**Interacting with Computers Advance Access published October 22, 2015**


doi:10.1093/iwc/iwv036

# Stakeholder Attitudes Toward and Values Embedded in a Sensor-Enhanced Personal Emergency Response System

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**This paper provides an empirical understanding of concerns that the application of a sensor-enhanced medical alert system, or personal emergency response (PER) system, raises from the perspective of care receivers (users) and care providers. Data were gathered in the context of a field trial of a PER system supporting both user-initiated alerts and automatic fall detection alerts. The system was tested at two residential care facilities for 3 weeks. Drawing on data primarily from post-trial group and pair interviews, we describe and compare care receivers' and providers' views on the following emerging concerns: (i) form factor and ergonomics, (ii) system feedback and user control and (iii) sensor precision and trust. Based on feedback from stakeholder groups, we discuss potential value biases, or discriminating factors, embedded in the evaluated PER system. We also discuss the implications of our findings for a value-driven design agenda for future PER systems.**

RESEARCH HIGHLIGHTS

- Assistive technology comes with embedded values that have implications for the care situation, independently of the user's or the designer's, original intent.
- The findings from the study indicate that users (care receivers) and professional care providers have different concerns related to the use of sensor-enhanced PER systems and different perspectives on how these types of systems can add value.
- The different perspectives held by users and their professional care providers are not necessarily incompatible. There may be room for design to negotiate diverse perspectives and value priorities.
- Designing for users' safety is not only about designing for immediate emergency situations (e.g. accidental falls). It is also about designing systems and devices that seamlessly integrate into mundane physical and social activities of users' everyday lives.

*Keywords: assistive technologies; value bias; values in design; empirical studies in HCI; personal emergency response (PER) systems; ubiquitous and mobile devices*



*Received 13 April 2015; revised 11 August 2015; accepted 27 September 2015*

## 1. INTRODUCTION

Assistive technology is increasingly considered to play a central role in promoting human values such as safety, security and autonomy for people with special care needs (e.g. older adults and persons with physical or cognitive disabilities). This trend can in many ways be seen as a result of recent years' advances in mobile and sensor technology, which again have opened up for new assistive technology applications such as remote monitoring and automatic alert systems. However, technology designed to serve assistive purposes also risks having an obtrusive effect on the lives of users by conflicting with their practices, desires and values. For example, assistive technologies have been linked to stigmatization and labeling of users, loss of privacy and reduced autonomy (McLean, 2011). Some users may be at risk from value biases or orientations that may be embedded in assistive technology (Astell, 2006). In the context of care, we find that design and application of assistive technology can raise difficult issues related to both ethics and acceptance among care receivers and care providers (Lindsay *et al.*, 2012; Mulder *et al.*, 2009). In many cases, our understanding of how assistive technology fit with stakeholders' perceived needs, desires and priorities is still limited.

Medical alert systems, or personal emergency response (PER) systems, form one type of assistive technology envisioned to be re-invented through modern mobile and sensor technology. Traditionally, PER systems are used to help people with special care needs signal their need for assistance or medical attention. This is typically achieved through a wearable push-button alert device, which can place the user in direct contact with a care provider via an in-house speaker-phone. One vision for next-generation PER systems is that sensors and context-aware technology can support automatic detection and notification of health critical incidents, such as falls, both indoors and outdoors. Existing research works on sensor technology for care and assistive purposes have explored how this type of functionality can potentially be achieved by drawing on contextual information about the user and his or her situation, such as body movements, posture and physical location (Aud *et al.*, 2010; Garrido *et al.*, 2013; Jansen and Deklerck, 2006; Lopes *et al.*, 2013; Ozcan *et al.*, 2013; Ugolotti *et al.*, 2013). In this way, a PER system can potentially also serve in situations where the care receiver is unable to push an alert button. The envisioned benefits of imbuing PER systems with sensor technology typically include increased safety for seniors, more efficient care management and enhanced possibilities for timely interventions from care providers (Dumitrache and Pasca, 2013; Leone *et al.*, 2011).

While the application of sensor technology in PER systems comes with promises of added benefits for both care receivers and care providers, there is a risk that the evolution toward the next-generation PER systems is driven by wrong assumptions or insufficient knowledge about the context of use, the users and their values. To help improve the empirical basis for future design, this paper aims to explore how the premises that a PER system puts on use, or what can be understood as the system's built-in value biases, affect the attitudes of relevant stakeholders toward the technology. Specifically, we seek to answer the question: *What areas of concern does the use of a PER system with automatic fall detection alerts raise among care receivers, and how do their concerns compare with those held by their professional care providers?*

We attempt to answer this question by investigating how different design features influence the perceived value that the two stakeholder groups recognize in a PER system. Our exploration is based on a field trial in which a system combining traditional push-button alert devices and automatic fall detection devices (sensor belts) was tried out at two Norwegian residential care facilities. Data on attitudes toward the PER system were collected through post-trial interviews. We use the attitudes that the two stakeholder groups held toward the PER system as a basis for discussing differences in concerns between the stakeholder groups, value biases that may be considered embedded in the assessed technology, and design implications for next-generation PER systems.

Through this paper we hope to contribute to novel and reflective thinking about a value-driven design agenda for future PER systems.

## 2. BACKGROUND

### 2.1. Technology and value bias

The social and ethical implications of technology have attracted considerable attention within human–computer interaction (HCI) over the last two decades. The embedded values approach (Flanagan *et al.*, 2008; Nissenbaum, 1998) and the value sensitive design (VSD) approach (Friedman and Grudin, 1998; Friedman and Kahn, 2003; Friedman *et al.*, 2002), which emerged during the 1990s, were invented in response to a growing need among HCI researchers and practitioners for dealing with human values in design and application of technology in a systematic and theoretically grounded manner. These approaches have matured over the last two decades as a result of critiques and suggestions for evolution and further development (e.g. Borning and Muller, 2012; Le Dantec *et al.*, 2009; Yetim, 2011).

