way to work
Integrity and dignity	The solutions should not violate the dignity of the operators
Reliability	The operators should be able to trust the solutions
Inclusion	The solutions should be accessible to operators with different capabilities and skills

Safety issues are typically studied by expert assessments, and many standards give instructions on safety issues. While these safety activities are important, in the framework, we wanted to focus on the workers' point of view. Based on safety standards [42], we defined safety requirements to guide design (Table 3). In the design process, the proposed solutions and implementations have been checked against these requirements.

Table 3. Safety requirements in *Factory2Fit project*.

Requirement	Description
Freedom of accidents	The solutions should be free from risks of accidents
Freedom from long term hazardous effects on people	The solutions should be free from hazardous substances, noise and radiation and ergonomics should be adequate
Awareness of safety	The operators should be able to recognize hazardous and safe situations

By now, systems usability and user acceptance have been utilized in design activities indirectly: they have been included as the evaluation viewpoints in evaluation activities that support human-centered iterative design. In the next sub section, we describe our experiences of the evaluation activities.

6.2 Using the Framework in Individual Design and Evaluation Activities

In the following, we describe three case studies of utilizing the design and evaluation framework in the design and evaluation activities in the *Factory2Fit* project. We describe how we used the framework and we discuss related benefits and challenges.

Case 1: Evaluation of Four Factory2Fit Concepts

The design and evaluation framework was utilized in the evaluation of four concepts that were developed in the project. The concepts aimed to engage workers for participatory design of factory operations, knowledge sharing and training. The concepts were utilizing augmented and virtual reality (AR/VR) and context-aware social media. Factory workers evaluated the concepts in two workshops. The concepts were presented one by one to the participants as demonstrators and/or videos. After each presentation, the participants filled in a questionnaire that guided them to consider the chosen evaluation themes (user acceptance, UX and safety). In the questionnaire, participants also evaluated foreseen impacts on job satisfaction. After the participants had filled in the questionnaires, we had a follow-up group interview. In the interview, they were asked about the benefits, the challenges and development ideas of the presented concept. This revealed attitudes and expectations to explain the results gathered with the questionnaires. After the concepts were evaluated in this way, the group discussed about the presented entity of concepts and their potential to support their work.

Besides workers' experience and acceptance of the concepts as well as safety issues and expected impacts on job satisfaction (i.e., aspects of the framework), concepts' main benefits, challenges and development ideas were formulated by the factory workers. They could point at diverse issues related to usability, safety or ethical issues. In general, workers' feedback of the concepts was positive.

Our aim is to develop the framework while using it. That is why we analyzed the benefits and challenges of the framework after the case study. As a benefit, the framework guides the data collection in evaluations and makes data comparable with other research partners. This is important in a large research project with several evaluation activities carried out by different partners in different countries. The framework also supports keeping in mind the main aim of the project - to influence work well-being. Even if direct impacts cannot be measured until the solutions are in actual use, focusing on foreseen impacts in the evaluations helps developing the solutions to support this aim. During the design process, we have several different evaluation activities. The framework needs to be utilized adaptively, so that the focus is chosen according to the current design phase. The perspectives of the evaluation should then be chosen accordingly. However, in the user interviews, we should be open for all the perspectives. For instance in this study we did not focus on usability as we were dealing with early concepts. Still the users were commenting about the expected usability challenges with the forthcoming solutions. We also left ethics out, as we considered that the concepts did not include ethically sensitive issues. However, in the interviews the users pointed out foreseen ethical problems. Based on these results, we decided to include in the forthcoming user studies all the perspectives, even if with a smaller set of questions.

Case 2: Evaluation of a Social Media Platform

The design and evaluation framework was applied in the evaluation of a social media platform. The social media platform integrates a social media messaging system with a production environment so that the discussions can be connected to physical elements of the production line or to the status of the line such as a certain error situation. The purpose of this evaluation was to get feedback to the design from workers and other stakeholders. Nine participants (factory workers and other factory stakeholders) participated in the evaluation. The prototype system was first introduced to them and then they were divided into two groups, where they could try out the system guided by the facilitators. When trying out the system, the participants were asked about problems, improvement needs as well as pros and cons related to the system. In the end, the participants filled in a questionnaire. The questionnaire included UX, user acceptance and usability perspectives from the framework. Impacts were assessed with two questions in the questionnaire regarding anticipated changes in knowledge sharing practices. Results show that the participants liked the system and agreed that the usability was on a good level. They suggested many important improvements for the system.

