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# Designing Smart Home Technology for Fall Prevention in Older People

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**Abstract.** Falls in older people constitute one of the major challenges in healthcare. It is important to design technologies that can help prevent falls and improve falls management. Smart home technology could be of importance in this context, but the technology has to be user-centred or adapted to be useful in this particular context. This study assessed usability of paper and interactive prototypes of a smart home touch screen panel. The study implemented five scenarios related to fall risk, fall assessment and exercise guidance, designing a smart home interface for independent living in general and fall management in particular. A usability evaluation showed that older people had positive experiences when using the touch screen interface. The study demonstrated the need for user-centred interfaces for older people in the context of falls prevention.

**Keywords:** Falls, Seniors, Scenarios, Usability, Evaluation, Smart home, Interface design

## 1 Introduction

Falls in older people constitute one of the major challenges in healthcare. Falls are an important public health issue. Each year, 35% of people over the age of 65 experience one or more falls. Between 10 and 25% of fallers sustain a serious injury [1]. This has implications regarding independence, reduced quality of life, and health care costs [1]. Therefore it is important to design technologies that can help prevent falls and improve falls management. Smart home technology could be of importance in this context, but the technology has to be purpose-designed or adapted to be useful in the context of fall prevention and fall management service.

Smart home technology often is envisioned to contribute to increased safety, security and well-being of people with special care needs. However, user acceptance of smart home technology that aims to serve assistive purposes is generally low

among elderly people. Therefore the technology needs to be developed through an iterative, user-centered design (UCD) approach [2]. The system and technology constantly take into account input from different stakeholders of the system to improve usability of the system. In the context of fall management, stakeholders include senior citizens, doctors, health professionals and physiotherapists.

This study aimed to assess the usability of paper and interactive prototypes of a smart home touch screen panel. A user-centered design approach was employed to collect the requirements of a smart home system for fall management. On the basis of such requirements, the interface of a smart home system was developed. Subsequently, usability evaluation of the smart home system was conducted with older people.

## 2 Scenarios for requirement analysis

Different approaches exist to assess the user-centered design aspect of technologies. Scenarios can be used as a way to explain conditions in which a system can be used. A scenario is an idealized but detailed description of a specific instance [3]. The goal of scenarios is to identify situations in which the system can be used. In this sense, a scenario presents and situates solutions [4].

The system requirements for smart home systems for fall management were defined through development of scenarios. The scenarios represented everyday tasks of relevance for older home-dwelling persons that can contribute to prevent and manage falls. These scenarios were developed based on input from 17 human movement scientists, physiotherapists, health professionals and human-computer interaction researchers. Through internal consensus, the decision was made to focus on a set of five core scenarios in which smart home systems can be used by seniors. These scenarios include: Exercise, Exergame, Walking, Fall detection, and Self-test. The core scenarios descriptions were used to select the required technology and develop the appropriate user interaction and user interface.

### 2.1 Scenarios Description

The following section describes the scenarios, their underlying concepts, and the deployment solutions.

**Exercise.** Kari's physiotherapist has recommended she try to incorporate some exercises into her daily routine to improve her muscle strength and balance, while requiring no extra time.

*Concept:* She is taught how to use the furniture and items in her home to do some muscle strengthening exercises. She is reminded about the exercises and given a demonstration of them via the interface (video clip, animated gif). She can schedule these exercise reminders or else, if she chooses, she can also select to do the exercises at any time.

*Deployed Solution:* By using the touch screen interface, the user can select to view video exercises for strength and balance tailored to older adult users. These videos are

also scheduled to appear as a reminder to the user to perform the exercises at an appropriate interval, selected upon installation. Motivational messages are delivered to the user upon completion of a short questionnaire regarding the exercises.

**Exergames.** Ingrid heard about an exergame from a friend who said the game was entertaining, challenging and would help her to improve her balance and stepping ability.

*Concept:* Ingrid interacts with the smart home panel to select the appropriate time for here exergame use. The smart home system reminds Ingrid when it is time for her exergame via persuasive messages. Her score is saved and a record of improvement is available to her.

