USABILITY AND ACCEPTABILITY OF A FALL MONITORING SYSTEM

Narciso González Vega

Master's Thesis in Gerontology and Public Health
Faculty of Sport and Health Sciences
University of Jyväskylä
Autumn 2017

ABSTRACT

Narciso González Vega (2017). Usability and Acceptability of a Fall Monitoring System. Faculty of Sport and Health Sciences, University of Jyväskylä, Master's Thesis in Gerontology and Public Health, 41 pp.

Falls and injurious falls affect one third of the older people. Those experiencing a fall might be unable to call for help remaining unattended for a long time. Pain, hypothermia and dehydration are common consequences. Additionally, ensuing fear of falling may reduce physical activity leading to functional decline and possibly institutionalisation. Monitoring fall events the CONFIDENCE system could summon emergency assistance automatically thus reducing the negative consequences of falls.

This thesis is part of the European FP7 project "Ubiquitous care system to support independent living" (CONFIDENCE) which developed a fall monitoring system based on three-dimensional (3D) localisation of bodily worn radio frequency (RF) tags. Usability and acceptability are factors influencing the possible market success of technological innovations such as CONFIDENCE.

The purpose of this study was to research the usability and acceptability of this system among 24 older people. Participants filled in the WHOQOL-BREF, Falls Efficacy Scale International, mobile phone expertise, usability and acceptability questionnaires. They interacted with the system wearing and removing the RF tags, and initiating and dismissing user-initiated- and system-detected-alarms through a smartphone interface. Data were analysed with the SPSS software. Performance time differences were subjected to ANOVA and *t*-tests. Associations among variables were studied with Spearman Rho (ρ) correlation tests.

Performance time in the alarm tasks was similar when performed with the dominant and non-dominant hands. There were no errors in task-goal achievement. Task performance did not differ when comparing two versions of the user interfaces. Performance and usability questionnaire reports indicated good usability of the system.

The results suggest that the acceptability of the prototype was high and significantly (all ps $< .05$) associated with age (advantages-age $\rho = .43$, disadvantages-age $\rho = -.46$), FES-I ($\rho = -.43$), and the WHOQOL-BREF environment domain ($\rho = .41$). In real-life conditions, future prospective research should focus on the usability and acceptability of this or comparable systems, and whether these influence fear of falling and quality of life of faller vs. non-faller older adults.

Keywords: older adults, fall detection, information and communication technology, usability, technology acceptance, CONFIDENCE project

LIST OF ACRONYMS

3D	Three dimensions or three-dimensional
ADL	Activities of daily living
AI	Artificial Intelligence
CONFIDENCE	FP7 project Ubiquitous care system to support independent living
FES-I	Falls Efficacy Scale - International
FES-I-FIN	Finnish translation of the Falls Efficacy Scale - International
FP7	European Union's Research and Innovation funding programme for 2007-2013
GPS	Global Positioning System
IADL	Instrumental Activities of Daily Living
ICT	Information and Communication Technologies
IoT	Internet of Things
ISO	International Organization for Stadardization
MPE	Mobile Phone Expertise
MPERS	Mobile Personal Emergency Response System
PC	Personal Computer
PDA	Personal Digital Assistant
PERS	Personal Emergency Response System
PEU	Perceived Ease of Use
PU	Perceived Usefulness
RF	Radio Frequency
SMS	Short Message Service or text message
SUS	System Usability Scale
TAM	Technology Acceptance Model
THL	National Institute for Health and Welfare, Finland. Terveyden ja Hyvinvoinnin Laitos
UF	Usage Frequency
UTAUT	Unified Theory of Acceptance and Use of Technology
WHO	World Health Organization
WHOQOL-BREF	World Health Organization Quality Of Life assessment abbreviated version of the WHOQOL-100 scale

CONTENTS

1 INTRODUCTION

Falls and fall-related injuries represent serious problems for older people, their relatives, and societies through the strain placed on limited health system resources. Alternative definitions of fall can be found in the literature, including the World Health Organisation's (WHO) definition (WHO 2007). In an attempt to develop a common framework in the research on falls and fall-related injuries, the Prevention of Falls Network Europe provide a consensus definition of fall as "an unexpected event in which the participants come to rest on the ground, floor, or lower level." (Lamb et al. 2005, 1619). In developed countries, more than one third of people older than 65 years fall each year (Kannus et al. 1999; WHO 2007). Those experiencing a fall might be unable to call for help remaining unattended for a long time. Some of the most common acute consequences can be pain, hypothermia, pneumonia, and dehydration (Tinetti et al. 1993). Furthermore, subsequent fear of falling may lead to reduced physical activity, functional decline, reduced quality of life and possibly institutionalisation (Tinetti et al. 1993; Fleming et al. 2008; Hartholt et al. 2011).

Due to methodological limitations, it is difficult to compare the economic burden that falls in older people pose across countries (Davis et al. 2010). Burns et al. (2016) reported yearly direct medical costs of $637.5 million and $31.3 billion for fatal and non-fatal falls respectively. In Europe and globally, a comparable dimension of the problem exists due to the similarities in demographic and health trends (WHO 2007). Davis et al. (2010) reported annual costs of $23.3 billion in the United States versus US $1.6 billion in the UK. The mean cost of a fall requiring hospitalization in the USA was $26,483 (Davis et al. 2010). Hartholt et al. reported total health care costs of €474.4 million annually for fall-related treatment in The Netherlands. The treatment of one hip fracture case was €18 233 (Hartholt et al. 2011). In Finland, the hospital cost for inpatient care due to fall accidents was close to €400 million (National Institute for Health and Welfare (THL) Finland 2017). Data from 2012 showed that there were 7 500 hip fracture events in one year and the cost for each treatment was €20 000 (THL 2017).

Similarly to fall accidents, reduced fall-related self-efficacy or fear of falling, and fear of being left unattended in case of sudden trouble can decrease quality of life and increase the speed of decline of the ability to perform activities of daily living (ADL). These conditions may lead older people to self-imposed isolation, refusal of mobility, mobility restrictions, and admission to institutional care (Tinetti et al. 1990; Franzoni et al. 1994; Cumming et al 2000; Friedman et al 2002; Delbaere et al. 2004; Czaja & Lee 2007; Deshpande et al. 2008).

Scientific research has indicated that many older people would rather live in their own homes as long as they can (Ryan et al. 2009). Falls, however, may be factors imposing serious limits to their wishes. In a prospective study involving community-dwelling people over the age of 71, after adjustment for other factors, falls were found to be an important predictor of admission to a nursing home (Tinetti & Williams 1997).

This thesis is part of the CONFIDENCE project. The technical objective of the European Framework Programme 7 (FP7) project CONFIDENCE (grant no FP7 ICT-214986) was the development and integration of innovative information and communication technologies (ICT) for the detection of abnormal events, such as falls, or unexpected behaviours that may be related to a health problem in older adults. Hence, the project proposed and developed a system by means of which increased fall-related self-efficacy, independence in ADLs, and quality of life of older people could be attainable (Czaja & Lee 2007). Using the system could support their active participation in society and the possibility to live in their own homes longer than without this ICT support (Quemada et al. 2009). Operating as a fall detector and emergency call system, CONFIDENCE could contribute to reduce the length of time older people lie on the floor after a fall (Fleming et al. 2008).

Naturally, these hypothesised outcomes for older people and other stakeholders in the value chain could only be achieved if this innovative care system reached the market. It is frequently argued that a precondition for successful market access of ICT innovations is the acceptance of these by the intended target users, i.e., the older people (Turner et al. 2010; Mitseva et al. 2012; Hawley-Hague et al. 2014; Louie et al. 2014; Vaziri et al. 2016). Therefore, the study of the acceptability of the CONFIDENCE system appeared unavoidable. During the life-cycle of the project, it was not required to take the research results to the commercialisation stage. However, it seemed clear that learning about the usability and acceptability of the prototype could offer great support for possible commercialisation undertakings and to advance the scientific knowledge in the area of usability and technology acceptance of innovative ICTs for active ageing and independent living.

The main scientific question addressed in this thesis was whether the CONFIDENCE system would be usable and acceptable for the older participants, i.e., would the users be able to operate and accept such monitoring system if they would need it or if they would benefit from it?

This research is important because, to the best of our knowledge, is the first study to analyse the usability and acceptability of a fall and behaviour monitoring ICT system for older people which is based on real time 3D localisation and interpretation of the position of the body using RF signals.

2 TECHNOLOGICAL CONTEXT

The following sections convey more exhaustively the ICT system and its operational features. Some systems somewhat related to CONFIDENCE and commercially available are presented. These can help to understand the advantages and disadvantages of ICTs targeting the silver economy market.

2.1 The CONFIDENCE system

The prototype of the CONFIDENCE system was developed as the main output of the project with the same name. It aimed at increasing the quality of life and security of the elderly people extending their personal autonomy and participation in society. The system monitors the position of the body in 3D through RF signals. The older person or user wears 2 RF devices/tags on the left and right ankles, 1 RF tag on the waist (possibly on the belt), and 1 more on the upper part of the chest. These body tags transmit their signals to 4 RF sensors or receivers which are placed on the corners of the walls of one room. Both the body-worn tags and the wall-mounted devices are transceivers, i.e., transmit and receive radio signals (Luštrek et al. 2015). The information received by the wall-mounted receivers is then processed by a software application to provide 3D location information, and is further processed to reconstruct the position of the body and interpret the activity of the user, e.g., walking, sitting, lying down, and falling (Luštrek et al. 2012; Pogorelc et al. 2012). If there is a fall, the system produces an alarm that the user acknowledges by pressing a button on a portable device. The portable device is a mobile smartphone carried by the user with hardware buttons and touch screen user controls or software buttons. When the user acknowledges an alarm detected by the system or initiated by her or himself, this alarm information is forwarded to a designated care provider, the emergency services (112), or other person chosen by the user. The alarm receivers are informed about the incident by means of a text message (SMS), a voice message pre-recorded on the base computer, or a phone call allowing direct communication between the older person and the alarm receiver. In this study, the alarm receiver, i.e., the researcher connected through a normal/voice telephone call. Upon reception of this information, the alarm receiver can initiate an adequate response to the situation, e.g. call the user to ascertain the nature of the incident or an ambulance. If the user were not able to acknowledge the alarm because she or he is unconscious or cannot move, after a short period of time the call is transmitted automatically to the care provider, the emergency service 112, or other designated alarm receiver. Accidental operation of the smartphone, i.e., false alarm, can be deactivated by the user pressing/tapping another button on the smartphone. Hence, the users can obtain help when they would not be able to summon it by themselves (Mirčevska et al. 2009).