As such, this study could be regarded as a basic usability research. However, in the workshop also impacts and development ideas were discussed. For example, the integration of workers discussions with production data could improve performance and job satisfaction. In addition, the possibility to share knowledge could engage workers more with their work and work community. The gamification feature could motivate some people to share knowledge more actively.

As a benefit, by using the design and evaluation framework it was possible to enhance traditional usability studies towards considering impacts of a system on work well-being and on productivity. The results pointed on the high value of qualitative data gathered via interviews or group discussions as many possible impacts were raised in the discussions but in the questionnaire, we were only asking about impacts on knowledge sharing. Similar to Case 1, this case points on the importance of qualitative methods for complementing questionnaires for assessing the various aspects of the framework in the future.

Case 3: Design and Evaluation of Worker Feedback Dashboard

The design and evaluation framework was utilized in the participatory design of Worker Feedback Dashboard, a web-based solution giving personal data-based feedback to machine operators at a factory (the design process is described in [47]). The idea of the solution is that it gives personal feedback both on selected well-being metrics through a wearable self-tracking device and on relevant production metrics through the machinery of the factory, enabling the workers to see potential connections between these and thus empowering operators to make behavioral changes.

All aspects of design and evaluation framework were addressed during the development process. Before the actual participatory design, the usability and user experience of several wearable self-tracking devices were evaluated in the expert evaluation by the researchers and the potential ethical issues were identified in an expert workshop (the study is described in details in [48]). Before designing the first prototype, also factory workers were involved to give their initial feedback on the acceptability of the concept idea. We also visited two factories (pilot sites of the project) to gain understanding on the work context, which helped us in considering the safety aspects and the potential user acceptance. Based on user understanding, we first designed the user experience goals highlighting for example the role of positive feedback (empowering user experience) and the importance of not disturbing the user's work tasks (ensuring safety). The key design implications were derived from these goals.

When initially evaluating the first prototype, we showed it to factory workers, who could comment it freely, and express their potential concerns and further ideas. With a short questionnaire, we assessed usability related issues (e.g. whether it is easy to understand the data shown), user acceptance related questions (e.g. whether the solution seems to provide value to users through interesting or useful content), and ethical issues related to the solution (whether the solution seems questionable). Based on the user feedback, refinements to the design were made.

The design and evaluation framework will be further utilized when piloting the refined functional prototype as a part of actual factory work. We are planning to conduct a 2-month usage pilot, which gives us understanding of the real user acceptance and user experience, as well as usability issues during long-term use. Based on the long-term use, we can evaluate whether using the solution may involve safety risks and can see what kind of ethical issues are brought up by the users. The design and evaluation framework will be utilized when defining the questionnaires and interview questions for the pilot.

7 Conclusions and Future Work

We have presented a framework to guide design, evaluation and impact assessment activities so that they support creating Operator 4.0 solutions that have a positive impact on work well-being. We have started to utilize the framework in our research project and we have found that the framework has supported defining a common vision and high-level goals for the development work. In the evaluation processes, it is beneficial to integrate different perspectives. However, in practice we have faced challenges as evaluation activities are different and not all the chosen viewpoints can always be included due to the complexity of the framework and the variety of tools required for the practical usage of the framework. During the early phases of the project, impact assessment has been based on foreseen impacts by different stakeholders. During the forthcoming long-term pilots, we will see if we indeed can show impacts in work well-being based on our Operator 4.0 solutions.

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Techno-Trust and Rational Trust in Technology – A Conceptual Investigation

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Abstract. Trust is essential when using technology. If people do not trust new technology, they do not accept it. If people do not accept new technologies such as autonomous ships, their development is hampered in the absence of financial support. The importance of trust brings into question the essential conceptual components of phenomena that contribute to trust. This knowledge is required for the basis of investigating trust in technology. Especially, it is important to understand why humans trust. The reasons can be intuitive but they can also be supported by rational arguments. The latter type of trust can be called rational trust. A beneficial way of considering rational trust in technology can be reached by defining aspects of technologies that should be investigated when attempting to design for trust in technology. Therefore, the basic conceptual dimensions of technology supported actions are analyzed in order to define the essential elements of rational trust in technology.

