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Designing a system interface for elderly people in a smart home system: A practice based research

Venere Ferraro, Lucia Rampino

Design Department, Politecnico di Milano

Abstract
New technologies, such as ICT, are developing rapidly and are used by ever larger parts of the population, including elderly people. The rapidly ageing population has increased the interest towards smart home technologies and "ambient-assisted living" (AAL) for a safer and more independent living. Indeed, according to the World Health Organization, 7% of the world's population is now over 65 years and approximately 20% of it will be aged 60 or older by 2050.

This paper describes the outcome of a co-financed research project, aimed at developing a prototype of a smart home system designed to improve daily life of cognitively auto sufficient elderly people living on their own. The activity was carried out by an Italian consortium established within the Design Department of Politecnico di Milano, a household-appliances manufacturing company (Whirlpool Europe), an ICT company (MR&D) and a non-profit organization for disabled people caring (Fondazione Don Gnocchi). The objective of the research was to develop a smart environment made up of a user interface, several home appliances and a home sensors network. The authors will illustrate the activity led by Design Department: the design of the system interface that represents the medium between the user and the all-smart home system. The paper will go through the main phases of the research: the definition of user requirements for the system interface, the design of the user interface and the usability tests of the developed prototype with elderly people.

Finally the results will show how the main challenge of the research activity was designing a user interface able to provide a simplified interaction with the system, avoiding negative impacts for those elderly not used to interacting with high-tech products.

Keywords: user-centred approach, practice based research, elderly people, interface design

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Introduction

The UN Department of Economic and Social Affairs Population Division predicts that between 2100 and 2300 the proportion of the world population in the 65 or over age group is estimated to increase by 24% to 32%, and the 80 or over age group will double from 8.5% to 17%.

As confirmed by the World Health Organization, Italy is, in Europe, among the first countries where the rate of ageing population has been more intense and fast. Overall, Italian population between 65-74 years is 10.3% of the resident population, while that of 75 years is up 10.0%. The increasing number of elderly people living on their own brought to the development of technological solutions such as remote health conditions monitoring devices or tele-assistance whose aim is to make their life more comfortable and safer (Campani *et al,* 2003).

With the rapid population ageing that is occurring world-wide, there is an increasing interest in "smart home" technologies. The concept of smart home is a promising and cost-effective way of improving home care for the elderly and/or the disabled, allowing greater independence, maintaining good health and preventing social isolation (Chan *et al,* 2009).

The term 'smart home' is used for a residence equipped with technology that allows monitoring of its inhabitants and/or encourages independence and the maintenance of good health. As the technology is still evolving, there is neither an appropriate definition of a 'smart home' nor an exact distinction from terms used in relation to 'smart homes', such as 'assistive technology' or 'telemedicine' or 'e-health' or 'telehealth' or 'gerontechnology'.

In this paper, we describe the outcome of a co-financed research project of Lombardy Region aimed at designing and testing a ***smart system for elderly people living on their own***. The activity was led by an Italian consortium established within the Design Department of Politecnico di Milano, Whirlpool Europe, an ICT company (MR&D) and a non-profit organization (Fondazione Don Gnocchi).

The smart system was made up of:

- Four (4) home appliances;
- Home sensors network;
- Smart System Interface.

Although the rapidly emerging "smart homes" movement is worldwide, the literature evaluating the validity, efficacy, practicality of smart homes technologies is comparatively sparse (Morris *et al,*

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2012). Moreover, the diffusion of home automation technologies is taking place at a slow pace. Such a slow diffusion could be reasonable due to technical reasons (communication standards, for example) or high cost, but to a lack of addressing users real needs. Indeed as different people have varying needs, the system must be tailored to each individual (Chan *et al*).

In the field of designing Interactive and Smart products/systems, there are different approaches (Saffer, 2010):

1) User-centred Design (UCD)

2) Activity-Centred Design

3) System Design

4) Genius Design

Approach	*Overview*	*Users*	*Designer*
User-centered design	Focus on user needs and goals	The guides of design	Translator of user needs and goals
Activity-centered design	Focus on the tasks and activities that need to be accomplished	Performers of the activities	Creates tools for actions
Systems design	Focus on the components of a system	Set the goals of the system	Makes sure all the parts of the system are in place
Genius design	Skill and wisdom of designers used to make products	Source of validation	The source of inspiration

Figure 1: The Four Approaches to Interaction Design

From those approaches, the authors chose the user-centred one with the aim of merging technical possibilities with users' needs and requirements. Products developed using the UCD methodology are optimized for end-users and emphasis is placed on end-users needs and expectations from the final product. Both authors belong to the Design Department of Politecnico di Milano. They will thus illustrate the activity led by their Department: the design of the system interface. The project overall duration was 18 months and the expected output was a functional prototype, to be tested in a real context. For this reason, a graphic application was developed to run on an existing tablet (Windows Tablet, 10 inches).