Theoretical principles that typically underlie approaches in computer ethics, such as VSD, can be traced back to 20th century media theorists, such as Ellul (1990) and Postman (1993). According to these principles, technology is inscribed with *biases* during design. In this context, biases typically refer to value orientations, approximations, assumptions and prejudices that reflect those held by the designer, the society or both (Friedman and Nissenbaum, 1996). Biases inscribed into technology during design can come into effect in various ways, independently of the user's (or the designer's) original intent (Ellul, 1990). In this sense, technology is regarded as an autonomous force that acts on its users. The effects of this force can be subtle, unforeseen and difficult to recognize a priori (Friedman *et al.*, 2006).

In HCI research literature related to computer ethics, *bias* in information and communication technology has been used to denote computer systems that 'systematically and unfairly discriminate' (Friedman and Nissenbaum, 1996). The term 'unfair discrimination', as used by Friedman and Nissenbaum

(1996), refers to the denial of an opportunity or good, or the assignment of an undesirable outcome to an individual or group of individuals, on grounds that are unreasonable or inappropriate.

Applied to PER systems, then, the non-neutral perspective on technology, which is implicit in the embedded values approach and value-sensitive design framework, holds that the technology does not simply play a passive role in provision of care and assistance. Rather, assistive technology can be regarded to come inscribed with a 'care ideology' that has effect of its own. This paper explores the effects that are latent in PER systems (and which sometimes play out), how care receivers and professional care providers experience these effects, and how the stakeholders' attitudes toward the system are affected.

### 2.2. Toward a value-driven design philosophy for assistive technology

The question of how information and communication technology can support people with special care needs in coming years and contribute to sustainable welfare societies has garnered interest both within HCI (e.g. Lindsay *et al.*, 2012; Shinohara and Wobbrock, 2011) and more broadly (e.g. Rocha *et al.*, 2013; Smeaton *et al.*, 2012). Drawing on recent HCI literature (see below), the value implications of technological interventions in care have emerged as a central topic. The growing research interest in topics related to assistive technologies and human values mirrors in many ways the shift that has taken place over the last two to three decades in the culture of care. This shift has implied moving away from a conservative medical model of care, in which the primary focus has been on management of disease and symptoms, toward a more holistic *person-centered* model, which also takes the individual care receiver's experiences, needs and values into account (Epp, 2003; Jones, 2011; Kitwood, 1995). Yet, development of assistive technology is still largely driven by a pure medical model (Blythe *et al.*, 2005).

## 3. RELATED WORK ON ASSISTIVE TECHNOLOGY

There are a number of studies related to design and application of assistive technology that have contributed to providing a better understanding of value-related issues that design and application of assistive technology can raise. The short review presented below represents a careful selection of literature we consider particularly relevant in this context.

Mankoff *et al.* (2010) discussed how they used the field of disability studies and *social models* of disability to identify new challenges of ethical import to the design of assistive technology. In particular, the article points to the problem that design of assistive technology tends to only focus on the person's disability and how it can be 'fixed' rather than designing for the person as a whole, and also taking disabling social barriers into consideration. Similar issues are also discussed in a paper by Ripat and Booth (2005). Mankoff *et al.* (2010) also describe how they found disability studies to inspire new thinking about how assistive technology is designed and the role it plays in users' everyday lives.

We also find examples of studies that have focused on design and application of specific assistive technologies and relevant value-related issues. For example, in the context of designing safe walking technology for people with dementia Lindsay *et al.* (2012) found that designers and users can have radically different views on design issues. Lindsay *et al*. further suggest that to overcome such differences (and thus increase the likelihood of user acceptance of a given technology) requires empathic relationships between the users and designers. The authors further argue that by forming such quality relationships, designers will be more likely to 'see beyond' the disease-related symptoms of a person with dementia, and be more attuned toward the views and values held by that person.

In another study also focusing on safe walking technology for people with dementia, Holbø *et al.* (2013) found that users tended to have strong empathy for their family care providers, and that they were highly concerned about causing unnecessary stress or anxiety to them. As such, the users preferred technology that not only alerted their care providers in case the user lost track of his or her location, but which also offered a means for the user to manage the situation himself.

Dahl and Holbø (2012) conducted a study that is similar to this study in terms of topic and applied methodology. The study explored value biases of positioning technology applied in dementia care, and identified several design aspects that could potentially have undesirable and even devaluing effects on the person with dementia. This included lack of interactive possibilities for the person with dementia, lack of privacy mechanisms and design features that might contribute to stigmatizing the user.

Shinohara and Wobbrock (2011) studied how assistive technology use is affected by social contexts and interactions. The study revealed that acceptability for assistive technology goes beyond functionality and usability aspects, and argue that design to a greater extent should prioritize the social context in which the technologies are used to avoid labeling or stigmatization of users. Similar arguments can also be found in an article by Blythe *et al.* (2005) who suggest that a fundamental design challenge for HCI is to make assistive technologies that are *socially dependable*.

The studies described above do by no means give a complete picture of value issues that arise in design and application of assistive technology. Rather, we consider a set of research papers to exemplify some of the wide variety of relevant issues.

## 4. RESEARCH DESIGN

The objective of this study is to explore care receivers' and care providers' attitudes toward a sensor-enhanced PER system and identify central areas of concern. Through the study we aim to inform a value-driven design agenda for future PER systems.

We approached the topic through an empirical investigation that involved two main steps. First, we carried out a field trial of a sensor-enhanced alert system applied at two different residential care facilities for a period of three weeks. One of the main purposes of the field trial was to help promote critical reflections among the two stakeholder groups involved, with regard to the PER system being evaluated.

Next, we conducted post-field trial group interviews with users and pair interviews with professional care providers to investigate attitudes toward the system, and the extent to which the system met their expectations, perceived needs and desires.

### 4.1. Research sites

The field trial was conducted at two Norwegian residential care facilities. Both centers facilitated a nursing home for people requiring full-time care and residential care homes for people who are capable of living more independently, and who only require home care assistance. Both centers offered welfare facilities such as cafés, hairdresser, pedicure, etc.

The majority of the care receivers at the two centers were senior citizens above 65 years. However, the centers also provided care services for people of younger age with special care needs.

Initial inquiries prior to the field trial revealed that accidental falls were a relatively frequent incident among the care receivers at both centers. As such, the research sites were found suitable for experimenting with automatic fall detection and notification technology.