Keywords: Rational trust · Techno-Trust · Human-technology interaction Design

1 Introduction

Trust is the most commonplace pre-condition and emotional state for people interacting with technology. Emotional states are important for an individual as they determine the positioning (physical, social, cultural, psychological, contextual etc.) of external and internal phenomena [1]. Thus, as an emotional state, trust defines the relationship between a person, and self, in regards to the phenomena that are to be trusted. Consequently, trust is vital in determining how people should act in situations that require the dependency of an individual towards something for which there is no definite outcome [2]. People decide to undergo positive actions if they trust the consequences of taking action, but they hesitate or take a negative stance in situations where they do not trust.

Normally, trust concerns people and the interactions between people. Yet, trust can also be associated with technical artifacts and technologies. In the latter case, trust can be called techno-trust. Trust in aviation technology means trust in aircraft, as well as trust in pilots, technicians and air traffic controllers [3]. Thus, technology should be seen in the context of techno-trust in a broad systemic sense and not only as a technical artefact.

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Although trust is based on emotions or feelings, it involves cognition. Indeed, human emotions are always implicated with cognition. The mind operates as a whole. Cognition is important in representing and interpreting what the situation at hand entails and emotions define its value to the individual. The process which integrates emotions with cognitions is often referred to as appraisal [1, 4–6].

Emotions are intimately linked to the human self and their motives [1, 3]. Motivation is the trajectory of human action [7]. Motivation drives people towards a particular goal, due to the fact that human action is goal oriented. Humans are intentional in thought and action [8–12]. Mostly these affairs are characterized by positive or at least better feelings and states than the initial state, and for this reason feelings are important in analyzing motives for action [13]. However, before it makes sense to pursue some definite goal acting person, one must trust that the goal can be reached without harmful consequences.

Technology comprises tools to reach the goals in life and for this reason trust in technology, i.e. techno-trust, is so important in understanding why people behave with technical artifacts in the way that they do. This is why the cognitive-affective theory of emotion - Appraisal [1] - also plays a central role in investigating motives and motivation related to technology supported actions. If a person does not feel positive about an action that is to be taken, or about its technical support, one very probably will not take this action.

An important issue in investigating trust is why people trust someone or something. The critical question is that of what justifies our trust. People can trust, because they feel that the trustee is trustworthy. However, their gut feelings and intuition can betray them, and one can ask a question as to why one trusts something. The "why" question essentially changes the nature of trust. Feeling-based trust is intuitive. It does not have any solidly justifiable grounds. However, upon asking and answering the question "why", the condition of trust is converted into a form of grounded or rational trust. Thus, instead of emotional belief, trust can be based on justifiable reasons such as the laws of science. Trusting based on justifiable or provable reasons and arguments can be called *rational trust* [14–16].

All the so-far presented viewpoints to trusting in technology require elaboration. Therefore, the paper's authors shall consider the conceptual structure of rational trust in technology in this paper. The goal is to explicate the conceptual structure of rational trust in technological contexts. To satisfy this task, one must firstly study what rationality means in trusting. Secondly, it is essential to consider how techno-trust differs from other common forms of trust. Thereafter, it is possible to consider the plausible main components of trusting technology, i.e., these entail the issues one must pay attention to while developing trust in a specific technology. Finally, it is possible to summarize the main arguments and present why it makes sense to analyze the conceptual structure of techno-trust

2 Rational Trust

For any individual, trust is a mental state [17, 18]. Therefore, trust can be very intuitive or tacit by nature. The schema is simple: I feel so good about this thing/person/situation, and therefore I trust it/them. Such emotional and intuitive trust is not based on reflected considerations and it can easily lead to serious errors. Positive feelings do not guarantee that phenomena are really trustworthy and that they can perform the tasks that the user expects them to. Especially, long-range consequences of use may be difficult to assess on the grounds of good feelings or gut instincts.

An interesting example of a feeling based technology is a cigarette. Smoking feels good. It may be relaxing and even presents a means of social interaction and bonding. Therefore, many people like smoking. However, the long term consequences are controversial. Smoking can cause illnesses and early death. Yet, these facts do not necessarily concretize as any form of potential reality in the minds of many smokers as for them, the future consequences do not belong to their present life experiences. In the case of smokers, a positive intuitive emotional state is sufficient for using cigarettes.

