Designing usable interface for people with dementia

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Article Information

Keywords:
Assistive Technology,
Dementia,
Human-Computer Interaction,
Usability Evaluation.

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Abstract

Purpose:
This study describes an User-Centered approach to design an User Interface (UI) to support daily activities of people with dementia. Such interface is the main hub of a home automation system able to monitor the house and reminds to the users some information when they approach the door to leave the home.

Method:
In order to involve end users in UI evaluation at the end of the first stage of the design process, a specific experimental protocol, based on task analysis, structural interview, and behavioral observation, is defined. It allows to evaluate user-machine interaction considering aspects related to both adequacy of product feature and user's subjective opinion and behavior.

Result:
A disposable high fidelity prototype of the UI is realized by using a touch screen tablet. Two tests, respectively dedicated to verify the adequacy of the icons and the understandability of the interface, are performed. A total of 20 subjects with different MMSE score are involved.

Discussion & Conclusion:
Results show that people with low and medium dementia are able to understand and use the touch interface and provide some suggestion about how the GUI can be improved. Finally, some approaches to support the future development activities and the next usability tests are discussed.

1 Introduction

The worldwide elderly population is rapidly increasing. Data from the United Nations [1] suggest that this trend is likely to continue through the next century: in 2009 one in eight people was 65 years old and over; by 2050, one in five will be 65 or older. It is estimated that one-third of European population will be over 60. The number of "oldest old" aged more than 80 is expected to grow by 180%.

Obviously, Governments are concerned about these population trends and about the associated rise in the cost of healthcare provision, due to the corresponding increase in chronic diseases such as diabetes, asthma, arthritis, heart failure, chronic obstructive pulmonary disease, dementia and a range of neurological disabling conditions.

In particular, Alzheimer's Disease, the most common form of progressive dementia, occurring in an estimated 10% of people over 65 years of age. In this disease, areas of the brain controlling memory, language, and perception are slowly destroyed by an inflammation process in the areas of the brain controlling these functions. The brain function of a person who has Alzheimer's disease continues to get worse until the person dies. Death may occur after as few as 3 years or as long as 20 years after an accurate diagnosis is made. The earlier is the onset, the more insidious the disease process.

In 2001, 23.4% of people over 65 living alone were affected by cognitive impairment short of dementia and 4.8% suffered from full-edged dementia. For people over 85, those numbers respectively were 38% and 27% [2]. Obviously, the number of elderly who live alone is going to grow.

Recently, many efforts have been made to develop intelligent environments to support 'ageing in place'. In fact, technology-rich environments can be useful to promote independent living [3].

Like other older adults who live alone, many people with Alzheimer's disease and other dementias want to remain independent and prefer living alone to the other options available to them [4, 5]. For such persons, living in familiar surroundings and maintaining regular routines can be reassuring and with the right support can often help the person maintain their independence for a longer period of time. In fact, when a person with dementia moves, either to live with a family member or to enter a care home, they may feel disorientated and experience further confusion, so there are some clear benefits for enabling the person to stay at home while this is still practical. Consequently, a specific area of interest is related to understanding how a person with dementia can be supported to live alone.

One potential solution lies in the provision of ICT-based solutions: a wide range of assistive technologies has been developed to support elderly people. However, few of these technologies have specifically focused on developing cognitive prosthetics for people with dementia [6].

In this context, this research work aims to improve quality of life and levels of independence of elderly people with mild dementia, through the provision of new solution. It propose an User-Centred approach to design a touch User Interface (UI) which is the hub of an home automation system able to monitor the house and reminds to the users some information when they approach the door to leave the home. In order to involve people with dementia in the evaluation of the first stage of the design process, a specific experimental protocol is defined.

1.1 The door-reminder system

The proposed reminder system is composed by: a magnetic door switch, a tablet interface, RFID antennas and tags, a ThereGate (by There Corporation) embedded Linux and a PC-server.

The door sensor communicates by Z-Wave with ThereGate platform. Furthermore, ThereGate and RFID antennas communicate with the PC by Ethernet connection. In addition, the tablet communicates with ThereGate by WLAN connection.

The tablet used to built the door alarm prototype is an ACER ICONIA TAB A500: it is an Android tab equipped with a 10.1”-touch screen.

Figure 1 shows some devices used to assemble the door alarm system.