2.2 Personal emergency response systems

The use of ICTs is spreading rapidly, but the possible acceptance and uptake of these, especially by different cohorts of older people remain ambiguous (Mihailidis et al. 2008). Results of the MOBILATE project also indicated that older adults use some of the technological innovations infrequently. Some contributing factors to the usage of technology are educational level and income. Older people with high educational level and income tend to use new technologies more than those with lower educational and income levels (Tacken et al. 2005). This suggests that most of the existing technologies, and especially those under development, e.g., home automation, ambient intelligence, health monitoring body area sensor networks, might not reach the oldest segment of the older people (Tacken et al. 2005).

Rogers and Fisk (2003) indicated that the process from technological innovation development to a commonly used household device can take decades. For instance, this has happened in the cases of the World Wide Web, cars and television. In constructing new innovative forms of interaction, one of the challenges is how to get people to use the available possibilities effectively. This is a serious challenge for the ICT field, and it is also critical during the process of developing a care system for people with special needs. End-users may be interested in the emerging possibilities of care systems, but modest computing skills, inexperience, or poor system design can hinder the use and acceptability of ICT systems (Rogers & Fisk 2003).

CONFIDENCE can be considered a third generation of the personal emergency response systems (PERS) as it not only detects falls but also other deviations from normal motor activities of the user. The system employs RF technologies and smart discrimination through artificial intelligence (AI) (Mirčevska et al. 2009). It offers advances over the capabilities of systems based on activity detection using infrared sensors, inertial sensors such as 3-axial accelerometers, gyroscopes, and wireless alarm buttons worn as bracelets or pendants (Lee et al. 2007; Hamill et al. 2009).

The evolution of the PERS or social alarms is taking the systems to operate also outdoors. Mobile PERS use mobile telephone networks, satellite global positioning systems (GPS), and assisted GPS when more precise localisation is needed. In a press release by LifeComm, it was announced that PERS are becoming or will become mobile personal emergency response systems (MPERS). For instance, the LifeComm's MPERS, will use Qualcomm's Internet of Everything module and wireless chipset technology (Business Wire 2011).

Arguments favouring this technological move are that most of today's PERS only operate within the range of a home-based receiving system. However, active older people want to maintain their freedom and independence with the certainty of access to emergency assistance wherever they go. It has been reported that the LifeComm device will offer an unobtrusive means of remotely monitoring an older person. It will facilitate the customisation of the device settings and monitoring functions through web-based applications to social care personnel, relatives and the older users themselves (Business Wire, 2011).

Similar approaches such as the Vega GPS watch system developed by Everon consists of a wrist watch or bracelet and is used as a safety device for outdoor monitoring applications such as the location of people at risk of wandering (e.g., Alzheimer's disease patients) (Everon Oy 2016). Previously, this product was named PERSmobile for mobile personal emergency response system.

2.3 Contributions to maintain independence and functional ability

As noted earlier, older people sustaining an injurious fall are at greater risk of developing fear of falling, activity limitations, reduced self-efficacy in performing ADLs, diminished participation, impaired physical performance, and increased risk of institutionalisation among other negative outcomes. The intelligence and predictive capabilities of the CONFIDENCE system represented some of the main innovations of this research and development project (Pogorelc et al. 2012).

Used regularly by an older person, the system could be able to discriminate deterioration of mobility function, or abnormal changes in behavioural patterns which would be otherwise unnoticeable for the user (Mirčevska et al. 2009). With this information, the users could seek specialised medical consultation and initiate primary preventive measures aimed at reducing fall risks such as balance or strength training (Sihvonen et al. 2004; Pajala et al. 2008).

Compared to other systems that rely on the purposive action of the user, such as the alarm button, CONFIDENCE can perform this alarm procedure without the intervention of the user. This can help to avoid situations where an older person has been found at home lying on the floor after hours or days (Fleming et al. 2008).

In sum, CONFIDENCE could reduce the time elapsed between an older person suffers a fall-related accident and she or he receives emergency assistance. Releasing the older person from this concern, CONFIDENCE could contribute to support active and independent ageing. Monitoring the functional ability of the older person could enable earlier preventive interventions aimed at maintaining an adequate functional status. Quality of life, as a result, could be maintained or improved.

3 USABILITY AND ACCEPTABILITY

Personal computers (PCs), smartphones, and tablet PCs are interactive ICT systems widely used by people of all ages. Generally speaking, usability is a feature of ICT systems that conveys how easily and efficiently a user can operate them. Many consider that older people are not interested in using ICT because is it complex and difficult to use, i.e., ICT demonstrates low usability (Fisk & Rogers 2002; Tacken et al. 2005; Wandke et al. 2012). Wandke et al. reasoned that a main determinant of the difficulty older people find when using ICT resides in hardware and software designers and developers. This is, ICT developers do not incorporate the needs, abilities and limitations of older users into the development process as system requirements (Fisk & Rogers 2002; Czaja & Lee 2007; Wandke et al. 2012).

In the field of research on human-computer interaction, the notion of usability implies that a device or system is designed with a generalized view of the psychology and physiology of the user. A usable system is thus efficient to use, e.g., it takes less time to accomplish a particular task; easy to learn and use, and its use is satisfying. In the International Organization for Stadardization (ISO) standard ISO 9241 (1998) usability is defined as the extent to which a product can be used by specific users to achieve specific goals effectively, efficiently and with satisfaction in a specific context of use (ISO 1998). Researching and understanding the interaction between a system and a user provides insights on how the product is perceived by the users and working in reality. These insights are not attainable by traditional market research methods. For example, needed functionalities or design flaws not anticipated at the product design stage may be identified after observing and interviewing users while interacting with the system (Brooke 1996).

Nawaz et al. (2014) studied the usability of a smart home interface for independent living particularly focused on fall management. Five senior citizens with an average age of 77±6 years explored and performed different tasks on paper mock-ups and interactive prototypes in five scenarios related to fall risk, fall assessment and exercise guidance. They reported results obtained with a system usability scale showing that users liked the interface and had a positive reaction towards the usefulness and usability of the system.

Some usability concerns included confusion between the interface of the manufacturer and the space dedicated for physical activity and fall management, difficulty to read, and inactive screen (Nawaz et al. 2014).

Vaziri et al. (2016) investigated the usability and acceptance of the iStopFalls system. It aims at reducing fall risk factors, such as impaired balance and poor muscle strength. The exercise programmes that can contribute to prevent falls are delivered through Microsoft-Kinect games (Vaziri et al. 2016). The system consists of technologies such as a set-top box, a PC, a Microsoft-Kinect sensor for movement detection and voice control, a Senior Mobility Monitor, an alternative tablet PC, and an interactive television (Gschwind et al. 2015; Marston et al. 2015; Vaziri et al. 2016). Using the system usability scale (SUS) (Brooke 1996), 60 participants (23 males, 37 females, average age 73) evaluated the usability of the system as good (mean SUS score = 62; SD = 15.58). Aspects of the system hindering its usability included malfunctions, long loading times, and the complexity of the tasks. The authors concluded that the system shows good usability characteristics. They proposed that in order to improve technology acceptance, motivational, age, and gender factors should be taken into account in the design of fall prevention systems (Vaziri et al. 2016).

Acceptability or technology acceptance refers to the favourable reception, consent and continued use of devices and systems newly introduced in the personal environment. This definition can be applied to more traditional assistive technologies, such as mobility, vision, and hearing aids, furniture and home adaptations (McCreadie & Tinker 2005), as well as to ICT-based assistive technologies including robots. The study of acceptability explores the relation of end-users motives and attitudes toward the device or system and the evaluation of the impact it may have in their lives (Mihailidis et al. 2008).

The technology acceptance model (TAM) and the unified theory of acceptance and use of technology (UTAUT), are the most commonly used frameworks to collect and interpret information about the acceptability of technical innovations by the intended users (Davis 1989; Venkatesh et al 2003). Perceived ease of use (PEU), and perceived usefulness (PU) are the factors that contribute to the acceptance of technical innovations. PEU and PU are defined by Davis (1989) as the extent to which a person believes that using a particular system would be free of effort, and the extent to which a person believes that using a particular system would enhance his or her job performance, respectively (Davis 1989). The theory of reasoned action supports the TAM framework to explain acceptance and use of new technology from the viewpoint of the users' internal beliefs, attitudes and intentions (Fishbein & Ajzen 1975). Consequently, the application of TAM when a technology is introduced could help to predict its future adoption and use (Turner et al. 2010).

Mihailidis et al. (2008) investigated the acceptability of home monitoring technologies such as PERS, and fall detection systems, as well as sensor systems with two groups of older people, i.e., 15 baby boomers (40-59 years; 5 women, 10 men), and 15 older adults (65 years and older; 8 women, 7 men). They collected data with a 24-item questionnaire with close-ended questions requiring yes/no answers, i.e., willing/not-willing. Generally, they found that the technologies would be acceptable if they permitted the participants to live in their own homes. The PERS was the most desirable of the home monitoring technologies because it was perceived as useful and familiar. On the contrary, lifestyle monitoring, automatic prompting to perform ADLs, and video cameras were the least desirable technologies participants were willing to install in their homes. There were no differences in preferences between age groups (Mihailidis et al. 2008).

A study by Wilkowska and Ziefle (2009) investigated the influence of computer expertise, and technical self-confidence on users' acceptance of a personal digital assistant (PDA). Acceptance to use the PDA was operationalised as the responses to the original PEU and PU questionnaire items formulated in the TAM (Davis 1989). One user group (n = 40) was instructed on the use of the PDA before the experiment and another group (n = 20) performed the experimental tasks without prior instruction. Acceptance was evaluated after completion of the experimental tasks. The data showed that computer expertise was positively and significantly associated with PEU and PU (Wilkowska & Ziefle 2009). Technical self-confidence was also positively and significantly correlated with PEU but not with PU. The group receiving instruction showed greater PEU than the non-instruction group (Wilkowska & Ziefle 2009).

The TAM model has been applied to investigate the effects of age and belonging to the technical generation on the intention to use a small-screen diabetes monitor device (Calero Valdez et al. 2009). Participants in this study performed five tasks on a simulated diabetes living assistant device. The authors reported significant correlations of age and performance success with acceptance of the device (Calero Valdez et al. 2009).

Technology developments for active and independent ageing have not only targeted older people as end users, but also formal and/or informal care providers. Mitseva et al. (2012) evaluated the acceptance of a personalised home care technology platform for older people with cognitive impairment and their informal caregivers. Home support services include safety monitoring through temperature and flood sensors, smoke alarms, electricity monitors for cooking activity, bed pressure sensors to determine sleeping patterns, and front and fridge door sensors. Safety alarms and/or notifications to the informal caregivers are transmitted as SMS text messages or e-mails. The informal caregivers interacted with the system through a mobile phone and a computer to access the web portal of the system. Seventeen informal caregivers rated the acceptance of the system. On average 65% of the informal caregivers would like to continue using the system after the study. Perceived benefits comprised reduced number of phone calls, travel time, and visits to check the condition of the older person. More spare time can be obtained as a result of the previous advantages (Mitseva et al. 2012).