Research Process

The paper will go through the four main phases of the research process led by Design Department: (i) definition of the user requirements for the system interface through a test session with elderly

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people, (ii) visual analysis of the home appliances (iii) design of the system interface, (iv) usability tests of the developed prototype with elderly people.

The main objective of the research activity was to design a user interface for a specific category of elderly, the one with *semi-technological illiteracy*. The term illiteracy refers to the lack of knowledge of a user group to perform specific tasks (i.e. visual illiteracy, sound illiteracy etc.) (Sarah, 2004).

Indeed the challenge was to ensure to elderly users: the ability to interact *easily* and effectively with all products and devices in the home; an *easy*, *clear* communication with parents and friends; the freedom to perform daily activities independently (washing, cleaning the house, doing the shopping, using home appliances). The accomplishment of those objectives required developing a system interface able to make the users easily control and gain feedbacks from the home-appliances and the sensors network.

Hereafter, each step of the activity is described in details.

1. Test session with elderly people

An interview session with twenty elderly, with semi-technological illiteracy, between the age of 68 and 75, was carried out. Among them, fourteen were completely auto-sufficient; six had low level of arthrosis. The objective of this test session was to understand user requirements for the system interface but generally to identify the benefits of a smart home system, both in terms of management of home appliances and of services and able to increase their autonomy and safety. The interview session was carried out through open questionnaire based on: lifestyle, future expectations on home appliances, safety and independence at home. Authors summarized the results of the interviews in information useful for the set of the entire smart home system:

- Social relationships are mainly connected to family and a few friends with whom the interviewees share common interests and activities.
- The most used home appliances are the cook-top, the washing machine and the refrigerator; the oven is used on special occasions.
- Interviewees living were mainly afraid of: gas leaks, thieves in the house, sudden illness, flooding.
- Interviews suggested some factors that would have increased their feeling of security such as: the possession of a cell phone and the possibility to make a video calling with relatives.

Several requirements for the user interface arose as well:

- An area dedicated to personal information: agenda with birthday reminder, medications time and appointments;

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- A simplified *user-friendly* interface compared with the existing home appliances' ones.

Following the test's results, the consortium decided to prototype a smart home system made up of four home appliances (refrigerator, washing machine, oven, cooktop) three kinds of sensors (gas emission, water loss and proximity sensor) and a smart plug for iron (as example of electrical devices consumption).

2. Visual Analysis of Home Appliances

Based on the analysis on the users, authors decided to transfer the four home appliances interfaces to the system's one, making it as similar as possible but simplified in order to avoid confusion in user understanding especially because the entire project deals with elderly not used to interact with high-tech complex products. Since the Smart Home System was made up of Whirlpool Home Appliances a visual analysis regarding their interface was carried out. The objective of this test was to analyse the interface of each existing appliance, in order to identify specific comprehension problems to be addressed in the design of the system interface. This test session, a speak-aloud one, was led on fifteen experts (designers and researchers) aged between 25 and 40. The test was carried out on expert users because the aim was to have both feedbacks on the comprehension of Whirlpool home appliances' interfaces and suggestions about the design of the new interface. Interviewees were asked to: (i) evaluate each home appliance interface on a scale from 1 to 5 and (ii) give general advices to improve each product. The result of this activity was a series of indication to set a framework of system interface. Hereafter the main suggestions are summarized:

1) *Washing machine:* reduce the number of information and options and give the user the possibility to integrate desired options in the standard program.

Figure2: Washing Machine AWOE 7300

2) *Fridge and freezer:* Stress the difference between information provided by the fridge and by the freezer.