### 4.2. Description of assessed PER system

The PER system we wanted to assess through the field trial consisted of a traditional push-button alert system used in combination with a system for automatic fall detection and subsequent alert notification. Below, we provide a brief description of the two subsystems and the organization of care services in which they were applied.

#### 4.2.1. *The push-button alert system*

The system consisted of wireless push-button pendants and wristbands (radio transmitters) and stationary two-way speaker-phones (radio receivers). The respective alert devices are shown in Fig. 1a–c.

Users are generally equipped with either a pendant or a wristband alert device. By pressing the alert button, a user can establish telephone contact with a municipal alarm call center. The alarm call center acts as a hub for alert notifications from care receivers distributed across the municipality. Upon receiving an alert, health-care personnel at the call center will attempt to contact the user via the two-way speaker-phone installed in his/her residence to further investigate the situation. Based on the response from the care receiver, the personnel at the call center decide whether the caller requires medical or other type of assistance. If the problem cannot be resolved, or if the care receiver does not respond to the call, the alarm call center contacts the staff at the care center via telephone and informs about the situation. The staff at the local care center then takes over the responsibility of following up the reported incident.

#### 4.2.2. *The automatic fall detection and alert system*

The automatic fall detection and alert system had been developed by a partner within one of the research projects (FARSEEING[1]) the current study was a part of. This part of the studied PER system represents its most innovative aspect, making use of automatic alerts enabled by sensors.

The system was designed as an elastic belt with a plastic snap clip buckle and pocket (with Velcro closure) to hold a smartphone (Samsung Galaxy S III). The smartphone acted as motion/fall sensor. It could be charged without being removed from the belt.

The belt was designed so that the embedded sensor (smartphone) would be placed along the central axis of the body of the person wearing the belt (Fig. 2), thus making the sensor more sensitive to detecting vertical displacement of the center of mass of the body.

Fall and motion sensing was provided by an Android application running on the smartphone. The application was designed to continuously monitor the user's physical motions and detect incidents that could indicate a fall. This was done by comparing data from the sensors embedded in the smartphone (i.e. tri-axial accelerometer, gyroscope and magnetometer) against predefined thresholds. In case a fall incident was inferred, the application would send a Short Message Notification (SMS) to predefined mobile phone numbers.

#### 4.2.3. *Configuration of the automatic fall detection system and integration with care services*

To define appropriate thresholds for the fall detection algorithm prior to the field trial, the sensor was tested in a laboratory against a set of different types of simulated falls. The general protocol for the testing is described in a paper by Bourke *et al.* (2011). Professionals in human movement science carried out the testing.

While the automatic fall detection system had the possibility to play audio feedback to the user when a fall was detected, the care providers were concerned that this could risk confusing and stressing users in their daily activities, particularly those

[1] (http://farseeingresearch.eu).

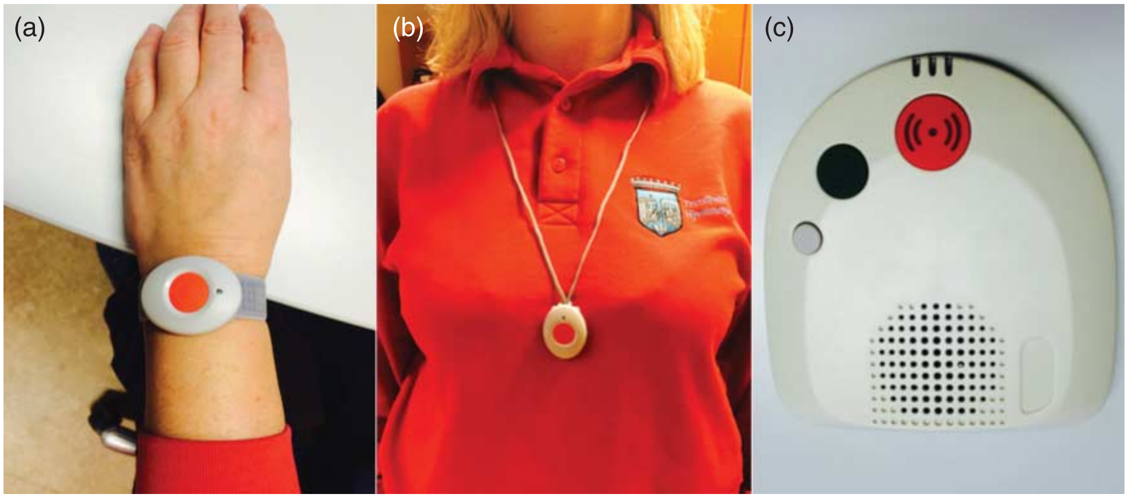


**Figure 1.** (**a**) Wristband alert device; (**b**) pendant alert device and (**c**) speaker-phone with alert button.

**Figure 2.** Fall sensor belt (back and front).

with cognitive impairments. Hence, it was decided to disable audio feedback during the field trial.

The push-button alert system in use at the care facilities was provided and maintained by a contracted supplier. Hence, we did not have the possibility to technically integrate the two systems described above. In collaboration with the staff at care facilities, we decided that SMS notification from the automatic fall detection and alert system should be sent directly to mobile phones shared by the local care teams at the two care facilities.

### 4.3. Ethical considerations

User studies where people with special care needs are stakeholders often raise ethical challenges related to how the group should be involved. Implementing new technology in existing care services can represent a potential risk to care receivers, e.g. due to potential technical malfunction, stress imposed by new routines and practices, and other events that may be difficult to identify a priori. These types of concerns highlight that involvement of certain user groups requires careful ethical consideration.

To ensure ethically responsible research, the following measures were taken:

(i) In order to inform about the motivation behind the study we arranged pre-trial information meetings with the staff and care receivers at the two study sites. This allowed us to demonstrate and explain how the sensor belt worked. Care receivers and care providers were also given the opportunity to try on the sensor belts, and ask questions concerning the study and the technology.
(ii) Health-care personnel at the respective care facilities initially suggested candidates for participation in the study. Decisions about participation were made after close dialog with the care receiver, his or her closest relatives, and professional care providers. Voluntary informed consent was set as a prerequisite for care receivers' participation in the study. Health-care personnel at the two care facilities judged the ability of care receivers to give informed consent.
(iii) Participation in the study required that the person already be familiar with the push-button alert system

implemented at the research site, and that he or she be equipped with a wristband or pendant device. We specifically informed care receivers and care providers that the automatic fall detection and alert system was not intended to replace the existing system, but supplement it.