Assistive robots are being developed to help older people in different domains of life. Louie et al. (2014) investigated the acceptance of older adults toward a human-like expressive socially assistive robot. Participants interacted with the robot in two scenarios: a memory card game, and a restaurant finding task. The results of a robot acceptance questionnaire indicated that participants had positive attitudes toward the robot and experienced minimal level of anxiety while interacting with it (Louie et al. 2014).

4 AIMS AND RESEARCH QUESTIONS

The aims of this thesis were to elucidate whether the prototype developed in the CONFIDENCE project would be usable for older Finnish people, and if they would demonstrate positive or negative attitudes towards accepting into use this technical solution to detect abnormal behaviours, such as falls, and summon emergency assistance. Additionally, the associations between acceptance and other study variables were examined to understand the motives that can lead to accept or reject innovative ICTs aimed at supporting active and independent ageing. Consequently, we collected data on socio-demographic, quality of life, concerns about falls, mobile phone expertise (MPE), task performance with the functional prototype, i. e., usability, and acceptability. The main research questions of this study were the following:

1) How easy to use is the CONFIDENCE system prototype for older Finnish people?
   1a) How two versions of the tag attachment mechanism compare in ease of use?
   1b) How two versions of the graphical user interface compare in ease of use?
2) What are the older Finnish people's attitudes about accepting to use CONFIDENCE?
3) How do acceptance attitudes towards the system, i.e., intention to use, perceived advantages and disadvantages, relate to variables such as age, educational level, fear of falling, and quality of life?

5 METHODS

The prototype of the CONFIDENCE system was developed using a user-centred centred methodology. The usability and acceptability of the system were studied among 24 older Finnish people in two studies which enrolled 12 participants each. Participants' feedback after the first usability and acceptability study suggested that the user interfaces, i. e., tag attachment mechanisms, and smartphone graphical interface, could be improved. With modified versions of the user interfaces, another iteration of the usability and acceptability evaluation was run in the second study. The first and second studies followed the same procedure except that in the second study the older people interacted with the two versions of the user interfaces.

5.1 Participants

The names of potential participant were collected from the pool of previous need and requirement elicitation studies performed in the project, senior organisations, and referrals from the users themselves. Their telephone numbers were obtained through the telephone catalogue. Older people living in Jyväskylä were contacted through the telephone and invited to the studies. Twenty four people, pooled across 2 studies with n = 12 each, consented to participate. They all were living independently in their own homes, and did not present diseases or other problems that could preclude their participation or pose personal risks. At the time the studies were completed, each of them was mobile phone user though none of them owned a smart phone or a mobile phone terminal provided with touch screen interface. Each of them was right handed with normal or corrected to normal vision and adequate hearing ability without hearing aids.

5.2 Instruments and materials

Usability, and acceptability information about the CONFIDENCE prototype was gathered through paper and pencil questionnaires, and task performance measures while the users interacted with the prototype (Van Vianen et al. 1996).

The interactive user interface of CONFIDENCE was implemented on a mobile smartphone. Hence, it could be possible that the level of expertise using a mobile phone influenced the usability and acceptance results. Adapted from Calero Valdez et al. (2009) MPE was measured with the PEU and usage frequency (UF) scales. Both PEU and UF are scored on a 6-point Likert scale. PEU asks questions such as "How easy is it for you to...?" (1 = very easy, 2 = easy, 3 = rather easy, 4 = rather hard, 5 = hard, 6 = very hard) and applied to the following functions of mobile phones: voice calls, text messages, Internet, alarm clock, e-mail, and address book. Similarly, UF is examined with questions such as "How often do you send text messages?" (1 = Daily, 2 = 2 - 3 times a week, 3 = once a week, 4 = 1 - 2 times a month, 5 = 1 - 2 times a year, 6 = never). The same functions included in PEU were included in the UF questionnaire. Total MPE is calculated as the square root of the product of the mean of all PEU and all UF scores and corresponds to a 6-point scale where 1 = highest MPE, and 6 = lowest MPE.

The acceptability questionnaire was adapted from that used and validated by Gaul and Ziefle (2009). It included 14 questions grouped into three categories: intention to use, advantages of using, and disadvantages or barriers to use the system. Each category contained 3, 6 and 5 questions respectively. Responses were scored on a 4-point Likert scale from 1 = totally disagree to 4 = totally agree. The questions presented to the participants of this research are shown in table 4.

The user interfaces of the CONFIDENCE prototype consisted of RF tags and a smartphone. The tags were 4 Ubisense Series 7000 Compact Tag with dimensions 38 x 39 x 16.5 mm, and 25 g weight (Ubisense 2013). Figure 1 shows the first and second versions evaluated by the participants with the corresponding attachment mechanisms.

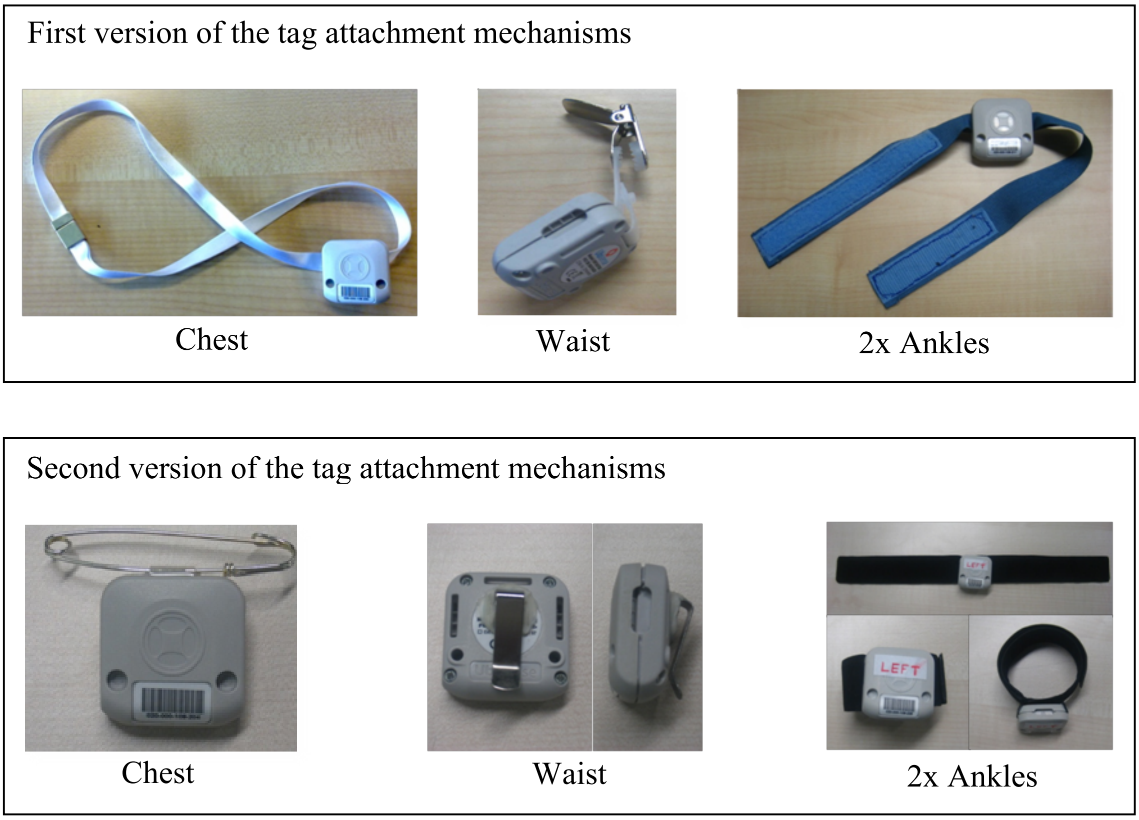

FIGURE 1. Two versions of the tag attachment mechanisms.

NOTE. Top panel: First version of the attachment mechanism of the bodily worn tags. Left: Lace to be worn around the neck. Middle: Safety clip placed on the waist, e.g., on the pants or belt. Right: Velcro tape placed around the ankles. Bottom panel: Second version of the attachment mechanisms of the bodily worn tags. Left: Safety pin placed on the clothes on the upper part of the chest. Middle: Clip placed on the waist, e.g., on the pants or belt. Right: Slap-on bracelet placed around both ankles.

The smartphone showing the two versions of the graphical user interface developed in the project are presented in figure 2. The smartphone was an HTC Touch Cruise mobile phone with dimensions 110 x 58 x 15.5 mm, 2.8” screen, and 130 g weight. The device run on the Windows Mobile 6.1 Professional operating system.

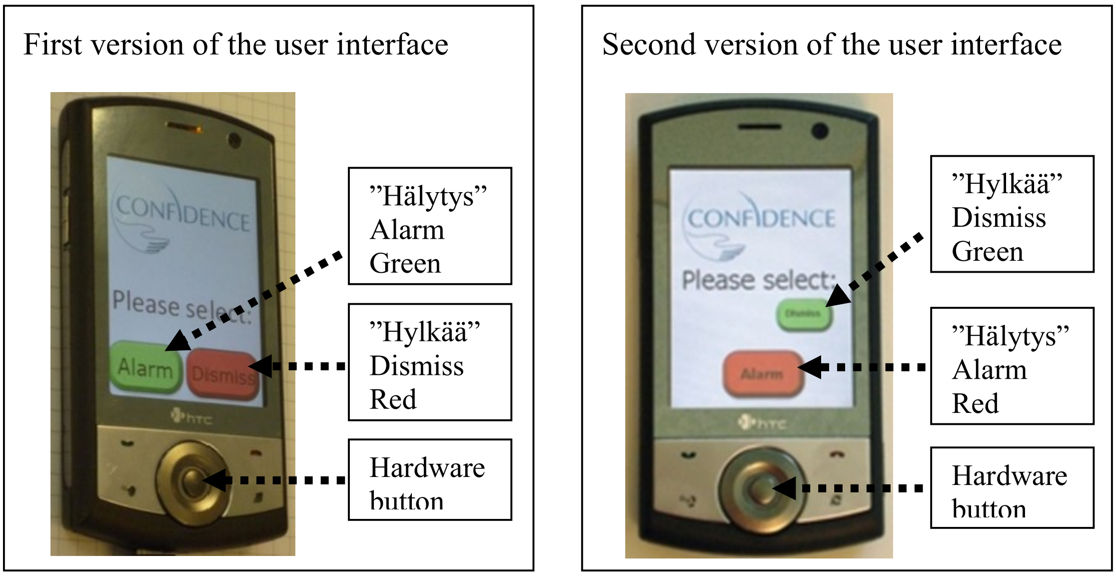

FIGURE 2. Two versions of the HTC Touch Cruise mobile phone graphical interface.