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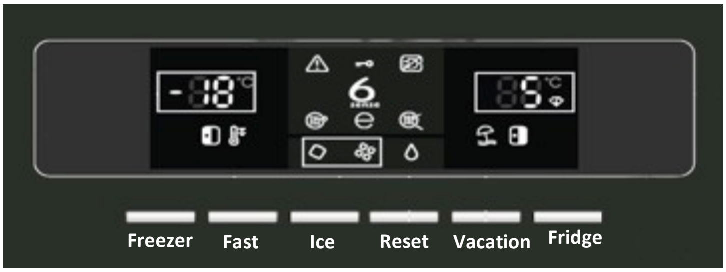

Figure 3: The Refrigerator SXS 2010

3) Oven: reduce the number of information; integrate special function with standard ones and grouping them in one menu.

Figure 4: Oven AKZM 656 IX

4) *Cook top:* increase icons' dimensions; make visible the increasing of the power; contrast the on/pause buttons from the background using colours; group the on/pause buttons;

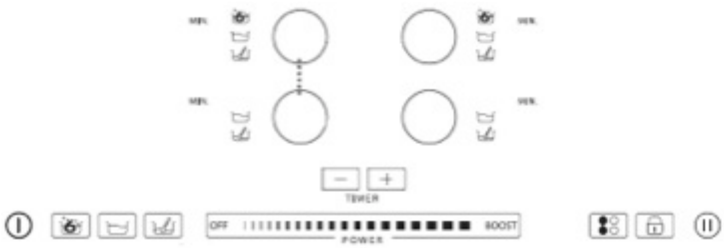

Figure 5: Cooktop ACM 751 BA

The results obtained by the visual analysis of the interfaces of the home appliances were used, together with the results gained by the tests with elderly people, as requirements for the design of the user system interface.

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3. The design of the system interface

The design of the user interface followed three main phases: the organization of the chart flow information, the identification of the graphic language, and the design itself.

A framework for the design of user interface accessible to illiterate users has been developed (Matthew, 2002). According to this framework, three options should be provided: notification to user, information available for user query, messages on screen. Authors merged this framework with the results coming from the interviews to the elderly. So, four typologies of information were elaborated:

1. *Visualization:* the system interface shows the state of the home system when the user accesses to specific information.
2. *Notification:* the system interface gives a message to the user (i.e. pop-up, blinking, beeping at the end of washing/cooking programme)
3. *Warning:* the system interface shows a message that stays active until the user acknowledges it (i.e. gas emission). The notification is given through pop-ups or sound effects.
4. *Increasing Warning:* the message is given in the same way of the warning one but with stronger colours and annoying sound. If the user doesn't realize what it is happening, the system interface sends an SMS to a defined relative.

The Home Page of the System Interface aimed at simplicity. It was organized in three main areas (fig. 6):

1) *General Information* (on the left): Calling, State of the system, Good Night Function, Setting.

2) *Personal Data* (in the middle) where users can accesses to data such as calendar, daily medication, birthday reminder.

3) *Home Appliances' activation* (on the right): Oven, Fridge and Freezer, Cook top, Washing Machine.

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Figure 6: Home page user interface

The home appliances icons are designed to be in two statuses: grey (the appliance is connected but not in use) luminescent green (the appliance is connected and in use).

In the General Information area, user can access the *System Status* (fig. 7). A specific icon (the second one on the left) was designed for this function to remember the network of sensors and home appliances. This function tells the status of: Home Appliances (on, off, in failure), Iron (on, off), Tap water (open, closed), Sensor on the front door (open, closed), Sensor on the fridge door (open, closed), Consumption of the house (with different colours: from green to red).

Figure 7: Status of the system

In the "Home appliances activation" area, a specific interface for each appliance has been developed. The general layout of home appliances interface shows the same one of Whirlpool Appliances and uses the same icons. This way the users immediately recognize the layout and functions. For instance, the cooktop digital interface (fig. 8) shows which fire is on, its level of temperature and, if any, the cooking time set.