(iv) Weekly follow-up meetings at the two research sites were established to enable continuous dialog throughout the field trial between the research team and the users of the sensor belts and their care providers. It also helped us establish a more empathic relationship with the stakeholder groups involved. To be able to provide quick support for care providers in issues related to the experiment that would require more immediate attention (e.g. system failure), a research team member acted as a single point of contact.

(v) Formal ethical approval for the study was obtained from the Norwegian Regional Ethics committee (Ref. no 2014/311).

## 4.4. Participants

The user group consisted of 6 male and 14 female care receivers aged 28–103 years (mean age = 82.15) living in residential care homes at the two care facilities. Eight of the users had a previous history of registered falls that had taken place within 12 months prior to the field trial. Individual assessments conducted by physiotherapists prior to the field trial indicated that all the participants had an increased risk of accidental falls.

Four of the users had been diagnosed with dementia. The care personnel we talked to during the preparations of the field trial also suspected several of the other participating users' to also have mild cognitive impairments. However, no formal dementia diagnosis existed for these participants.

## 4.5. Data collection methods and analysis

The study combined various data collection methods including: (i) a logbook per research site that we encouraged care personnel to use for recording relevant events and experiences from day to day use of the PER system, for example, fall incidents, users' responses, technical problems and usability issues); (ii) weekly follow-up meetings with users and care providers and (iii) post-field trial group and pair interviews with representatives from both stakeholder groups.

### *4.5.1. Logbook*

The main purpose of the logbook was to help us form an understanding of relevant events taking place and experiences from the trial that could be further addressed in the interviews. This enabled us to discuss concrete events with the interviewees.

### *4.5.2. Weekly follow-up meetings*

As previously noted, we established weekly follow-up meetings at the two care facilities. This was done to get in close contact with the users, and collect information about their experiences during the field trial. One of the key methodological motivations for the weekly follow-up meetings was to help the research team become more attuned toward their needs and the affective and emotional quality of their use experiences.

### *4.5.3. Interviews*

In order to form a qualitative understanding of relevant stakeholders' attitudes toward and experiences from using the sensor-enhanced PER system, two joint interviews were conducted at each research site—one group interview with a convenience sample of care receivers (four participants per interview) and one pair interview with their daily professional care providers. The participating care receivers had varying degrees of physical movement dysfunction, and some also had mild cognitive disabilities, such as speech and memory problems. A total of three male and five female care receivers participated in the two group interviews. The professional care providers who participated in the pair interviews were all female.

The interviews were conducted during the week after the field trial had been completed.

Our main motivation for conducting group and pair interviews (as opposed to individual interviews) was to promote and allow discussion among the participants concerning their experiences from the field trial. The exchange of ideas, perceptions and experiences among participants are among the key benefits associated with such approaches (Kuhn, 2000). As such, group and pair interviews can add richness to the dialog that is difficult to achieve in individual interviews.

The interviews with care receivers and care providers were done separately in order to (i) reduce the likelihood that one part would withhold experiences, opinions or ideas out of uncertainty of how the other part might respond and (ii) ensure that the care receivers were given a voice in the evaluation, without the risk of being invalidated by their care providers. Each group and pair interview lasted ∼1 h.

### *4.5.4. Analysis*

The interviews were audio recorded and transcribed. The transcriptions from the interviews, along with notes taken during the interviews and events described in the logbooks, were analyzed by the interviewer in search of factors that influenced the participants' attitudes toward the assessed PER system.

To analyze the transcribed text and organize it into meaningful units, we attached descriptive codes to text segments. The coding process consisted of three iterations. First, each theme that emerged in the text was given a primary keyword, such as 'Body placement' and 'Battery charging' and combined with some words from the quote to capture the meaning as interpreted by the analyst. Next, the descriptive codes were reviewed for consistency. This involved checking that the codes were used in the same way for different text segments, and combining codes (using the most descriptive term) where different codes had been used to describe the same theme. Finally, the codes were grouped into thematic categories relevant to our research question and labeled. The resulting categories, or *emerging areas of concern*, are described in the subsequent section.

## 5. EMERGING AREAS OF CONCERN

From the collected data we identified three areas of concern: (i) form factor and ergonomics (of alert and sensor devices), (ii) system feedback and user control and (iii) sensor precision and perceived trust. For each of the areas, we first present aspects of the system that appeared to shape the care receivers' (i.e. the users) attitudes and interaction with the system. Next, we present the care providers' perspectives on the same issues.

### 5.1. Form factor and ergonomics: the users' perspective

Physical and ergonomic aspects of both the push-button alert devices and the sensor belts were discussed extensively in the interviews. These aspects appeared to affect users' interaction with the PER system in multiple ways and to raise concerns among the users related to wearability, aesthetics and self-management.

#### *5.1.1. Wearability*

The physical shape of the alert devices and the extent to which the devices fit into the users' daily activities appeared to strongly affect user practices, such as *how* the devices were carried by the users. Gemperle *et al.* (1998) used the term 'dynamic wearability' to describe the interaction between a human body in motion and a wearable object. As further described below, we found that the dynamic wearability of the alert devices had implications both with respect to the users' accessibility to push-button alert devices and, to some extent, the precision of the sensor belts.

One of the challenges with respect to pendant alert devices and their dynamic wearability, as explained by the users, was that the neck cord to which the device was attached could risk becoming stuck or entangled. The users described various incidents where they had experienced the cord to become entangled with an arm, other care receivers or objects in their physical environments (such as the armrest on a user's wheelchair). The incidents were all examples of situations in which wearability issues not only caused difficulties for the users, but also made it challenging for the users to actually reach the alert button to call for assistance.

From the interviews, we also learned that the users often would take measures to prevent alert devices from becoming a hindrance in daily activities or otherwise cause discomfort. This applied both to manually operated alert devices and to the sensor belts. For example, users described how they sometimes would take off the pendant alert device and/or the sensor belt, e.g. when performing bathroom activities, and store the devices on places where they perceived them to be easily reachable in case of need.