NOTE. Left panel: first version of the user interface with the green Alarm and red Dismiss soft buttons side by side. Right panel: second version changing the buttons to a vertical orientation, red Alarm bottom, green Dismiss button above the alarm one.

The environment where the research took place and one participant operating the smartphone are presented in figure 3.

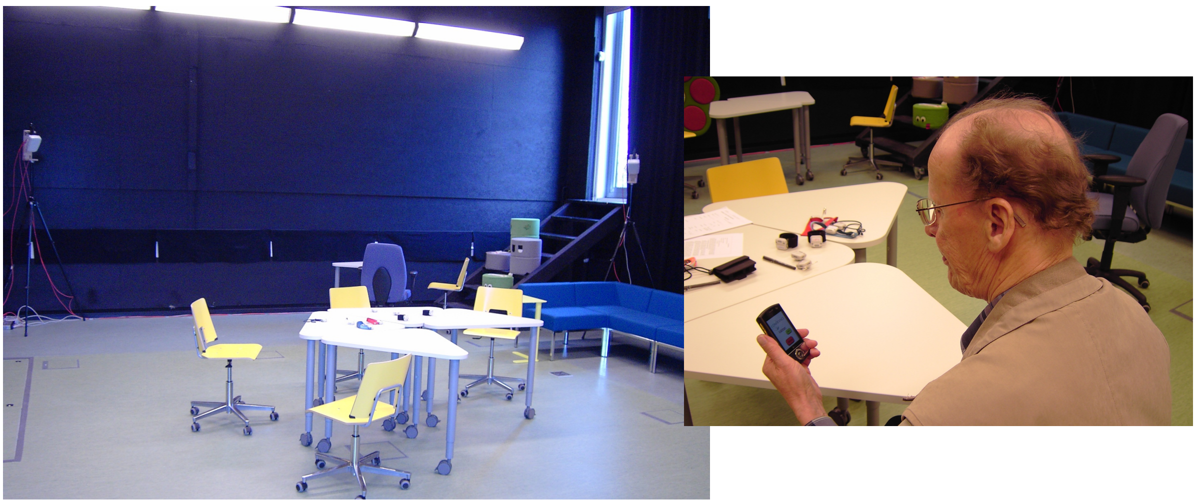

FIGURE 3. Room showing the installation of the CONFIDENCE prototype. On the right side, one participant is operating the second version of the smartphone interface. The photograph of the participant is reproduced with his explicit consent.

Data on the socio-demographic and quality of life characteristics of the users were collected with the WHOQOL-BREF questionnaire (WHO 1996) in its Finnish version (Manssila & Koistinen 2006). Quality of life was assessed because it may represent one of the possible psychological factors that could influence the users' acceptance of the system. The WHOQOL-BREF is a sound multidimensional cross-culturally valid assessment instrument, with 26 items scored on a five-point Likert scale (Skevington et al. 2004). Assesses four domains: self-rated physical health and function, psychological health, satisfaction with social relationships, and satisfaction with material/environmental aspects of life. The four domain scores denote an individual's perception of quality of life in each of them. The domain scores are scaled in a positive direction (i.e. higher scores denote higher perceived quality of life). The mean score of items within each domain is used to calculate the domain score which is then transformed into a 4-20 scale which is comparable to the WHOQOL-100 (WHO 1996; 1998; Skevington et al. 2004). Domain scores were computed using the procedure shown in WHO (1996, 12) with SPSS (v. 22). There are also two items that are examined separately: question 1 asks about an individual's overall perception of quality of life and question 2 asks about an individual's overall perception of their health (WHO 1993; 1996; 1998).

Concerns about falling were assessed with the Falls Efficacy Scale International (FES-I) translated into the Finnish language by a native Finnish researcher. At the time the studies were conducted, i.e., January 2011, and May 2011 respectively, the approved Finnish version of the FES-I was not available. The Finnish version of the scale FES-I-FIN was produced and approved by the Urho Kekkosen Kuntoinstituuttisäätiö (UKK-Instituutti) (2011) after the study had concluded. The FES-I instrument is a self-report questionnaire providing information on the level of concern about falls for a range of ADLs and instrumental activities of daily living (IADLs). The questionnaire contains 16 items scored on a four-point scale (1 = Not at all concerned, 2 = Somewhat concerned, 3 = Fairly concerned, 4 = Very concerned). For 2-group discrimination purposes, i. e., low vs. high concern, the estimated cut-points are: 16–22 and 23–64. For 3-group classifications, i.e., low, moderate, and high concern, the estimated cut points are: 16–19, 20–27 and 28–64 (Delbaere et al. 2010).

5.3 Procedure

The participants read and signed the informed consent for the study procedure. The ethics review board of the University of Jyväskylä Finland approved this before the research begun. There were no inducements to take part in this research. Communications between researcher and participants took place in the Finnish language. The procedure consistently followed its standardized format in both studies. Exception was made for the usability evaluation with the initial and modified versions of the user interfaces in the second study.

Firstly, the installation of the system and the user interfaces, i.e., tags and smartphone, were presented in understandable language for the participants. The researcher explained that the system monitors the position of the body in 3D through RF signals. This information is processed to reconstruct the bodily posture of the user and discriminate normal from hazardous situations such as falls. The user wears 4 RF devices/tags and manages the system through a smartphone.

Secondly, the participants filled in the WHOQOL-BREF, mobile phone expertise, i.e., UF, PEU, and FES-I questionnaires, in this order. Thirdly, the participants were familiarized with the smartphone, hardware and software buttons, and the alarm task sequences. After a complete understanding was reached, they performed the following tasks on the system: (1) attachment and removal of the 4 tags to the ankles, waist, and upper part of the chest, i.e., and a necklace in the first study, and a safety pin in the second study. In the second study, tag attachment and removal was performed twice, once with each version of the tag attachment mechanisms as shown in figure 3. (2) initiation and dismissal of user-initiated-alarms, and (3) acknowledgement and dismissal of system-detected-alarms through the smartphone.

Tasks (2) and (3) were performed twice in the second study, once with each version of the graphical user interface. In order to control for possible version order effects, performance with each version of the tags and graphical interfaces were counterbalanced. Chosen at random, half of the participants followed the first-second version sequence, the other half followed the reverse order. Tasks (2) and (3) were performed both with the dominant and non-dominant hands. Task performance measures included task completion time, and accuracy. Completion time was measured since the researcher indicated START to the participant until the last button tap in the task sequence was performed. Participants were instructed to perform the tasks as fast and accurately as possible.

They filled in a usability questionnaire immediately after completing the user-initiated-alarm, and another after the system-detected-alarm. At the end of the session, the participants filled in the acceptability questionnaire, were debriefed, and thanked for their contribution.

They were encouraged to ask questions and express their opinions about the system and their experiences at any time during the research session. Exception was made for the situations when they undertook the user-system interaction tasks because it could interfere with their accuracy or completion time.

5.4 Statistical analyses

Data are shown as means (*M*), standard deviations (*SD*), frequencies (*f*), and percentages (%). Statistical analyses were performed with the IBM SPSS (v. 22) software. An alpha level of .05 was used for all statistical tests. Completion time differences in user-system interaction tasks were subjected to repeated measures ANOVA and *t*-tests. Associations between acceptability and other variables were studied with Spearman Rho (ρ) correlation tests.

6 RESULTS

Pooled across the two studies (*N* = 24), socio-demographic, self-rated quality of life (WHO 1996), concerns about falls assessed through the FES-I scale, MPE, and Quality of life domain scores are shown in table 1. In the first study (*n* = 12), one of the participants had never married, and all of them accomplished primary or tertiary education. One participant in the second study (*n* = 12) did not finish the secondary education.

TABLE 1. Sociodemographic characteristics, quality of life, falls-related self-efficacy and mobile phone expertise of the overall study sample.

Variables	*N* = 24
Age, *M* (range)	71.13 (64-80)
Male (*f*)	13
Marital status (*f*)*	
Married	12
Divorced/separated	5
Widowed	6
Education (*f*)†	
Primary	13
Tertiary	10
WHOQOL-BREF (*M* ± *SD*)	
Global SR QOL	3.8 ± 0.5
Global health satisfaction	3.7 ± 0.8
Physical health domain	13.9 ± 1.04
Psychological domain	12.4 ± 0.7
Social relationships domain	15.1 ± 1.8
Environment domain	16.2 ± 1.5
FES-I (*M* ± *SD*)	20.1 ± 2.8
MPE (*M* ± *SD*)	3.4 ± 1.0

NOTE. * One person was single. † One person did not finish the primary education. WHOQOL-BREF considered the last 4 weeks, scale 1-5, 1 = low, 5 = high, domain scores were transformed to a 4-20 scale comparable to WHOQOL-100; Falls Efficacy Scale-International (FES-I) scale 1-4, 1 = not at all concerned, 4 = very concerned, values 16-19 = low concern, 20-27 = moderate concern, 28-64 = high concern; MPE = mobile phone expertise; MPE = sqrt (mean PEU * mean UF), scale 1-6, 1 = high, 6 = low; *M* = mean; *SD* = standard deviation; *f* = frequency.

6.1 Usability of the prototype

Performance of the participants while interacting with the tags and the smartphone were used to assess the usability of the prototype. Firstly, tag wearing performance results are presented. Secondly, results of the user interaction tasks with the smartphone are shown. Task completion time and accuracy were the quantitative dependent variables included in the statistical analyses. Completion time was measured in seconds with a stopwatch by a trained researcher. The stopwatch was accurate to the hundredth of a second. Performance accuracy was not a sensitive measure. Each participant performed the tasks without errors. Thus, accuracy measures are not reported.

6.1.1 Tag wearing performance

First Study ($n = 12$). A paired samples *t*-test, showed that putting on the tags was significantly slower ($M = 38.14$, $SD = 14.06$) than taking them off ($M = 15.87$; $SD = 5.33$), $t(11) = 5.84$; $p < .001$, $d = 1.69$.

Second study ($n = 12$). Tag usability measured as completion time in seconds was analysed with an analysis of variance (ANOVA) with tag version (first version, second version) and tag wearing (put on, take off) as within-subjects factors. The ANOVA revealed main effects of tag version, $F(1, 11) = 120.1$, $p < .001$, $\eta_p^2 = .92$, and tag wearing, $F(1, 11) = 9.01$, $p = .012$, $\eta_p^2 = .45$. Performance with the first version was slower ($M = 35.79$; $SD = 6.22$) than with the second one ($M = 16.35$; $SD = 3.86$). It was faster to take off the tags ($M = 22.79$; $SD = 4.83$) than to put them on ($M = 29.35$; $SD = 6.32$). The interaction tag version by tag wearing was not significant, $F(1, 11) = 1.3$, $p = .278$, $\eta_p^2 = .11$.