It is not difficult to find similar technical artifacts, which are chosen rather on the grounds of immediate intuition than grounded reflections. Ready examples can be seen in many building materials such as asbestos, paints, and glues. In fact, all products have possible risks in some respect, though they do not have the same kinds of lethal consequences as cigarettes. Consumers do not know, for example, all the important details of technologies and therefore their trust is based on intuition. However, it makes sense to ask as to whether or not it is sufficient that one feels confident with a technological artifact or system in order to trust it.

The notion of rational trust emerges from the above dilemma. Rational trust means that people have good grounds to trust some technology. Instead of just feeling confident, in rational trusting people ask whether they have reasonable grounds to trust it. They test their feelings by considering how just their feelings are. Thus, a medical doctor who has to remove parts of patients' throats every week may easily see the risks of smoking differently to a smoker who lacks expert health knowledge. She or he has different reasons for feelings towards smoking.

The question of feeling confident takes on another form when one asks why she or he trusts some form of technology. One may ask what the well-founded or rational reasons for trusting something are. Rational trust is important as it entails the idea of testing and verifying trust. Thus, the notion of rational trust converts trust and trusting from everyday emotional intuition into scientifically grounded action. Rational trust means that people seek evidence, confirming the justification of their trust [16].

In the case of rational trust, the trustor should have facts upon which grounds the trust is based. These facts are empirical observations or other methodologically established states of affairs. This means that the focus of analyzing trust should be re-focused from the emotional towards empirically tested and confirmed thinking. However, before any empirical analysis is possible, the researcher should have ascertained a thorough understanding of the issues to which attention should be placed in order to ground the trust.

Rational trust thus means trust which is based on rational arguments. In order to trust a person, there must be justifiable grounds for trusting. He or she needs to have knowledge about the factors which affect the trustworthy components of a technology. Decent grounds for believing that one can trust transforms thinking from emotional to knowledge-based trust. There are seldom any instances in which anyone can be sure that all the relevant data is present, and whether or not the most optimal interpretation of this data. Rational trust would however, be based on information that exceeds that of purely the information delivered by invested stakeholders, e.g., developers/owners of a company issuing the technology. Thus, the more data collected about the technology and its components, the more rational the trust relationship becomes, because there are justifiable reasons to trust the system.

3 Techno-Trust

The above section focused on rational and knowledge-based trust. This is important for technology design, particularly from the perspectives of both functionality and reliability in the mechanical and automation sense. It is also important to understand the psychological mechanisms behind what contributes to the rational basis of trust in human-technology interaction. Trust is a notion, which is normally associated with other people [15, 17]. One can trust a spouse, teenagers, business partners, medical doctors and maybe even some strangers. In special cases, trusting a person can also mean the question of confidence (in the other) and self-confidence (in oneself), i.e., trusting that one can do what he or she hopes to do. In both cases, one can speak about human-to-human trust as the same kind of trust as reliance on how a human being can and will behave in some context.

Another common form of trust is reliance on organizations. Examples can be seen in governments and companies. People trust organizations as they have grounds to trust them [16]. They do not always have any possibility to check that the organizations act in a trustful manner. People in governments and in companies keep changing. Only the organizational identities and structures are somewhat stable. This is why trust in organizations is focused rather on the way the organizations operate than on individual members of the organizations. This type of trust is common in politics and business life.

However, trust in technology is not precisely like the two types of trust presented above. In techno-trust, technical artifacts bring a new kind of additional element into discourse [18]. The new question is how well people can predict the behavior and performance of technologies when they support human actions. A tool, which cannot help people in their everyday life, is not trustworthy.

Techno-trust requires, thus, on the one hand trusting machines - causal systems - and on the other hand, trusting people whose actions area intentional (e.g., the design and/or operation of the machines). The difference between causal and intentional can be explained as follows: causal actions are consequences of internal states of machines, their behavioral history and the immediately preceding events. Intentional actions must be explained on the grounds of states of affairs (motivation, goals, direction), which guide and influence the future states of affairs. The duality of techno-trust makes it a challenging concept. People have intention, machines exhibit causality, and while the machines are not intentional in themselves, there are always people behind (designing, developing and using) the machines. One must have an idea about what people will and can do with technology that has special performance capacities.