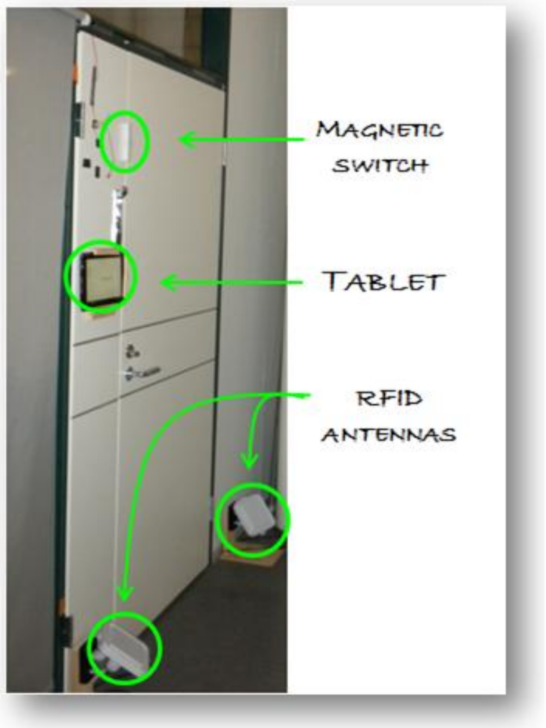

Fig. 1. Some devices used to assemble the door alarm: the magnetic sensor, the tablet and the RFID antennas.

While the ThereGate platform, the PC-server can be placed in each part of the environment, the magnetic door switch sensor and the tablet are located on the door. Instead, the RFID antennas are located around the door in order to detect the person who is approaching the door. The concept is to provide an RFID tag to the user and one to each everyday personal object. As a result, the antennas and the whole RFID technology not only are able to detect the people but also allow to detect and uniquely labelled each equipped tag-object that the user holds within the pocket and within the handbag (e.g., glasses and wallet). Since the tablet communicates with the ThereGate platform, the tablet interface is able to show to the user the information concerning the detected (or undetected) objects. Moreover, thanks to the surrounding Ambient Intelligence, the tablet is able to show all information regarding the sensing devices data, that are placed throughout environment. Consequently, when the magnetic sensor is switched (i.e., when the user opens the door in order to go out), the tablet can keep the user’s attention and show all the useful information.

2 Research Background

The term 'assistive technology' refers to 'any device or system that allows an individual to perform a task that it would otherwise be unable to do, or increases the ease and safety with which the task can be performed' [7].

Ambient assistive technology should try to help senior citizens with cognitive impairment in one or more of the following three ways [8]:

Assurance: the system should provide assurance that the person is safe and that he is performing necessary daily activities. If something happens, the system should react and the caregiver should be alerted.

Compensation: the system should help the senior citizen compensate for her impairment and assist her in her daily activities by reminding her of what she needs to do and how she should to do it.

Assessment: the system should allow the caregiver to assess the senior citizens cognitive status based on continuous observation.

In order to design high usable interactive systems, understanding needs and limitations of end users is a crucial issue. In fact, product usability depends on the characteristics of the end users and on the particular context in which it is used [9]. Consequently, users involvement during design process is particularly important, especially when designers have very different awareness of users’ needs. This can be achieved by adopting an user-centered perspective in each stage of the design process.

According to ISO 13407 standard [10], a proper User-Centered Design (UCD) process is structured in the following iterative phases: a) identification of users’ needs and establishment of requirements for product; b) development of alternative designs to meet such needs; c) building of interactive prototypes which can be communicated and assessed; d) evaluation of what is being built throughout the process and of the user experience it offers.

In order to implement successfully UCD methodology it is necessary involve people with dementia in design evaluation. A major challenge in such assessment is the methodology aspects on how to best understand, measure and interpret their experiences.

Many studies aiming at exploring the experiences and lifestyle of persons with dementia have used a qualitative approach, using interviews or systematic observations as a mean to gather information. Qualitative interviewing and analysis techniques provide an opportunity to obtain a detailed, flexible in-depth understanding of individuals’ beliefs and perceptions relating to a particular issue [11, 12]. At the same time there is an identifiable and consistent pattern in interview research of recruiting only those individuals with the likely ability to articulate their views. Consequently, only persons who do not have aphasia will be able to participate. Because of this, interview research conducted with persons who have dementia remains significantly limited compared to research involving the general population [11].

Reviews of interview studies conducted with persons with dementia confirm, despite the challenges of problems of expression, that it is possible to study their experiences in a way that is meaningful using adapted interview strategies [13].

Observations of the activities of the person with dementia are another indirect way to understand how the person with dementia experiences aspects such as the usefulness and usability of assistive devices. Observation studies of persons with dementia are most common in case of persons with moderate to severe diseases. However, observation methods used as complement to simultaneous open interviews can provide advantages when the subjects are affected by mild or moderate stage of dementia. An example of this approach was used in an evaluation study on the use of assistive technology to support safety among people with dementia in a group dwelling [14]. Such a study showed that the use of an ethnographic approach, involving both spontaneous open interviews in combination with participant observations provided reach and relevant data for the evaluation.

3 The Method

The approach adopted throughout the present project focuses on a user-centered design process which follows a sequence of three steps:

analysis of the needs of people with mild dementia to help identify areas of interest that could be improved thank to technological devises.

definition of design solutions accordingly to ICT design guidelines and construction of interactive prototypes;

evaluation of the solutions through the involvement of people with mild or moderate dementia.