6.1.2 Interaction with the smartphone interface

User-initiated-alarm situation. In the first study (n = 12), the usability of the smartphone was evaluated by means of the instantiation of the alarm by the user through its hardware button (see figure 2). The time required to complete the alarm task was analysed with a 2 x 2 ANOVA with function selection (alarm, dismiss) and handedness (dominant, non-dominant) as within-subjects factors. The analysis yielded a significant effect of function selection $F(1, 11) = 20.44$, $p = .001$, $\eta_p^2 = .65$ indicating that the time required to tap the alarm button was slower (M = 12.19; SD = 4.93) than to tap the cancel button (M = 5.99; SD = 3.11). The effect of handedness was not significant $F(1, 11) = .41$, $p = .53$, $\eta_p^2 = .04$. The interaction function selection x handedness was not significant either $F(1, 11) = .07$, $p = .8$, $\eta_p^2 = .006$.

The second study (n = 12) compared two versions of the smartphone's graphical interface while the users initiated the alarm function through its hardware button. A 2 x 2 x 2 ANOVA with interface version (v1, v2), function selection (alarm, dismiss), and handedness (dominant, non-dominant) as within-subjects factors did not yield any significant main effects of interface version $F(1, 11) = .44$, $p = .52$, $\eta_p^2 = .04$, function selection $F(1, 11) = .07$, $p = .79$, $\eta_p^2 = .007$, or handedness $F(1, 11) = 1.15$, $p = .31$, $\eta_p^2 = .09$. Neither of the interaction effects interface version x function selection $F(1, 11) = .32$, $p = .58$, $\eta_p^2 = .03$, interface version x handedness $F(1, 11) = 3.83$, $p = .08$, $\eta_p^2 = .26$, function selection x handedness $F(1, 11) = .001$, $p = .98$, $\eta_p^2 = .00$, or interface version x function selection x handedness $F(1, 11) = .15$, $p = .71$, $\eta_p^2 = .01$ were significant.

Table 2 presents the responses to the usability questionnaires presented in the 1st and 2nd studies after the participants had completed the user-initiated-alarm tasks through the hardware button of the smartphone.

TABLE 2. Frequencies (*f*) on the usability questionnaire presented after the user-initiated-alarm task in the first study (n = 12), and in the second study (n = 12) after performing the task with the first (1st v.) and second versions (2nd v.) of the graphical user interface.

	1st study		2nd study			
			1st v.		2nd v.	
Usability question (*f*)	YES	NO	YES	NO	YES	NO
Are the characters visible?	12	0	10	0	12	0
Are the buttons sufficiently distant?	12	0	11	0	12	0
Are the colours immediately understood?	10	2	10	1	12	0
Are the words immediately understood?	10	2	11	0	12	0
Would it be worse to have buttons of different shapes?	7	5	8	3	7	5
With your visual ability, is the interface easy to use?	11	1	10	1	12	0
With your motor ability, is the interface easy to use?	12	0	11	0	11	1
Is it easy to take out the smartphone from its case?	11	1	10	1	11	1
Is the smartphone easy to hold on your hand?	9	3	11	0	12	0
Would soft buttons be replaced with hard buttons to prevent accidental operation?	8	4	4	7	4	8
Total	102	18	96	13	105	15

System-detected-alarm situation. In the first study (n = 12), the performance of the users when the alarm situation was automatically detected by the system was analysed with a 2 x 2 ANOVA with function selection (alarm, dismiss) and handedness (dominant, non-dominant) as within-subjects factors. Neither of the main effects nor their interaction resulted in significant F ratios. Function selection yielded an $F(1, 11) = .94$, $p = .36$, $\eta_p^2 = .09$, handedness $F(1, 11) = .104$, $p = .75$, $\eta_p^2 = .01$, and the interaction function selection x handedness $F(1, 11) = .002$, $p = .97$, $\eta_p^2 = .00$.

The second study (n = 12) compared two versions of the graphical user interface of the smartphone when the alarm situation was automatically detected by the system. A 2 x 2 x 2 ANOVA with interface version (1st v., 2nd v.), function selection (alarm, dismiss), and handedness (dominant, non-dominant) as within-subjects factors revealed a non-significant main effect of interface version $F(1, 11) = .03$, $p = .87$, $\eta_p^2 = .002$. Function selection $F(1, 11) = 7.42$, $p = .02$, $\eta_p^2 = .403$, and handedness $F(1, 11) = 5.87$, $p = .03$, $\eta_p^2 = .35$, showed significant effects respectively. Neither of the first order interaction effects involving the interface version were significant, interface version x function selection, $F(1, 11) = .06$,

$p = .82$, $\eta_p^2 = .005$, nor interface version x handedness, $F(1, 11) = 3.31$, $p = .096$, $\eta_p^2 = .23$. However, the interaction function selection x handedness yielded a significant *F* ratio of $F(1, 11) = 5.1$, $p = .045$, $\eta_p^2 = .32$, indicating that the time required to tap the alarm button was slower using the dominant than the non-dominant hand ($M = 29.03$; $SD = 8.42$ vs. $M = 24.4$; $SD = 4.42$), and tapping the dismiss button was only slightly slower with the dominant than with the non-dominant hand ($M = 23.22$; $SD = 2.72$ vs. $M = 22.63$; $SD = 3.46$). The second order interaction interface version x function selection x handedness was not significant, $F(1, 11) = 1.05$, $p = .33$, $\eta_p^2 = .09$.

The responses given to the usability questionnaires presented after the participants completed the system-detected-alarm tasks are presented in table 3.

TABLE 3. Frequencies (*f*) on the usability questionnaire presented after the system-detected-alarm task in the first study ($n = 12$), and in the second study ($n = 12$) after performing the task with the first and second versions of the interface

	1st study		2nd study			
			1st v.		2nd v.	
Usability question (*f*)	YES	NO	YES	NO	YES	NO
Are the characters visible?	12	0	11	0	10	0
Are the buttons sufficiently distant?	12	0	11	0	9	1
Are the colours immediately understood?	10	2	11	0	10	0
Are the words immediately understood?	10	2	11	0	9	1
Would it be worse to have buttons of different shapes?	9	3	6	5	5	5
With your visual ability, is the interface easy to use?	11	1	9	2	10	0
With your motor ability, is the interface easy to use?	11	1	10	1	10	0
With your hearing ability, is the alarm clearly perceptible?	12	0	11	0	9	1
Overall, do you find the alarm clearly perceptible?	12	0	10	1	7	3
Total	99	9	90	9	79	11

6.2 Acceptability of the prototype

The responses given to the acceptability questionnaire presented after the participants had concluded each task with the user interfaces of the prototype are presented in table 4.

TABLE 4. Frequencies (*f*) on the acceptability questionnaire (*N* = 24)

Acceptability question	Disagree	Agree
Intention to use (*f*)		
Using the CONFIDENCE system would increase my life contentment and satisfaction	5	19
Can you imagine using the CONFIDENCE system to live longer independently at home?	2	22
Can you imagine using the CONFIDENCE system to facilitate your living condition?	3	21
% Intention to use	14%	86%
Advantages (*f*)		
I would use the CONFIDENCE system in order to save my money for caring	6	18
I would use the CONFIDENCE system in order to save public caring costs	1	23
I would use the CONFIDENCE system because in case of emergency the system facilitates medical help	1	23
I would use the CONFIDENCE system in order to keep independency	5	19
I would use the CONFIDENCE system because it reliefs me from worries about my safety/health	9	15
I would use the CONFIDENCE system because it is unobtrusive without attracting public attention	6	18
% Advantages	19%	81%
Disadvantages (*f*)		
I would be reluctant to use the CONFIDENCE system because I fear that the device is not reliable	18	6
I would be reluctant to use the CONFIDENCE system because others would come to know about my health state	23	1
I would be reluctant to use the CONFIDENCE system because I do not want to feel stigmatized as old and sick	24	0
I would be reluctant to use the CONFIDENCE system because the tags could shift and get out of place	17	7
I would be reluctant to use the CONFIDENCE system because I do not feel able to use the Portable Device	22	2
% Disadvantages	87%	13%

NOTE. Answers were transformed from a scale 1 = Totally disagree to 4 = Totally agree to a dichotomous scale 1-2 = Disagree; 3-4 = Agree.

Bivariate Spearman rank correlations between sociodemographic, falls-related self-efficacy, quality of life, MPE, and acceptance measures were performed in order to discover which variables were associated with positive attitudes towards using the system. The WHOQOL-BREF's Global SR QOL, global health satisfaction, and the psychological domain were also included in the analyses. Only the most relevant correlations are presented in table 5.

TABLE 5. Spearman's Rho correlation coefficients between age, education, FES-I, WHOQOL-BREF domains, MPE, and acceptability measures ($N = 24$)

Variable	1	2	3	4	5	6	7	8	9	10
1. Age	—									
2. Education	-.45 *	—								
3. FES-I	.45 *	-.31	—							
4. Physical	-.05	.10	-.27	—						
5. Social relations	.28	-.11	.17	.20	—					
6. Environment	.00	.31	-.27	.69 **	.38	—				
7. MPE	.54 **	-.48 *	.03	-.32	.18	-.12	—			
8. Intention to use	.24	-.44 *	.13	.29	.29	.12	.18	—		
9. Advantages	.43 *	-.07	.12	.24	.35	.41 *	.32	.53 **	—	
10. Disadvantages	-.46 *	.13	-.43 *	-.32	-.36	-.36	-.11	-.34	-.34	—

* $p < .05$ level; ** $p < .01$ level

NOTE. FES-I = Falls efficacy scale international; Physical = WHOQOL-BREF physical domain score; Social relations = WHOQOL-BREF social relations domain score; Environment = WHOQOL-BREF environment domain score; MPE = mobile phone expertise; MPE = sqrt (mean perceived ease of use * mean usage frequency), scale 1-6, 1 = high, 6 = low;. WHOQOL-BREF considered the last 4 weeks, scale 1 -5, 1 = low, 5 = high, Domain scores were were transformed to a 4-20 scale comparable to WHOQOL-100; Falls Efficacy Scale-International (FES-I) scale 1-4, 1 = not at all concerned, 4 = very concerned, values 16-19 = low concern, 20-27 = moderate concern, 28-64 = high concern; correlations for Intention to use, Advantages, and Disadvantages were computed with the sum of scores of each question in these categories measured on a 4-point Likert scale 1 = Totally disagree to 4 = Totally agree.

7 DISCUSSION

The aims of this study were to evaluate the usability and acceptability of the CONFIDENCE prototype among 24 older Finnish people through task performance and paper and pencil questionnaires. Additionally, the associations between acceptance and individual variables, such as quality of life, concerns about falls and expertise in the use of a mobile phone were investigated.