We also learned that dynamic wearability to a large extent also affected how users chose to carry the sensor belt on their bodies. For example, users who were highly dependent on using wheelchairs pointed out that they experienced it as uncomfortable to sit with the fall sensor belt on for longer periods, as the bulkier part of the fall sensor belt (i.e. the pocket with the smartphone) would press against their back. One of the participants explained how she would try to fix the problem by attaching the belt so that the smartphone pocket became located over the hip where the wheelchair was more spacious) rather than wearing the smartphone on the lower back. Similar practices to enhance comfort in various situations, such as rotating the belt or taking it off (when sitting, going to the bathroom etc.) were also reported by other users.

These findings illustrate how dynamic wearability can affect both accessibility to push-button alert devices, as well as precision of sensor-enhanced alert devices (e.g. automatic fall detection devices).

Through incidents described in the logbooks and discussed in the interviews, we became aware that the physical design of alert devices can also play a role in activation of unintended alert calls. During one of the interviews, one user described how she had struggled with opening the belt buckle when attempting to take off the sensor belt. She explained that as the belt buckle came loose, she had accidentally dropped the one end of the belt, causing it to sway from the other hand still holding the belt. The incident was detected as a fall by the fall sensor belt, and the care personnel were notified.

Another user described a different incident leading to an unintended alert call. The incident occurred when he was trying to take off the sensor belt while he was seated in his wheelchair. The user explained how the belt got stuck between his body and the wheelchair. In this case, the alert call was triggered as the user attempted to pull the belt loose quickly and by force.

As further described below, the users expressed mindfulness about using their push-button alert devices to call for attention; this is to avoid burdening care providers with non-critical issues. Both the situations described above, in which alert calls had been triggered unintentionally, highlight how subtle aspects of PER alert devices' physical design can imply undesired effects in a care context.

#### *5.1.2. Aesthetics*

The group interviews highlighted that the aesthetics of the devices affected users. Regarding pendant alarm devices, for example, some of the users described how they in some situations would tuck the device underneath their clothing, rather than wearing it on the outside (where the alarm device would be more ready at hand in case of need). While such practices to some extent were performed for practical reasons (e.g. to prevent the device from becoming entangled), we learned that in many cases the underlying motive was cosmetic considerations. In other words, these were practices related to the users' mindfulness about their physical appearance and how they presented themselves to others in various social contexts.

Many of the users claimed that the visual appearance of alarm devices was a concern of higher priority for woman than for men. The care providers we talked to, however, expressed that both male and female care receivers had similar concerns regarding aesthetics.

#### 5.1.3. *Self-management*

The interviews generated discussions concerning management of, and daily routines related to, assistive devices. The discussions with the users revealed that the group in general had a strong desire to manage assistive devices themselves. This included charging the sensor belt, as well as taking the belt off and putting it on without assistance. Many of the users expressed that being able to manage ordinary tasks of everyday life was important to them. Some of the users explained that even though they were aware that they could receive assistance from care personnel, they were very reluctant to ask. For example, one care receiver said that: 'I've been lectured for not pushing the [alarm] button when I should have . . . but I think that the girls [care providers] already have more than enough to do'. Mindfulness about burdening care providers with non-urgent tasks was given as another reason for why many of the users preferred to manage the sensor belt on their own.

With respect to the sensor belt, feedback from the users revealed aspects of the design that made self-management challenging. One user explained how he, due to motor problems, struggled with charging the fall sensor belt. Specifically, the user described how he found it difficult to put the charging pin in the charging port of the smartphone. Other users pointed out that they found it difficult to take off the belt on their own, because the plastic snap clip buckle required too much hand and finger strength to allow for easy opening. This type of responses highlight the risk that assistive technologies in some circumstances may lead to *excess disability* (Brody, 1971), i.e. the loss of opportunities due to factors not related to impairments but due to discriminating demands that external factors (such as technology or the environment) put on certain groups of people.

### 5.2. Form factor and ergonomics: the care providers' perspective

From the participating care providers' point of view, two specific concerns related to the physical design and body placement of the alert and sensor devices emerged as central. Both aspects were strongly related to the safety of care receivers, as perceived by the care personnel.

First, care providers highlighted the benefit they perceived in alert devices that could be strapped onto the users (e.g. wristbands, belts etc.) rather that devices that could be more easily removed (e.g. pendants). One of the problems that the care providers pointed out with the latter was that some of the care receivers, particularly those with cognitive impairments, tended to forget to bring the devices with them when moving about, or lose track of where they stored their devices. This required the staff to spend time on searching for lost devices.

Secondly, the care personnel highlighted the benefit they perceived from being able to *visually confirm*, in an effortless manner, that the care receivers carried the alert devices. We learned that devices that were easily visible (e.g. wristbands), serve as a cue and reassurance for the care personnel that the care receivers were appropriately equipped in case of an emergency event. In this sense, the high visibility of the wristband devices served as a means to reduce their concerns in their everyday work. While pendant alert devices also could serve a similar purpose, practices such as tucking the devices underneath clothing made them less ideal, from the perspective of the care personnel.

Regarding the fall sensor belt, the care providers explained that they occasionally had to physically examine if care receivers wore them. This was particularly the case with care receivers with reduced cognitive functioning, as they sometimes could not remember if they carried it or not. As such, the fall sensor belts implied more obtrusive routines of checking whether the users carried them or not.

### 5.3. System feedback and user control: the users' perspective

In addition to form factor and ergonomic aspects of alert devices, the interviews also provided an understanding of the users' and care providers' views on interactive aspects of PER systems. In particular, issues related to system feedback and user control were discussed.

#### 5.3.1. *System feedback*

The discussions related to system feedback mainly emerged as a result of the users' detailed accounts of situations in which an alert notification had been triggered explicitly by the user via his or her push-button device, or implicitly by the sensor belt.