4 Technology-Supported Actions

Technologies are meant to make human life easier and to raise the quality of life. When technology is involved in human action, the actions are referred to as technology-supported actions (TSAs) [3, 19]. The term TSA has been largely embraced by the rationale of the design methodology of Life-Based Design (LBD) [3, 19]. The reason why this is significant in the present context is that TSAs describe any action that is enabled and mediated by the use of a technological artifact or system. Technical artifacts are mostly used to aid the accomplishment of a goal during some kind of human action, whether for every day, safety critical or entertainment purposes. These are just some instances in which technology-supported actions play a major role in the life context of humans. Thus, human action is the key attribute of any kind of technology, which renders the element of trust and act of trusting as paramount to human technology interaction.

Technological innovations are meant to make our actions easier and on a general level. Techno-trust means that technology should be reliable in terms of its capacity to improve people's lives. Steamships were used to transport people and goods. To trust in the new transportation technology of that time meant that people expected this technology to operate successfully. Thus, trust in technology means trust in technology's function and performance and its ability to aid the progression of human life.

For example, if a bike keeps breaking down, it is not trustworthy. A bike owner cannot trust such a bike and it can be said that the bike is unreliable. People often distrust technologies because the technology cannot help them reach their action goals, even though they should. However, it is essential to ask which aspects of any technology should be considered as contributing to trust building in relation to any particular technology. A useful concept for the analysis f this issue is that of the 'technology-supported action' (TSA) [3, 19].

While the concept of TSA refers to any action during which people use technology, we can see that the notion of trust is vital for the commitment of an individual to rely on any artefact or service in order to anticipate the successful completion of a task based on this technological support. Thus, its conceptual structure can be used to present ontologies for human use of technology. Ontologies are systems of general concepts in differing fields that explicate basic information contents, or common understandings, associated with the field in question [3, 20–22].

TSAs have similar structures across fields. The structure is important when further developing conceptual analyses of trust. Here, a general model of action is utilized comprising five conceptual components. These components can be called conceptual attributes of a TSA. The components include: the goal, agent or human being, technical artifact, object of action and context [3, 19].

Generally a TSA can be referred to as any human action that a person undertakes with the aid of any technical artefact. It is easy to see that this very simple definition is valid in any situation in which people use some artefact. It does not matter whether a person uses a hammer and nails to fix a staircase or nuclear power stations to keep machines operating. They always carry out technology supported actions.

The first point of any action is its goal (driven by motivation) [13], which also determines why the action is undertaken and how the action is described and classified. For instance, the goal of travelling is to move from one place to another and possibly provide experiences of extraordinary, or out of the ordinary, phenomena. Actions are something that people actively engage in (intentionally or unintentionally) rather than passively receiving them. If a tractor accidentally hits a person it is the unintentional event of an accident situation, if the person has jumped in front of the tractor in order to commit suicide, it is an intentional action. This difference between the unintentional and intentional also delineates the difference between design (intentional) and non-design (unintentional). Glen Parsons argues that inventions and innovations no matter how effective are not design in the first instance if they were unintentionally, or accidentally, created [23]. An object or system only *becomes* design, once there is intention behind its application, promotion and eventual use or action. In order to understand action it is essential to define the goals of the acting person.

Another necessary component of TSAs is the agent or the human being who carries out the action. He or she can be called the actor or agent. If no one intentionally engages in action (such as design or use), actions cannot be spoken of from the perspective of deliberate action. Therefore, deliberate actions are intentionally committed by agents performing these actions [3, 8–10, 12], while undeliberate actions (as the result of fear response or surprise when designs malfunction etc.) remain somewhat outside the scope of intentional design-use ontologies. For example, a surgeon is operating on a patient. He is therefore the actor. The patient is the object of the action, yet, in many cases while the patient is not active they have intentionally made the choice to seek medical help. In turn, when trusting a surgeon, one trusts the surgeon's expertise. Trust in their expertise is the sum of the surgeon's training plus past patient cases. Thus, once again, trust in a service in determined by the data supporting or rejecting this trust.

The third conceptual component of TSAs is the technical artifact. The term technical artefacts refers to some tool, instrument, machine or program, which people use to support their actions. Technical artifacts either make it easier to carry out actions or they entirely enable actions that would otherwise be impossible. Thus, microscopes, for example, enable people to see bacteria or cells. Consequently, artefacts can in the case of TSAs be seen as enablers.

The fourth conceptual component or conceptual attribute of technology-supported actions is the object of action. An object of action is anything that can be affected by the action. For instance, the goal of mining is to mine minerals in order to be used in the production of everyday life objects. Alternatively, the goal of a movie is to provide information or entertainment to the agent. Objects can be natural, social as well as informational. Their main feature is that they form an essential goal component of intentions in TSAs.