The main findings of this study suggest that the user-system interaction was easy and efficient. Neither did the participants commit errors while completing the tag attachment or the alarm tasks. Reponses to the acceptability questionnaire indicate that the participants had positive attitudes towards using the system. Variables associated with the acceptability of the system included age, education, FES-I, and the environment domain of the WHOQOL-BREF instrument.

Task completion time when removing the tags was significantly faster than when putting them on. Statistical comparison of the first and second versions of the tag attachment mechanism showed that task completion time was significantly faster with the second version. The results indicate that the usability of the tag attachment mechanism was good, particularly that of the second version.

No errors were observed while performing the user-initiated-alarm tasks in either of the two studies. Completion times were reasonably fast in both studies. In the second study, the factor interface version was not significant. This indicates that the redesign of the Alarm and Dismiss buttons in the second version did not effectively improve participant's performance. Whether the tasks were performed with the dominant or non-dominant hand did not result in completion time differences in either study. Together with the lack of performance errors, the absence of completion time differences between dominant and non-dominant hands in the user-initiated-alarm tasks suggests that the smartphone interface was easy to use for the older Finnish participants.

In the first study, the analysis of the system-detected-alarm tasks did not result in significant effects of function selection (Alarm, Dismiss), nor handedness (dominant, non-dominant hand). Participants completed the alarm and dismiss functions with similar speed. In the second study, the effect of interface version was not robust. The factors function selection, and handedness, as well as their interaction yielded significant effects. This finding is discussed in more detail later. However the interaction system version x function selection x handedness was not significant. These results indicate an unnoticeable advantage of the modified version of the graphical interface. This is concordant with the results found in the user-initiated-alarm tasks.

Answers to the usability questionnaires after the user-initiated-alarm tasks generally indicated a good usability of the smartphone interface. In the first study, 102 of 120 (85%) were positive answers to the usability questions. Participants unanimously gave positive answers to the questions concerning the visibility, distance between the Alarm and Dismiss buttons, and demands of the smartphone on the motor abilities of the users. In the second study, after performing the same tasks with the second version of the interface a similar pattern of positive responses (88%) emerged. The questions related to the understandability of the colours and wording of the software buttons, visual ability demands, and ease of handling the smartphone received unanimous positive answers in addition to the questions indicated in the first study. The usability answers given to both versions of the interface were not qualitatively discrepant.

The participants showed a greater proportion of positive than negative opinions about the usability characteristics of the smartphone interface. The usability questionnaire presented after the system-detected-alarm tasks in the first study resulted in 99 of 108 (92%) positive answers to the questions. Responses were in the same direction as in the user-initiated-alarm task. Each participant gave positive answers to the questions on auditory perceptibility. In the second study, the first version of the interface received more positive answers than the second version, this is 90 and 79 respectively (83% vs. 73%). There was one missing response to each question. The missing answers were distributed between two participants. Two missing answers per question were observed on the second version of the interface. Two of the participants who did not answer any of the usability questions generated these missing responses.

Though comparisons with other studies are difficult and should be evaluated critically, it is interesting that the results extracted from the usability questionnaires appeared to be more favourable in ours than in other studies. Vaziri et al. (2016) found that participants younger than the average 72 years rated the usability of the system higher than the older participants. In the present research, it is difficult to estimate if age could have an effect on perceived usability because the age of the participants was in a range of 16 years. Questionnaire ratings were above 73% positive responses indicating good usability of the system while in Vaziri et al. the average score on the system usability scale was 62%. The fall prevention system in Vaziri et al. (2016) study is more complex than CONFIDENCE. Therefore, there may be more chances of finding usability limiting factors while interacting with it.

Nawaz et al. (2014) also reported good usability findings of a smart home interface for independent living aimed at fall management. Five users evaluated the system by means of paper mock ups and interactive prototypes while our study enrolled 24 older adults. In user-centred and participatory research and innovation endeavours, it is common to use mock-ups of the system under consideration. This method allows to carry out fast concept design-user testing iterations and correct system design flaws early in the life-cycle of the project. We employed related user-centred procedures firstly to obtain user needs and requirements specifications and later to validate the system concept (González et al. 2009). The present usability and acceptance evaluation of the functional prototype was the final iteration of the user-centred processes of the project.

Generally, participants answered positively the questions about accepting the use of the CONFIDENCE system. Concerning *intention to use*, 22 of 24 (91%) participants showed that their most frequent motive to use the system was to live longer at home independently. This finding adds supportive data to earlier research tasks of the project. We carried out a users' needs and requirements specification study in the very beginning of the CONFIDENCE project with 23 older people (mean age 75.5, range 65-92, 12 female, and 11 male) (Kalla et al. 2010). Eighty per cent of the participants showed positive attitudes towards the system and would prefer living at home with the support of ICT technology. Though this finding is not a proof of actual impacts of the CONFIDENCE system on older people's fear of falling or quality of life, in our opinion it suggests a proof of concept of one of the main societal impacts proposed by the project, i.e., enabling older people to live longer independently (Kalla et al. 2010). In the *advantages* section of the acceptability questionnaire, the results showed that 23 of 24 (92%) participants rated positively the opportunity to obtain medical help in the event of an emergency as one the main advantages of using the system (Hawley-Hague et al. 2014). Also, agreement with "...saving public care costs" was endorsed by 23 participants. A great proportion of the participants rejected the *disadvantages* stated in the questionnaire (87%). It is rather common that older people refuse to use, e.g., assistive devices, because nobody likes to show their weaknesses, or their dignity may be threatened (Wandke et al. 2012). However, 24 of 24 (100%) participants disagreed with the stigmatization statement in the questionnaire, i.e., "I would be reluctant to use ... because I do not want to feel stigmatized as old and sick." It is also not unimportant to point out that 22 of 24 (92%) participants were in disagreement with the item "I would be reluctant to use ... because I do not feel able to use the smartphone."

In the scientific literature, it has been argued that older adults are reluctant to use ICT innovations because of fear of computers, are difficult to operate or the older users do not feel capable of using them (Ryan et al. 1992; Marquié et al. 2002). The results found in the present study contradict these arguments. A tentative explanation is that the participants felt they were capable of using the prototype because it generally exhibited good usability and its function was designed to be simple, e.g., not demanding navigation through menus/options to select the desired functions on the graphical user interface of the smartphone.

The correlation analysis aimed at uncovering quantitatively which personal factors could be associated with the attitudes favouring the use of the prototype. Thus, the correlations of interest are those involving the acceptance variables intention to use, advantages, disadvantages and other variables. As shown in table 5, significant Spearman rank correlations were observed among the following 6 pairs of variables: intention to use-education, advantages-age, advantages-environment, advantages-intention to use, disadvantages-age, disadvantages-FES-I. Advantages of using the system correlated positively with age showing that older users also ranked the advantages higher. Disadvantages were more disagreeable for older ages. Intention to use was negatively associated with education. This shows that higher ranks in intention to use obtained lower ranks in education. Examining table 1, these results can be explained by the greater number of participants who had completed primary education compared with tertiary education. Higher ranks in the FES-I scale obtained lower ranks in disadvantages indicating disagreement with these. It appears that the older and more concerned about falls the person is the less important are the disadvantages. Contrary to Wilkowska and Ziefle (2009), MPE was not associated with any of the acceptance categories in this study. The advantages of using the system was positively correlated with the environment domain of the WHOQOL-BREF instrument. It could suggest that having a sufficiently supportive environment (e.g., financial resources, freedom and safety, access to health services, good physical environment) is positively associated with the perceived benefits of this system.

Limitations of this research are as follows: Participant recruitment was not done by randomization so they formed a convenience sample. Future studies should consider this methodological aspect. Results obtained in the usability and acceptability questionnaires should be understood as indicative because the items were elaborated specifically for the CONFIDENCE system. The standardized procedure of the research was pilot-tested (3 older volunteers) before the study began, albeit the validity and reliability of the questionnaires have not been tested. In the second study the factors function selection (alarm, dismiss) and handedness (dominant, non-dominat) yielded significant F ratios while interface version did not. Function selection was not significant in the first study. These effects can be attributed to the practice effect. The order of the tasks: alarm-dominant, alarm-non-dominant, dismiss-dominant, dismiss-non-dominant, were not balanced. The practice effect in the second study was somewhat expectable because the tasks were repeated (1st and 2nd interface versions) while in the first study the amount of practice was half of this. Knowingly, the order of the tasks was kept constant in order to reduce the complexity of the procedure for the participants. Their participation time, which was approximately 2.5 h, would have been extended perhaps unnecessarily. Future research, budgetary and time available permitting, should provide for these methodological controls. The usability results found in this study may not extrapolate to the use of the system in an everyday context. For instance, a smartphone interface with present day specifications would likely run other applications, such as messaging, Internet navigation, and social media apps concurrently to the CONFIDENCE system. Thus, direct access to the alarm function, as implemented in the prototype, might not be readily available unless explicitly designed with this goal in mind.

The strengths of this study in contrast to previous research are that we analysed the usability and technology acceptance of a system aimed at detecting falls by means of 3D localisation of RF signals and interpretation of bodily posture in real time with a fully functional prototype. To our knowledge, this is the first time that research of this kind has been done. Furthermore, the associations between technology acceptance, fall-related self-efficacy and quality of life contribute to an under-researched area of knowledge. Objective measures of user-system interaction performance combined with questionnaires were used to evaluate the efficiency, ease of use, and acceptability of the system. This approach is somewhat divergent from common research on TAMs that frequently employs questionnaire-based subjective data. We found that completion of alarm tasks was errorless indicating that it was easy for the participants to operate a novel system with an unfamiliar interface, i.e., a touch screen was not widely spread at the time of data collection. The CONFIDENCE project employed a user-centred methodology. Older people provided input at the requirements specification stage, and evaluated the proposed system model at the conceptual stage (González et al. 2009). In the present research, the usability and acceptability of the functional prototype of CONFIDENCE were investigated. This study adds confirmatory support to the positive attitudes reported in earlier stages of the project. The performance of the older Finnish participants with the prototype and their responses to the usability questionnaires suggest that the system was usable.

Ethical concerns, such as the processing of personal data, freedom, security, privacy, integrity, and dignity arise when ICT systems and services collect, analyse, and communicate personal data (González-Vega et al. 2011). Active and independent ageing of older people can be effectively supported by current technologies such as smart homes or ambient intelligence (Van Hoof et al. 2007). These systems can be based on simple devices or on complex infrastructures such as Internet of Things (IoT) (International Telecommunication Union 2012). It can be argued that the more complex the system is, the more likely it is that ethical challenges appear. The complexity of the system may originate from the technology itself and from the range of humans involved in the support process, e.g., older people as end-users, service providers, and formal and informal caregivers (González-Vega et al. 2011). Thus, special attention is needed to ensure that the system and each of its components conform to norms and ethical principles by implementing the required technical, e.g., authentication, data encryption, and person-based mechanisms, e.g., understandable information about the system (European Parliament Council 1995, 2002; Wasieleski & Gal-Or 2008; Staudemeyer et al. 2017). The acceptability of ICTs for active and independent ageing may be improved when the systems adhere to ethical principles and regulations. As CONFIDENCE was developed within an integral ethical framework from its inception, the acceptability results obtained in this study could in part be attributable to that fact (González-Vega et al. 2011).