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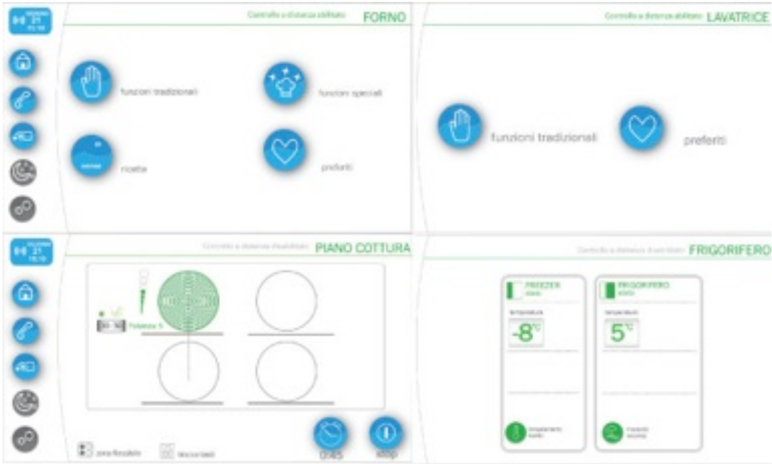

Figure 8: Appliances home

In the system interface a series of hidden pages concerning alarms has been developed. For instance if the user is using the iron and leaves it on for too long the system sends a warning to the system interface (pop-up, yellow colours with a beep). If the user doesn't switch off the iron the warning turns into an increasing warning (pop-up message, red colours, noising beep). If the user still doesn't see the message, the tablet will send a message to the relatives. The same happens with water tap. (Fig. 9)

Figure 9: Examples of alarms

Evaluation of the designed system

A prototype of the whole system was realized and tested in a real apartment, to provide users a realistic environment. A test session, done through the questionnaire, was led. It was mainly aimed

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at evaluating the level of understanding and the degree of satisfaction in the use of the system interface.

The interviews were framed in three steps: explanation of the interview purpose and of the home automation system; the use of user interface through different scenarios; final interview and evaluation. The questionnaire consisted of a series of questions regarding: the use of home automation system; the level of perceived safety in the use of such a system; the effectiveness of the user interface. It was conducted on ten (10) elderly people. The users were part of the first panel of user in order to compare their expectations with the results.

After the test session, seven users evaluated the user interface as easy to use while three of them evaluated it as neither easy nor difficult. In general, the system interface was evaluated as *a user-friendly device* and perceived not as complex as a personal computer.

Based on user opinions, the strengths of the system interface were: the use of great size buttons; the clear use of colours for the different states of the appliances; the use of a common graphic interface; the presence of enhanced visual and sound feedback.

The test session helped to evaluate the designed system in terms of strengthen and weakness. The system was evaluated as easy to use but users required a general explanation both for understanding how to manage home appliances and the features offered by the system (i.e. check of gas emission, door open). Besides, users needed some time to gain familiarity with the tablet especially concerning the touch technology; after several tests and trials, users understood what pressure to use and what kind of feedback they got.

Below is a summary of the test session:

System interface: According to the users, it is really useful to have a tablet able to manage home appliances status (on, off, failure) and home security. This possibility was considered really helpful especially for elderly with physical disability. The weight of the tablet instead has been considered a negative aspect because it affects the portability and the freedom of movements in the house.

Home appliances and sensors: Users generally appreciated all the features that make him/her feel safer in the use of appliances and avoiding inconveniences and hazardous conditions. They appreciated the notification about blackouts and burning food on the cook top, the alarm about the loss of water on the washing machine**,** the presence of a customizable program for the oven and the washing machine.

In general, the ability to manage the home system was considered very useful especially thanks to the presence of alarms notifications that increase the sense of safety in the home (very important the presence of enhanced sound feedback). Moreover, the video calling function was considered very interesting, both for emergency use and possibility to call in general.

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Conclusions and further developments

The described project aimed at improving daily life of elderly people living on their own. It consists in a smart system designed for simultaneously making the user feeling independent (able of managing his/her home appliances) and safer (through home alarms). The project was evaluated as helping and satisfying; its development tried to answer to elderly demands thanks to tests done in different phases of the research activity. Despite the general positive feedbacks, some improvements are needed in order to make users completely satisfied in term of mode of use.

Regarding the graphic aspects, some improvements need to be investigated such as:

- Increasing in the readability of the information on the screen, in particular the visibility of the buttons and functions (i.e. make customizable fonts size);
- Make customizable screen contrast: a useful solution would be the self-regulation of the brightness / contrast depending on the lighting conditions of the various rooms of the house
- Customize the sensitivity of the buttons

Authors are also aware that another device for the user interface could be used as well. Elderly agreed that a Smartphone or a Smaller Tablet (same dimension as a Kindle) would be more appropriate. Besides, other technologies should be used such as voice control, especially to satisfy user with physical disability such as arthritis.

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