*Deployed Solution:* The user is prompted to use the exergame via a touch screen interface or they can select to use the exergame independently. Instructions are given to the user on how to use the exergame. Once finished the user's performance indicators are saved by the system and used to select the appropriate level for subsequent use. Persuasive and motivational messages are given to the user at the start of the game and upon finishing to provide encouragement.

**Walking.** Albin has become less active after his wife died 3 months ago. His physician encourages him to do more outdoor activity.

*Concept:* Based on feedback regarding weather conditions, the smart home system encourages the user to participate in outdoor walking. The user receives feedback on the distance walked and the length of time of walking based on smartphone monitoring and the smart home user interface, respectively.

*Deployed solution:* The user can assess the weather forecast via the touch screen interface to see whether the weather forecast is suitable for an outdoor walk. The user then selects the outdoor walk button on the 10-inch touch screen and commences the outdoor walk with the smartphone attached; they select to finish the outdoor walk upon return. If the user has improved walking time a motivational message is delivered. The user can also be prompted to go for an outdoor walk. Alternatively, the user can postpone the reminder for a certain amount of time.

**Fall Detection.** Kirstin fell in her living room some time ago. She injured her wrist, but was able to recover back to a standing position and contact help. She has since become concerned about not being able to get up and get help if she falls at later time.

*Concept:* Kirstin wears the Smartphone which works as a fall-detection sensor. If the user experiences a fall, the smartphone communicates with the smart home system and prompts the user to indicate whether they have fallen or not. If the user does not respond, cameras located in the home can be switched on to assess the situation. Thus, falls can be detected in different ways.

*Deployed solution:* If a specific movement signature is measured by the embedded inertial sensors in the phone attached to the user that resembles a fall signature, a message is sent to the smarthome system to raise a fall alarm. The touch screen interface then prompts the user to indicate whether they have fallen or not. If no

response is given, it is assumed that an actual fall has occurred and the alarm will be sent to an alarm central.

**Self-test.** Clemmensen is approaching 89. Clemmensen´s physiotherapist suggests to him to test his physical performance by regular measurement of his gait speed.

*Concept:* Clemmensen's gait speed is measured through a combination of the sensors and interfaces that are located around the home.

*Deployed Solution:* The user's gait speed is measured through a combination of pressing buttons on the 10-inch wall mounted touch screens and buttons located around the residence. The time taken to activate the combination of buttons in combination with the distances between them is used to estimate gait speed.

## 3 User Interface Design

A number of key elements were taken into account when designing the user interface for elderly users. For example, icons must be large enough to allow coarse pointing and seniors should be able to easily distinguish between the foreground and background colours.

The interface was evaluated using the system usability scale (SUS) [5]. SUS is a ten-item scale which provides a subjective assessment of the usability of a system.

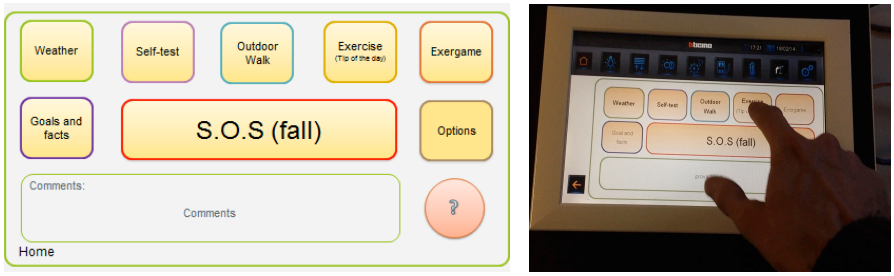


**Fig. 1.** The mock-up (*left*) and interactive prototype (*right*) of the user interface on a 10-inch smart home screen

As listed previously, the user interface for the Smart home system interface was designed with 5 main scenarios. The interface of the smart home technology was developed on the basis of these scenarios and allowed the older people to select any of the main actions. As shown in figure 1 (left), a mock-up was developed to visualize the interface of the system. The functional touch screen user interface was deployed on a 10" 16:19 LCD developed by Bticino[1]. Figure 1 (right) shows the deployment inside Bticino's smart home interface.