8 CONCLUSIONS

ICT innovations addressing falls and fear of falling among older adults could greatly contribute to support their independence, functional ability, and participation in society. CONFIDENCE could support active and independent ageing by means of two possible mechanisms. Firstly, by quickly seeking emergency assistance in case of a fall event, even if the person is unable to initiate the alarm process. This could reduce the fear to be left unattended of the older person if a fall or other discernible accident occurs. The second mechanism involves the learning capability of the system or AI. Behavioural changes deviating from normal individual patterns could be detected by means of this AI the system incorporates. The findings could be notified to the user or care professional when these deviant patterns can be indicative of functional decline or health problems. With this information at hand, preventive or remedial actions could be initiated before more critical conditions could develop.

The results of this study indicate that performance time in the alarm tasks was similar when performed with the dominant and non-dominant hands. Task-goal achievement was errorless. Completion times on two versions of the user interface were not significantly different. Good usability of the system was reported in usability questionnaires. The results obtained on the acceptability questionnaire also indicate that the acceptability of the prototype was high. Technology acceptance in this study was significantly associated with age, education, FES-I, and the environment domain of the WHOQOL-BREF instrument.

Future research endeavours on ICT systems targeting fear of falling and fall prevention in community dwelling older people should involve prospective studies carried out in real-life conditions. The usability and acceptability of these systems and whether they influence fear of falling and quality of life of faller vs. non-faller older adults warrant further research.

Acknowledgments: This research received funding from the European Community's Framework Programme FP7/2007-2013 under grant agreement nº 214986. I am grateful to the Finnish participants and the members of the CONFIDENCE consortium.

9 REFERENCES

Brooke, J. 1996. SUS: a quick and dirty usability scale. In P. W. Jordan, B. Thomas, B. A. Weerdmeester & I. L. McClelland (Eds.) Usability evaluation in industry. London: Taylor & Francis, 189–194.

Burns, E. R., Stevens, J. A. & Lee, R. 2016. The direct costs of fatal and non-fatal falls among older adults — United States. Journal of Safety Research 58, 99–103. doi: https://doi.org/10.1016/j.jsr.2016.05.001.

Business Wire 2011. Lifecomm to preview next generation mobile personal emergency response system at CES. Retrieved 17.01.2017. http://www.businesswire.com/news/home/20110105006517/en/Lifecomm-Preview-Generation-Mobile-Personal-Emergency-Response.

Calero Valdez, A., Ziefle, M., Horstmann, A., Herding, D. & Schroeder, U. 2009. Effects of aging and domain knowledge on usability in small screen devices for diabetes patients. In A. Holzinger & K. Miesenberger (Eds.) USAB 2009, LNCS 5889. Berlin Heidelberg: Springer-Verlag, 366–386.

Cumming, R. G., Salkeld, G., Thomas, M. & Szonyi, G. 2000. Prospective study of the impact of fear of falling on activities of daily living, SF- 36 scores, and nursing home admission. Journal of Gerontology: Medical Sciences 55A (5), M299–M305. doi: https://doi.org/10.1093/gerona/55.5.M299.

Czaja, S. J. & Lee, C. C. 2007. The impact of aging on access to technology. Universal Access in the Information Society 5 (4), 341–349. doi: 10.1007/s10209-006-0060-x.

Davis, E. D. 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly 13 (3), 319–340.

Davis, J. C., Robertson, M. C., Ashe, M. C., Liu-Ambrose, T., Khan, K. M. & Marra, C. A. 2010. International comparison of cost of falls in older adults living in the community: a systematic review. Osteoporosis International, 21 (8), 1295–1306. doi: 10.1007/s00198-009-1162-0.

Delbaere, K., Crombez, G., Vanderstraeten, G., Willems, T. & Cambier, D. 2004. Fear-related avoidance of activities, falls and physical frailty. A prospective community-based cohort study. Age and Ageing 33 (4), 368–73. doi: 10.1093/ageing/afh106.

Deshpande, N., Metter, E. J., Lauretani, F., Bandinelli, S., Guralnik, J. & Ferrucci, L. 2008. Activity restriction induced by fear of falling and objective and subjective measures of physical function: A prospective cohort study. Journal of the American Geriatrics Society 56 (4), 615–620. doi: 10.1111/j.1532-5415.2007.01639.x.

European Parliament Council 1995. On the Protection of Individuals With Regard to the Processing of Personal Data and the Free Movement of Such Data. (Directive 95/46/EC). Official Journal of the European Communities L281, 31–50. Retrieved 17.10.2017. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31995L0046:EN:HTML.

European Parliament Council 2002. On Privacy and Electronic Communications. (Directive 2002/58/EC). Official Journal of the European Communities L201, 37–47. Retrieved 17.10.2017. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:201:0037:0047:EN:PDF.

Everon Oy 2016. VEGA GPS watch. Retrieved 17.09.2016. https://everon.fi/ratkaisu/itsenainen-asuminen/.

Fishbein, M. & Ajzen, I. 1975. Belief, attitude, intention, and behaviour: An introduction to theory and research. Reading, MA: Addison-Wesley.

Fisk, A. D. & Rogers, W. A. 2002. Psychology and aging: Enhancing the lives of an aging population. Current Directions in Psychological Science 11 (3), 107–110. doi: 10.1111/1467-8721.00179.

Fleming, J., Brayne, C. & the Cambridge City over-75s Cohort (CC75C) study collaboration 2008. Inability to get up after falling, subsequent time on floor, and summoning help: prospective cohort study in people over 90. British Medical Journal 337:a2227, 1279–1282. doi: 10.1136/bmj.a2227.

Franzoni, S., Rozzini, R., Boffelli, S., Frisoni, G. B. & Trabucchi, M. 1994. Fear of falling in nursing home patients. Gerontology 40 (1), 38–44.

Friedman S. M., Munoz, B., West, S. K., Rubin, G. S. & Fried, L. P. 2002. Falls and fear of falling: which comes first? A longitudinal model suggests strategies for primary and secondary prevention. Journal of the American Geriatrics Society 50 (8), 1329–1335.

Gaul, S. & Ziefle, M. 2009. Smart home technologies: Insights into generation-specific acceptance motives. In A. Holzinger & K. Miesenberger (Eds.) USAB 2009, LNCS 5889. Berlin Heidelberg: Springer-Verlag, 312–332.

González, N., Kämäräinen, A., Kalla, O. & Velez, I. 2009. The CONFIDENCE system: Older people´s input at the requirements and conceptual model evaluation stages. In G.

Steendam, R. Chadwick, P. McCarthy, J. Lodge, S. Rodotà & G. Bonacchi (Eds.) Ambient intelligence and human security: Embedding science in society. Brussels, Belgium: IFB Press, 71–73.

González-Vega, N., Kämäräinen, A. & Kalla, O. 2011. Ethically inspired care information technology can enable freedom of choice of older users. Sociology Study 1 (6), 452–459.

Gschwind, Y. J., Eichberg, S., Ejupi, A., Rosario de, H., Kroll, M., Marston, H. R., Drobics, M., Annegarn, J., Wieching, R., Lord, S., Aal, K., Vaziri, D., Woodbury, A., Fink, D. & Delbaere, K. 2015. ICT-based system to predict and prevent falls (iStoppFalls): Results from an international multicenter randomized controlled trial. European Review of Aging and Physical Activity 12:10. doi: 10.1186/s11556-015-0155-6.

Hamill, M., Young, V., Boger, J. & Mihailidis, A. 2009. Development of an automated speech recognition interface for personal emergency response systems. Journal of NeuroEngineering and Rehabilitation 6 (1), 26. doi: 10.1186/1743-0003-6-26.

Hartholt, K. A., van Beeck, Ed F., Polinder, S.; van der Velde, N., van Lieshout, E. M. M., Panneman, M. J. M., van der Cammen, T. J. M. & Patka, P. 2011. Societal Consequences of Falls in the Older Population: Injuries, Healthcare Costs, and Long-Term Reduced Quality of Life. Journal of Trauma-Injury Infection & Critical Care 71 (3), 748-753. doi: 10.1097/TA.0b013e3181f6f5e5.

Hawley-Hague, H., Boulton, E., Hall, A., Pfeiffer, K. & Todd, C. 2014. Older adults' perceptions of technologies aimed at falls prevention, detection or monitoring: a systematic review. International journal of medical informatics, 83(6), 416-426. doi: http://dx.doi.org/10.1016/j.ijmedinf.2014.03.002.

IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.

International Telecommunication Union 2012. Recommendation ITU-T Y.2060. Retrieved 8.04.2014. http://www.itu.int/rec/T-REC-Y.2060-201206-I.

Kalla, O., González, N. & Kämäräinen, A. 2010. The CONFIDENCE system and the contributions of older people during its development. AALIANCE conference Ambient Assisted Living: Technology and Innovation for Ageing Well, Malaga, Spain, 1–7.

Kannus, P., Parkkari, J., Koskinen, S., Niemi, S., Palvanen, M., Järvinen, M. & Vuori, I. 1999. Fall-induced injuries and deaths among older adults. JAMA 281 (20), 1895-1899. doi:10.1001/jama.281.20.1895.

Lamb, S. E., Jørstad-Stein, E. C., Hauer, K., Becker, C. & on behalf of the ProFaNE Group 2005. Development of a common outcome data set for fall injury prevention trials: The prevention of falls network Europe consensus. Journal of the American Geriatrics Society 53 (9), 1618–22. doi: 10.1111/j.1532-5415.2005.53455.x.

Lee, J. S., Hurley, M. J., Carew, D., Fisher, R., Kiss, A. & Drummond, N. 2007. A randomized clinical trial to assess the impact on an emergency response system on anxiety and health care use among older emergency patients after a fall. Academic Emergency Medicine 14 (4), 301–308. doi: 10.1197/j.aem.2006.11.017.

Louie, W. Y. G., McColl, D. & Nejat, G. 2014. Acceptance and attitudes toward a human-like socially assistive robot by older adults. Assistive Technology 26 (3), 140-150. DOI: 10.1080/10400435.2013.869703.

Luštrek, M., Gjoreski, H., González-Vega, N., Kozina, S., Cvetković, B., Mirchevska, V. & Gams, M. 2015. Fall detection using location sensors and accelerometers. IEEE Pervasive Computing 14 (4), 72-79. doi: 10.1109/MPRV.2015.84.