One participating user described his experience from an accidental fall in the hallway outside his residence. Since he was unable to get up on his own after the fall, he had decided to press the alert button on his wristband to call for assistance. However, because the fall occurred outside the residence (beyond the hearing distance of the speaker-phone), and because neither the wristband nor the fall detection belt provided him any feedback, he could not know if his alarm call had been received. The user further described the anxiety he experienced as he laid helpless and in pain on the floor, and not knowing if and when help would arrive. The user also pointed out that the stress he experienced may also have added to the perceived waiting time.

The incident described and other similar incidents that the users had experienced triggered discussion within the groups about how PER systems could be designed to reduce perceived anxiety in emergency situations. From these discussions we learned that the users perceived an added value in receiving some type of intelligible system feedback (e.g. via the wristband) indicating that their alarm call had been received and that care personnel had been dispatched. The participating users considered this type of feedback a means that had the potential to reduce anxiety in emergency situations. As one user suggested: ‘If the [PER system] could give off a sound . . . that way you would feel much safer’.

Issues related to the absence of system feedback to the users also emerged in discussions concerning other non-emergency aspects of use. For example, some of the users expressed uncertainty during the field trial and the interviews about system status and the operational radius of the device, i.e. whether the device would only work indoors similar to the push-button devices they were equipped with or if it also would work outdoors. The uncertainty that the users expressed can in many ways be ascribed to the lack of system status feedback to the user (e.g. whether it is on-line or off-line).

#### *5.3.2. User control*

Incidents in which the users had inadvertently triggered the fall alarm notification when attempting to remove the belts led to discussions about user control. Specifically, the question whether users should be provided means to prevent system-initiated alert notifications from being sent was debated. One potential way to offer users such an option, and which was discussed during the interviews, is to have the system inform the user that it is intending to send an alarm notification (e.g. via visual feedback shown on an interactive wristband), and then give users a time window in which they have the possibility to prevent the system from taking its intended action. As pointed out earlier, many of the users expressed that they were generally reluctant to use their push-button alert devices except for emergency situations. Some argued that having the opportunity to prevent the fall detection belt from sending an undesired alarm notification therefore made sense.

### 5.4. System feedback and user control: the care providers’ perspective

The participating care providers were generally reluctant toward the idea of PER systems informing users about on-line/off-line status, inferred events and action taken on behalf of the user. Specifically, they highlighted that the diversity both in cognitive functioning but also sensory function (eyesight and hearing) was high among the care receivers. Based on this, the care personnel argued that feedback, in many cases, would need to be tailored for specific users. One specific concern raised in this context was that poor or ambiguous system feedback, or system feedback that potentially could startle the users (e.g. sudden audio feedback or LED lights that indicate status) risked doing more harm than not providing system feedback to users at all. From the care providers’ perspective, inappropriate system feedback could add to anxiety and stress in users both in their daily life and in the context of emergency situations. This concern was the reason why audio feedback from the fall detection belt was disabled prior to the field trial.

Regarding the issue of user control, the care providers expressed reluctance toward providing care receivers the possibility to override autonomous actions taken by a PER system, for example, stopping an alert notification before it is sent. The care providers’ main concern was that users could potentially stop the alarm either by accident or based on naïve or ill judgments about their own health condition in the context of, e.g. a fall. In this sense, user control could potentially represent a safety hazard, as seen from the care providers’ perspective.

### 5.5. Sensor precision and trust: the users’ perspective

Data gathered from the logbooks showed that six falls had taken place without being detected (false negatives). The data also showed that on three occasions the fall detection prototype had incorrectly inferred that a user had fallen (false positives). One reported fall was detected by the prototype system. Based on these data, we wanted to find out more about how sensor precision affected technology acceptance among the two stakeholder groups we interviewed.

Feedback from the users suggested that carrying the fall detection belt did not add to their perceived safety in daily activities per se. One user, for example, said that: ‘I cannot say that I felt more safe . . . although I understood the purpose of the [sensor belt]’. According to the participants, their experiences from situations in which the fall detection belt had gotten the context wrong rather contributed to reducing their trust in the system.

Regarding false positives, the users considered this to be a burden mainly for the care providers. We did not receive feedback suggesting that the occurrence of false positives caused care receivers to explicitly change their interaction with the fall detection belt to avoid other unintentional alerts to be set off (e.g. avoiding taking off the belt themselves).

### 5.6. Sensor precision and trust: the care providers’ perspective

There was a general consensus among the care providers that false negatives and false positives to some extent undermined the argument that sensor-based alert devices add to care receivers’ safety and security.

Regarding the occurrence of false positives, and how it affected their attitudes toward automated alert devices, however, the care providers expressed diverse views. Some of the care providers raised the concern that false positives could potentially become an added burden in their daily work. In their view, some care receivers frequently used the push-button PER system also to call attention to more non-emergent issues (e.g. checking when the next meal would be served). They explained that the use of the PER system for such purposes in some cases could be a source of stress, as it made it more challenging for care personnel to make the right prioritization about which patient to attend to first if multiple alarms were raised at the same time. One care provider expressed particular concerns regarding the effect non-emergent alarms had on the provision of care service: 'Those who frequently activate the alarm and request assistance for all kinds of tasks do so at the cost of other care residents'.

Hence, some argued that it was important that automatic alert devices did not add to the perceived problem of too many non-critical alert notifications.

Others expressed a more tolerant attitude toward false positives, and considered it (quote) 'part of the job' to attend to care receivers whenever alerts were triggered, independently of reason for the incident. Provided that the amount of false positives did not prevent them from getting their daily job done, some of the care providers explained that they were willing to tolerate a fair portion of false positives since they regarded the system to nevertheless add to the general safety of the care receivers.

One potential explanation for the mixed attitudes among the participating care providers regarding false positives can be differences in workload at the two different care sites.

### 5.7. Summary of key findings

Before we move on to discuss the results described above, we provide a brief summary of the main findings for each of the identified areas of concern:

(i) *Form factor and ergonomics*: from the users' perspective, concerns related to form factor and ergonomic aspects of alert devices were: dynamic wearability, aesthetics and inclination of some users to wear the devices openly, and possibilities for self-managing of devices.

The care providers generally sympathized with the users' concerns. The care providers, however, highlight the perceived benefit of being able to visually identify, in an unobtrusive manner, that care receivers carried their alert devices with them.