[1] http://www.bticino.it/cons/content/dettaglio/prodotti/bt_28/MultimediaTouchScreen/bt_8

## 4 Usability Evaluation of Smart Home User Interface

The usability evaluation of the smart home touch screen interface was conducted with five senior citizens with an average age of 77±6 years (range from 72-87 years). To show the full functions of the system, high-fidelity paper prototypes were used in addition to a functional touch screen interface. The participants were asked to think aloud when exploring and performing different activities using the interface.

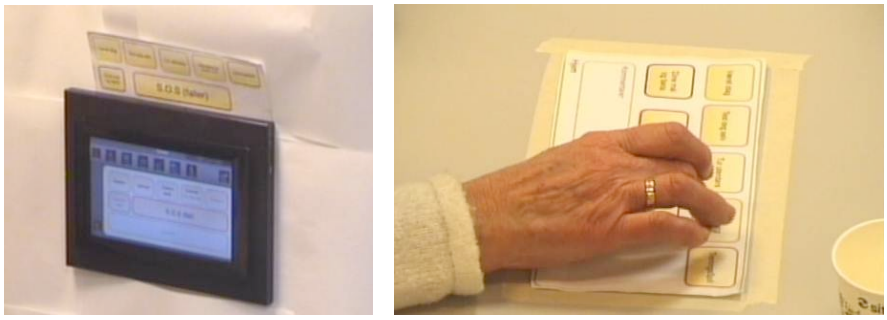

**Fig. 2.** An example of interactive prototype (left) and paper prototype (right) used in the usability experiment

First, the participant started to explore different options on the interface of the touch screen. The interface was in English. A high fidelity paper prototype in Norwegian was initially provided along the touch screen interface (figure 2, left). Later participants were offered the possibility to explore these options of the interface on the paper prototype in Norwegian which was placed in a rectangular box (figure 2, right).

**Table 1.** System usability of smart home touch interface

| System usability scale questions | Mean | SD |
|---|---|---|
| This system will help me stay in shape | 3,8 | 0,84 |
| The system is simple to use at home | 4,0 | 0,00 |
| System is motivating and fun | 4,0 | 0,71 |
| I will tell family and friends that I use this system | 4,2 | 0,84 |
| I will setup this system at home | 4,5 | 0,58 |
| I will prioritize to buy this system even if it costs much | 3,2 | 1,48 |
| I will be able to use the system on my own | 4,4 | 0,55 |
| *It does not seem difficult to use the system | 3,4 | 0,89 |
| I will use it in the near future (soon) | 3,8 | 0,84 |
| The system fits with other seniors as well | 3,8 | 1,10 |

* Inversed the question

Rating: 1= strongly disagree, 2= disagree, 3 = neutral, 4 = agree, 5= strongly agree

The results of SUS showed that older people liked the interface and a positive reaction was received for usefulness and usability of system, see table 1. Usability issues

that came up were: confusion between the interface of the manufacturer and the space dedicated to the interface for physical activity and fall management, readability difficulty, and inactive screen. The participants wanted to be reminded about activities to be performed. These recommendations will be used by Bticino to further refine and update the final user interface.

## 5 Discussion and conclusion

The study implemented five scenarios related to fall risk, fall assessment and exercise guidance to be used to prevent and manage falls by use of smart home technology. To show the full functions of the system, the study used high-fidelity paper prototypes and a functional interactive prototype for system evaluation.

The usability evaluation showed that participants had positive experiences when using the touch screen interface. The positive experience of the seniors suggests that technologies should be designed to fulfill the particular needs of seniors. Usability issues that came up were: confusion between the interface of the manufacturer and the space dedicated to the interface for physical activity and fall management, readability difficulty, and inactive screen. The participants suggested to be reminded about activities to be performed. The study demonstrated the need for developing interfaces particularly for older people in the context of falls prevention.

This study underlines the importance and need to design smart home technologies for independent living in general, and for preventing and improving management of falls and fall-related activities for older people.

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