Finally, the last attribute of TSAs is context. Context is not an object of action, but it belongs to the action's environment - framing the interaction and encounter upon which the state of trust is established [24]. The environment of any TSA can be physical, biological, social or just informational. The main feature in the context is that in some way it defines the form of action. Yet, it has no role as a goal of action, although it often times sets the parameters of what the goal is, or could be, and why. Wind, for example, can make flying much more difficult, or frost can make the operations of harbor cranes more risky, but they are not targets of transporting.

In sum, TSAs have five conceptual components [3]. They are:

- Action
- Agent
- Technical artefact
- Object
- Context

These conceptual attributes define the contents of TSAs. If they can be explicated, it is possible to determine what the action is and to define why one can trust the action. Indeed, trust in TSAs connotes trust in the individual components of that action. If the agent cannot be trusted, or the rationality of action itself cannot be trusted, then trust in the particular action is not viable. However, all the given attributes of TSAs play a role when rational trust is built.

5 Autonomy and Trust

One example of considering how to build rational trust is provided by autonomous technologies. They operate more independently and issues of trust are for this reason a current point of discussion and speculation [25]. It is worthwhile questioning why people should trust autonomous cars, planes, air traffic controllers or ships.

Autonomous technologies can be used to undertake complex tasks, which have normally been occupied by people [26]. Of course, there is no level of general trust for any autonomous technology but one must analyze the intentions of users case by case. Thus, autonomous transportation of goods or autonomous radiology can be considered as trustworthy actions. However, smuggling drugs with autonomous drones is less so. This highlights the various dimensions of trust, that are often people-bound and intention dependent. In any case, most autonomous or semiautonomous actions that are increasingly being undertaken by technology are actions that people have done before. Thus, the focus on trust issues is more problematic than other attributes in regards to TSAs such as the goals of actions themselves.

Secondly, one must consider the issues of users. Autonomous technologies are more complex than most of the previous technologies. This is why it is essential to pay careful attention to the education and training of users. On the other hand, autonomous technologies replace users. Many truck drivers must reeducate themselves to undertake new tasks and professions. Of course, it is in many cases important to use the skills of people who have previously operated in the same tasks and retrain the professionals in the new ways of performing old tasks. The critical points in creating trust for people around autonomous technologies focus additionally on direct end-users, programmers, designers, and management. The skills of all these people should be analyzed and updated to improve the level of trust.

The most problematic issue in defining trust for autonomous technologies is the artefact itself. Autonomous technologies are novel forms of technical artefacts. This is why many theoretically and practically complex issues must be solved during the process of building trust towards these kinds of technical artefacts. For example, autonomous technologies may seem to have independent intentional capacities even if they do not possess any form of actual consciousness - the mechanism for intentionality [9].

Nevertheless, technical artifacts follow the laws of nature. They do not have intentions of their own. Even “intentions” of autonomous artifacts can eventually be seen as human defined intentions. Autonomous ships are used to transport goods. As ships can transport cargoes between many locations, it makes sense that routing is made by autonomous systems. They can choose their targets independently and vary these targets according to given parameters. These systems can normally learn new internal configurations and new ways of setting goals. Moreover, users cannot really determine the input values as the environment around autonomous systems keeps changing independently of the system, its users and its designers. This is why the systems can be said to have intuitive or spontaneous properties. Consequently, it can also be considered that they in some sense the systems have intuition as a consequence of their apparent spontaneity.

However, machines are not like people with their intentions [8–12]. Machines do not independently define the semiospheres [27], or context-dependent language sets (language games [28]) in which they operate. Their alphabets and the meanings of the alphabets and all data elements have been defined by programmers and designers. Also, algorithms are the result of a designer’s (designers’) work. This is why machines normally operate in limited semiospheres or domains [27, 29]. They do not have general intentions, which surpass semiotic (sign and symbol related systems) limits of predefined domains [30]. Thus, chess machines play chess well, but they are useless in terms of plotting out how to create the best painting of the century. Yet, this is not to say that developers of general artificial intelligence are not working on machines that can do just this - to flexibly multitask and transfer ‘thought’.