(ii) *System feedback and user control*: lack of intelligible system feedback when alert notifications were manually or automatically triggered appeared as a central issue among the users. The occurrence of false-positive fall detections by the sensor belt, and reluctance toward burdening care providers with non-critical issues led some users to argue for having the opportunity to prevent the fall detection belt from sending an undesired alarm notification.

The care providers' main concerns related to providing system feedback to users (e.g. in cases where an alarm notification was triggered) since vague or ambiguous feedback could risk stressing the users. The care providers also expressed skepticism against providing users means to prevent automatic or system-initiated alarms from being dispatched, due to the potential safety risk they perceived in this type of solutions.

(iii) *Sensor precision and trust*: The users perceived the occurrence of false positives a burden primarily for the care providers. Incidents where the fall detection system failed to detect a fall or wrongfully inferred a fall generally reduced the users' and the care providers' trust in the system.

The care providers expressed different tolerance toward the occurrence of false positives. Some considered it a potential source of added stress in their daily work, while other expressed a more tolerant attitude, as they considered the technology to contribute to the users' safety despite occasionally dispatching false alerts.

## 6. DISCUSSION

Having described the users' and care providers' attitudes toward the PER system, we turn our attention to central elements that separate the two stakeholder groups' perspectives. Based on the feedback from the stakeholder groups, and particularly the user group, we then identify and discuss what we consider possible value biases embedded in the system, i.e. potentially discriminating factors that may have an undesirable outcome from a user's perspective. Finally, we discuss the key implication for the design of future PER systems that can be drawn from this study.

### 6.1. Users' concerns vs. care providers' concerns

While care receivers' safety was a central issue among both stakeholder groups involved in this study, our findings highlight that the two groups, to some extent, had different perspectives on the concerns that emerged in the context of using the sensor-enhanced PER systems. This can suggest that the users and the care providers tended to have somewhat different priorities with respect to what values a PER system should support.

PER systems are in general designed with the purpose of maintaining the safety of users. For the users who participated in the group interviews, however, safety appeared to be one out of several other values of importance to them, and which they argued that a PER system should reflect. Examples of non-safety-related values included wearability and comfort-related aspects, aesthetics and self-management. We learned that, in the course of users' daily activities, safety occasionally came in conflict with other non-safety-related values such as those mentioned above. In such cases, users' practices suggested that they implicitly down-prioritized safety in certain situations due to other, more circumstantial factors. Taking off the safety alert device or adjusting its position on the body, either to increase level of comfort or for cosmetic purposes are example of practices that could be considered to reduce a care receiver's relative safety. In most cases, however, this type of decisions appeared to be taken on impulse, rather than on careful consideration.

Compared with the users, the care providers appeared to have a more one-sided focus on safety. While the care providers appeared to sympathize with many of the users' concerns regarding the PER system (e.g. lack of intelligible feedback to users), they also tended to assess the design suggestions that emerged through the group interview with the users from a safety perspective. Their main concern was whether the design suggestion could have potential negative impact on the users' safety situation. The tendency among care providers to prioritize care receivers' safety over autonomy or independence has also been discussed in other articles describing stakeholders' attitudes toward assistive technology applied in nursing home care provision (Robinson *et al.*, 2007).

### 6.2. Identifying potential value biases in the assessed PER system

Drawing from the feedback from the informants, and particularly the user group, what value biases, then, can be considered embedded in the assessed PER system? Below, we discuss three interrelated factors we regard particularly relevant in this context: the emergency-centeredness pervading design of PER systems, the risk of objectification of users and a 'one-size-fits-all approach' to PER systems.

#### *6.2.1. Emergency-centeredness*

The main purpose of PER systems is to help maintain the safety of users by offering users simple and effective ways to contact care providers when in need. In order to fulfill this purpose, however, we learned that particular attention needs to be paid not only to how the design solution works in potential emergency situations, such as falls. Aspects such as dynamic wearability (e.g. wearing comfort) and aesthetics play a significant role in this context. For example, we have previously discussed how these aspects influenced how users chose to carry (or not carry) the devices on their bodies, which again had implications for the users' accessibility to the alert buttons. In many ways, these findings highlight potential catches of 'emergency-centered' design thinking in development of PER systems and alert devices. As our results suggest, designing for users' safety is not only about designing for the immediate emergency situations (e.g. detecting an accidental fall). It is also about designing systems and devices that seamlessly integrate into mundane physical and social activities of users' everyday life. If these activities are ignored during design, users may be less likely to accept the design solutions and/or they may be more likely to use the solutions in ways that are ineffective in a given emergency situation.

#### *6.2.2. Objectification*

Implicit in the evaluated PER system, and in most traditional PER systems, is the notion of simplicity in use—attention can be summoned by the push of a button. With the use of sensor-enhanced PER system, the vision is that user–system interaction is even more simplified by allowing the system to send out alerts on the user's behalf.

While we acknowledge that 'simplicity in use' should be a central principle guiding design of PER systems and alert devices, we also see an inherent risk that this may lead to *objectification* of care receivers. Kitwood (1995) used the term *objectification* to refer to certain acts that would contradict person-centered care, such as excluding a person or treating them as if they had no thought or feelings. Aspects related to the design of the PER system, such as cutting the users out of the system feedback loop (e.g. both in emergency situations and everyday use) can in many ways be considered to lead to objectification of care receivers. Our findings suggested that, for many users, the loss of feedback from the system created uncertainty among them and tended also to diminish their trust in the system to some extent.

The example provided above illustrates the problem of conceptualizing the users of PER systems as passive objects, whose only role (as seen for a system perspective) is to trigger events that the rest of the system should respond to. As our results indicate, this objectification of users can come at the cost of the users' *perceived* safety.

#### *6.2.3. 'One size fits all'*

The PER system we evaluated reflected in many ways the assumption that one size fits all. While the system supported two different push-button alert devices, neither the push-button devices nor the sensor belts took into account that the user group can be highly diverse with respect to, for example, physical and cognitive function, preferences when it comes to managing alert devices themselves (charging, taking the wearable devices on and off), desire for system feedback etc. Though the application of a universal solution can be beneficial, e.g. in terms of service and management of devices, the problems identified above can in many ways be considered the cost of applying the same solution for all users.