Luštrek, M., Kaluža, B., Cvetković, B., Dovgan, E., Gjoreski, H., Mirchevska, V. & Gams, M. 2012. Confidence: ubiquitous care system to support independent living. In Proceedings of the 20th European Conference on Artificial Intelligence. IOS Press, 1013-1014. doi: 10.3233/978-1-61499-098-7-1013.

Manssila, S. & Koistinen, P. 2006. Kotona asuvien ikääntyneiden hyvinvointiindikaattorit. Sentek-hankkeen tutkimusraportti kp 1950, projekti 1618, Oulun kaupunki, sosiaali-ja terveystoimi/vanhustyön hallinto.

Marquié, J.C.,Jourdan-Boddaert, L. & Huet,N. 2002. Do older adults underestimate their actual computer knowledge? Behaviour &Information Technology 21 (4), 273–280. doi: 10.1080/014492902100002099 8.

Marston, H. R., Woodbury, A., Gschwind, Y. J., Kroll, M., Fink, D., Eichberg, S., Kreiner, K., Ejupi, A., Annegarn, J., Rosario De, H., Wienholtz, A., Wieching, R. & Delbaere, K. 2015. The design of a purpose-built exergame for fall prediction and prevention for older people. European Review of Aging and Physical Activity 12:13. doi: 10.1186/s11556-015-0157-4.

McCreadie, C. & Tinker, A. 2005. The acceptability of assistive technology to older people. Ageing & Society 25 (01), 91–110. doi: 10.1017/S0144686X0400248X.

Miesenberger, K., Bühler, C. & Penaz, P. (Eds.) 2016. Proceedings from 15th International Conference ICCHP 2016: Computers Helping People with Special Needs (Part 1). Switzerland: Springer International Publishing. doi: 10.1007/978-3-319-41264-1.

Mihailidis, A., Cockburn, A., Longley, C. & Boger, J. 2008. The acceptability of home monitoring technology among community-dwelling older adults and baby boomers. Assistive Technology 20 (1), 1–12. doi: http://dx.doi.org/10.1080/10400435.2008.10131927.

Mirčevska, V., Luštrek, M., Vélez, I., González-Vega, N. & Gams, M. 2009. Classifying posture based on location of radio tags. In P. Cech, V. Bures & L. Nerudová (Eds.) Ambient Intelligence Perspectives II - Selected Papers from the Second International Ambient Intelligence Forum 2009, Hradec Králové, Czech Republic, 16-17 September. IOS Press, 85–92. doi: 10.3233/978-1-60750-481-8-85.

Mitseva, A., Peterson, C. B., Karamberi, C., Oikonomou, L. Ch., Ballis, A. V., Giannakakos, Ch. & Dafoulas, G. E. 2012. Gerontechnology: Providing a helping hand when caring for cognitively impaired older adults—Intermediate results from a controlled study on the satisfaction and acceptance of informal caregivers. Current Gerontology and Geriatrics Research 2012, 19 pp. doi:10.1155/2012/401705.

National Institute for Health and Welfare (THL), Finland 2017. Older people. Retrieved 2.03.2017. https://www.thl.fi/fi/web/injury-prevention/accidental-injuries/older-people

Nawaz, A., Helbostad, J. L., Skjæret, N., Vereijken, B., Bourke, A., Dahl, Y. & Mellone, S. 2014. Designing smart home technology for fall prevention in older people. In C. Stephanidis (Ed.) International Conference on Human-Computer Interaction: HCII 2014 Posters, Part II, CCIS 435. Springer International Publishing, 485–490.

Pajala, S., Era, P., Koskenvuo, M., Kaprio, J., Törmäkangas, T. & Rantanen, T. 2008. Force platform balance measures as predictors of indoor and outdoor falls in community-dwelling women aged 63–76 years. The Journals of Gerontology: Series A 63 (2), 171–178. doi: https://doi.org/10.1093/gerona/63.2.171.

Pogorelc, B., Bosnić, Z. & Gams, M. 2012. Automatic recognition of gait-related health problems in the elderly using machine learning. Multimedia Tools and Applications 58 (2), 333-354. doi: 10.1007/s11042-011-0786-1.

Quemada, C., Val, I., Pietrzyk, M., Grün, T., González-Vega, N. & Vélez, I. 2009. A Smart Care System for Elderly People to Support Independent Living: CONFIDENCE. Smart Systems Integration, 11-19.

Rogers, W. A. & Fisk, A. D. 2003. Technology design, usability, and aging: Human factors techniques and considerations. In N. Charness & K. W. Schaie (Eds.) Impact of technology on successful aging. New York, NY: Springer, 1–14.

Ryan, A. A., McCann, S. & McKenna, H. 2009. Impact of community care in enabling older people with complex needs to remain at home. International Journal of Older People Nursing 4 (1), 22–32. doi: 10.1111/j.1748-3743.2008.00152.x.

Ryan, E. B., Szechtman, B. & Bodkin, J. 1992. Attitudes toward younger and older adults learning to use computers. Journal of Gerontology 47 (2), P96–P101. doi: https://doi.org/10.1093/geronj/47.2.P96.

Sihvonen, S., Sipilä, S., Taskinen, S. & Era, P. 2004. Fall incidence in frail older women after individualized visual feedback-based balance training. Gerontology 50 (6), 411–416. doi: 10.1159/000080180.

Skevington, S. M., Lotfy, M. & O'Connell, K. A. 2004. The World Health Organization's WHOQOL-BREF quality of life assessment: psychometric properties and results of the international field trial. A report from the WHOQOL group. Quality of life Research 13 (2), 299–310. doi: 10.1023/B:QURE.0000018486.91360.00.

Staudemeyer, R. C., Pöhls, H. C. & Watson, B. W. 2017. Security and privacy for the internet of things communication in the SmartCity. In V. Angelakis, E. Tragos, H. C. Pöhls, A. Kapovits & A. Bassi (Eds.) Designing, Developing, and Facilitating Smart Cities. Springer International Publishing, 109–137. doi: 10.1007/978-3-319-44924-1_7.

Tacken, M., Marcellini, F., Mollenkopf, H., Ruoppila, I. & Széman, Z. 2005. Use and acceptance of new technology by older people. Findings of the International MOBILATE survey: ‘Enhancing mobility in later life’. Gerontechnology 3 (3), 126–137. doi: http://dx.doi.org/10.4017/gt.2005.03.03.002.00.

Tinetti, M. E. & Powell, L. 1993. Fear of falling and low self-efficacy: A case of dependence in elderly persons. Journal of Gerontology 48 (Spec Issue), 35–38. doi: http://dx.doi.org/10.1093/geronj/48.Special_Issue.35.

Tinetti, M. E. & Williams, C. S. 1997. Falls, injuries due to falls, and the risk of admission to a nursing home. The New England Journal of Medicine 337 (18), 1279–84. doi: 10.1056/NEJM199710303371806.

Tinetti, M. E., Liu, W. L. & Claus, E. B. 1993. Predictors and prognosis of inability to get up after falls among elderly persons. JAMA 269 (1), 65–70. doi: 10.1001/jama.1993.03500010075035.

Tinetti, M. E., Richman, D. & Powell, L. 1990. Falls efficacy as a measure of fear of falling. Journal of Gerontology, 45 (6), 239–243. doi: https://doi.org/10.1093/geronj/45.6.P239.

Turner, M., Kitchenham, B., Brereton, P., Charters, S. & Budgen, D. 2010. Does the technology acceptance model predict actual use? A systematic literature review. Information and Software Technology 52 (5), 463–479. doi: https://doi.org/10.1016/j.infsof.2009.11.005.

Ubisense 2013. Ubisense Series 7000 Compact Tag. Retrieved 17.04.2017. www.ubisense.net/en/resources.

Urho Kekkosen Kuntoinstituuttisäätiö 2011. Falls efficacy scale international FES-I-FIN. Retrieved 24.09.2011. http://www.ukkinstituutti.fi/ammattilaisille/testaaminen/kaatumispelkokysely.

Van Hoof, J., Kort, H. S. M., Markopoulos, P. & Soede, M. 2007. Ambient Intelligence, Ethics and Privacy. Gerontechnology 6 (3), 155–163.

Van Vianen, E., Thomas, B. & Nieuwkasteele, M. 1996. A combined effort in the standardization of user interface testing. In P. W. Jordan, B. Thomas, B. A. Weerdmeester & I. L. McClelland (Eds.) Usability Evaluation in Industry. London: Taylor & Francis, 7–17.

Vaziri, D. D., Aal, K., Ogonowski, C., Von Rekowski, T., Kroll, M., Marston, H. R., Poveda, R., Gschwind, Y. J., Delbaere, K., Wieching, R. & Wulf, V. 2016. Exploring user experience and technology acceptance for a fall prevention system: Results from a randomized clinical trial and a living lab. European Review of Aging and Physical Activity 13 (6), 9pp. doi: http://dx.doi.org/10.1186/s11556-016-0165-z.

Venkatesh, V., Morris, M. G., Davis, G. B. & Davis, F. D. 2003. User acceptance of information technology: Toward a unified view. MIS Quarterly 27 (3), 425–478. Stable URL: http://www.jstor.org/stable/30036540.

Wandke, H., Sengpiel, M. & Sönksen, M. 2012. Myths about older people's use of information and communication technology. Gerontology 58 (6), 564–70. doi: http://dx.doi.org/10.1159/000339104.

Wasieleski, D. M. & Gal-Or, M. 2008. An enquiry into the ethical efficacy of the use of radio frequency identification technology. Ethics and Information Technology 10 (1), 27–40. doi: https://doi.org/10.1007/s10676-008-9152-z.

Wilkowska, W. & Ziefle, M. 2009. Which factors form older adults’ acceptance of mobile information and communication technologies? In A. Holzinger & K. Miesenberger (Eds.) USAB 2009, LNCS 5889. Berlin Heidelberg: Springer-Verlag, 81–109.

World Health Organization 1993. WHOQoL Study Protocol. WHO (MNH7PSF/93.9). Geneva, Switzerland: World Health Organization.

World Health Organization 1996. WHOQOL-BREF Introduction, administration, scoring and generic version of the assessment. Field trial version December 1996. Geneva, Switzerland: World Health Organization. Retrieved 5.06.2010. http://www.who.int/iris/handle/10665/63529

World Health Organization 1998. Programme on mental health: WHOQOL user manual. Geneva, Switzerland: World Health Organization. Retrieved 1.06.2010. http://cdrwww.who.int/entity/mental_health/evidence/who_qol_user_manual_98.pdf

World Health Organization 2007. WHO Global report on falls prevention in older age. Geneva, Switzerland. World Health Organization.