Techno-trust concerns the performance capacities of the technical artifacts. The crucial question relates to whether or not machines can do what they are supposed to do. This is why it is possible in theory and in principle to fully predict the behavior of any machine to the minutest detail and explain it causally. Whether or not the same can be done with human operators is a different type of problem.

While there are certain structures and systems (socio-cultural for example) that guide, frame and limit people in thought and behavior, individuals still have the capacity to set their intentions and to an extent semiospheres (areas of language, e.g., pertaining to particular hobbies, professions, social groups and class etc.) freely. They can intentionally perform positive and/or negative deeds, for example. They can change their tasks and professions without any deterministic processes. In this sense, human intentions are different from the “intuitions” or algorithms of machines. People set their own goals. Thus, in order to be able to predict human actions in technological contexts it is essential to be able to understand human motives and respective intentions.

Objects of actions for autonomous systems are still human objects. Autonomous systems are new kinds of tools for people to carry out more complex parts of human tasks. However, the ultimate goals and objects remain by far the same as before. People need to transport goods from one place to another. However, the object of this action does not change the ways in which humans are directly involved in controlling movement, its direction and defining routes. Autonomous machines are designed to realize human action goals and for this reason the action related trust issues do not essentially change.

Finally, one must pay attention to the contexts of action. It is evident that social contexts shall change in many ways. Firstly, there are jobs that will most certainly disappear [31]. The main goal of adopting autonomous technologies is to free people from various types of jobs that exist today and allow autonomous technologies to undertake them instead. However, if the social change is not taken seriously from the very beginning, the technologies will lose considerable amounts of trust.

The issue (changing forms of life) [19], or life circumstances, can be even more complex in relation to trust, than in relation to the artefacts themselves. Even such an elementary issue as to how autonomous technologies can operate in human contexts is an extremely complex network of systems. For example, autonomous parcel services have caused many problems in San Francisco, and consequently, the community needed to react in the form of establishing rules in order to operate with these systems.

It is essential to determine what future life will be like and how to eliminate harm caused to people. Social, organizational, economic, management and ethical issues remain to be solved. The fate of nuclear technologies shows how people can lose their trust in some technologies as the consequence of negligent actions. This is why it is important to develop autonomy in a very holistic manner. Contexts are really important in building trust in relation to autonomous technologies.

6 Why Does Ontology-Based Design Management Make Sense?

The example of developing autonomous systems illustrates that systematic analysis of techno-trust is important. The ontological structure of techno-trust, i.e. action, actor, artefact, object and context, can aid in developing holistic technology, innovation, design and development practices. Life-Based Design is an illustrative example of such practice [3], as Life-Based Design includes consideration for overall life systems, rather than simply those involved in technology interaction situations.

Ontologies for strengthening rational trust help people see what the main attributes are to be solved during such design processes. The goal of ontology work is to explicate the main design questions in some domain of design issues [3, 33–35]. These questions can be reused in managing subsequent design processes.

Ontology directed design is beneficial as it allows for the accumulation of design relevant information. Designers and innovation managers can know in advance what the critical issues are and even how they have previously been solved. This is why they need to always start from scratch. Rational trust exemplifies the use of ontologies in the design process in order to understand and predict trust conditions.

Thus, in conditions of rational trust, the foundations of the trust state can be identified and explicated. However, this is a complex process due to the changing semiotic conditions of the technology, its interaction and use context, person/actor (in their entirely) and their experience. For this reason it is worth applying explanatory models to investigate grounded trust, and more pertinently, techno-trust. If something defies expectations and fails to perform in a satisfactory way, it is possible to search for the reason or cause of why the trust relation failed. Therefore, it is also possible to identify the reasons for failure and thus dismiss or reject the foundations of rational trust.

Expectations depict the individual's anticipation of the end state. In the case of rational trust the trustor should be sufficient reasons and justifications (information) to predict and thus expect successful results. When observing the case of aircraft, aircraft design is the result of years (centuries) worth of research and development. The amount of data collected and applied as a result of this research and development means that people have substantial reason to trust the aircraft. Furthermore, the investment and knowledge generated through the years' worth of development also have resulted in aircraft being one of the safest forms of transport.

The represented schema of design for rational trust is important also as it makes design processes much more transparent and readily re-definable. The openness of processes and arguments is a suitable basis for building ontologies in design management. Through deciphering how to approach trust and its rationality, affords the development of a model on how to approach the problems of complex and socially holistic design issues.

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