### 6.3. Toward a value-driven design agenda for PER systems

We consider the stakeholder's concerns described earlier in this paper to raise several questions regarding how design of future PER systems can accommodate the different perspectives that emerged. In particular, we consider the different perspectives to form an interesting starting point for a *reassessment* of how these systems can provide added value both to users and care providers.

Rather than simply prioritizing the view of one stakeholder group over the other, we argue that there may be great potential in co-exploration of design solutions that are intermediary in the sense that they attempt to reflect the perspectives of both stakeholder groups. Although the participating stakeholder groups expressed different views on how a PER system could offer value, the emerging perspectives are not necessarily incompatible. For example, the concerns the care providers expressed toward providing richer system feedback to users were mainly related to certain *types* of system feedback (e.g. sudden audio feedback or LED lights that indicate status) which they assumed would be difficult for the users to make sense of—not the provision of system feedback to the users per se. Likewise, there may be ways to accommodate the different priorities with respect to wearability and comfort (users' priority) and simple cues that signal to care providers that the users are carrying their alert devices. The examples above illustrate an unexplored potential of future PER systems, and room for design to negotiate different values.

Our findings also highlight how relatively subtle design aspects of alert devices (e.g. an inappropriate body attachment mechanism or cumbersome battery charging) can lead to undesirable outcomes for the user or deny him or her certain possibilities. These findings illustrate how technological design also can play a role in the realization of human values, such as self-management.

A central lesson to be learned from this study is that to identify aspects of use that have implications for the design of PER systems, an ecological approach is required. By ecological approach we mean that designers need to not only take into consideration the emergency situations and how the system should present itself to users and care providers in such situations—It requires designers to take into considerations a wide variety of use situations and explore how the design solution can accommodate user needs and desires in these situations. As previously argued, such an approach can yield a better understanding of aspects that are essential for acceptance of technology among users and care providers, and can ensure that alert devices will fulfill their purpose in emergency situations.

Having discussed the concerns of key PER system stakeholders, however, does not mean that all the emerging issues can be easily fixed by design alone. One of the problems that arise when attempting to take the perspectives of different stakeholders as input to design is *what* and *whose* voice should be given greatest attention in cases of conflicting perspectives. Manders-Huits (2011) argues that such decisions need to be based on ethical theory, rather than having designers select, in an *ad hoc* manner, between different normative positions. In terms of implications for design, then, our findings do not allow us to be conclusive about prioritization of values.

### 6.4. Limitations of the study

Given the highly descriptive nature of the study and the limited number of stakeholders involved, the extent to which the views presented in this paper are representative for a wider user and care provider population remains an open question. Also, the majority of the usability and other value-related concerns discussed in this paper were derived from care receivers' and care providers' personal accounts after having used a particular implementation of sensor-enhanced PER system. We recognize that exposing the stakeholders to a different PER system implementation is likely to produce different use experiences, and potentially raise different concerns among stakeholders from those discussed in this paper. Rather than aiming to produce a comprehensive set of stakeholder concerns related to the application of sensor-enhanced PER systems, our goal in this paper has been to draw attention to the, often, subtle 'premises of use' that are built into such systems. These premises, or value biases, are likely to affect many aspects of care such as autonomy and empowerment of care receivers, and also the relationship between the care receiver and the care provider.

Lastly, we acknowledge that attitudes toward assistive technology may be highly context-specific. Existing work (Hersh and Johnson, 2008) suggests that attitudes toward assistive technology can be contingent on the cultural and social context, national context and local settings.

The fact that attitudes toward the assessed PER system was collected after the stakeholder groups had been given the opportunity to try out the technology in daily life and work adds to the credibility of the results.

## 7. SUMMARY AND CONCLUDING REMARKS

Through findings described in this paper we have attempted to form a qualitative understanding of care receivers' and care providers' attitudes toward a sensor-enhanced PER system after hands-on use experiences. Drawing on feedback collected through interviews with both stakeholder groups, we have discussed what separates their concerns, what we see as potential value biases of the assessed PER system and implications for a value-driven design agenda for future PER systems.

The research question that this study set out to answer was: *What areas of concern does the use of a PER system with* *automatic fall detection alerts raise among care receivers, and how do their concerns compare with those held by their professional care providers?*

Our results show that for the users, safety was one of several concerns that influenced their attitudes toward, and their interaction with the PER system. Design features that emerged as important from their perspective, and which they desired that a PER system could reflect included:

(i) form factor and ergonomics (dynamic wearability, aesthetics and possibilities for self-management);
(ii) system feedback and user control and
(iii) sensor precision and trust.

The care providers, on the other hand, gave the aspects of safety and prevention from harm as priorities over other concerns that were central from the perspective of the care receivers. As such, the care providers generally tended to assess pros and cons related to the design features above from a safety perspective.

Drawing on the feedback from the users, we discussed three potentially discriminating factors embedded in the assessed PER system: (i) the implicit notion that one size solution fits all users, (ii) the risk of objectification of care receivers by not providing appropriate system feedback and (iii) the potential drawbacks of 'emergency-centered' design thinking, i.e. designing only with emergency situations in mind, and disregarding how the solution otherwise integrates into the everyday lives and activities of the users. These three biases can to some extent serve as a rationale for the issues raised by the care receivers.

In terms of informing design of next-generation PER systems, we have argued that our findings call for a reassessment of how such systems can accommodate the needs and desires of different stakeholders. Essentially, many of the care receivers' concerns described in this paper question the conceptual model on which conventional PER systems (and other monitoring technologies applied in care) typically are based on. The findings discussed in this paper suggest that this model risks denying users certain possibilities and in some cases yields results that, from a users' perspective, may be considered undesirable. In this regard, we consider the different concerns identified in this study to serve as a valuable platform for future design explorations.

## ACKNOWLEDGEMENTS

We thank the participants who volunteered to take part in the field trials and focus group interviews, and thereby helped make this study possible.

## FUNDING

The research leading to this study has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreements no. 288940 (FARSEEING) and 317631 (OPTET). The study has also been funded by The Research Council of Norway under grant agreement no. 230435 (ADAPT).

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