This steps sequence can be undertaken more times throughout the duration of the project. Results from previous evaluation phases are analyzed in order to improve the design. The current study focuses on the first iteration within this methodology.

3.1 Analysis of user needs and definition of design solutions

The major problems that people with dementia face in life are due to cognitive impairments, which can make daily activities difficult to perform and may also lead to dangerous situations: citizens suffering from cognitive decline, often forget to perform important activities of daily life (ADL) as taking their medicine, eating or taking care of personal hygiene. People can also forget to turn off appliances and close doors or feel the need to leave the home in the middle of the night, when they should be sleeping.

Accordingly, the door-reminder system aims to provide compensation functions to the person who is leaving home, by using memory aids. These might help the user not only to improve their daily lives by reminding them to take some daily objects before leaving home, but also to address safety issue within the home environment. Memory reminders concerning the state of the house appliances could reduce the risk associated with living alone. It is possible to use memory aids and other reminders to help the person to use their skills longer. These may be useful in particular in the early to moderate stages of dementia, when the person is still able to understand the messages and to act upon it.

Based on these consideration, two scenarios has been defined:

- The user approaches the door to leave the home during the day;
- The user approaches the door to leave the home during the night.

In the first scenario, the system performs the following functions:

1) Get user's attention
2) Remind warning
3) Remind forgotten objects
4) Remind to close/lock the door

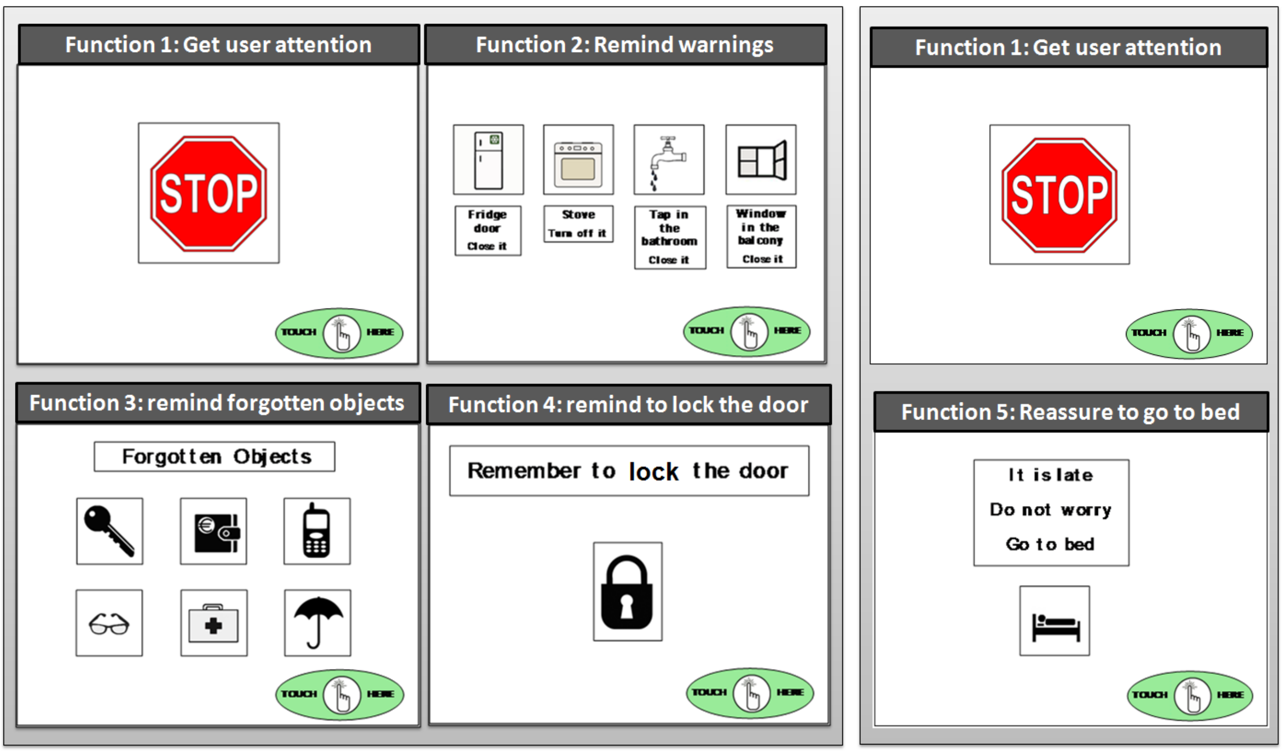

Fig. 2. Functions provided by the system in according to the first scenario (on the left) and to the second (on the right)

All information is provided through multimodal feedbacks (i.e., visual and audible).

The function 1 is simply an alert, which aims to stop the user in front of the door and capture its attention. The functions 2, 3 and 4 consist of some reminders, which are shown to the user before it leaves the home.

The various information is displayed one by one, according to an order of importance: firstly the warnings are shown (e.g., information concerning the stove, the oven, the windows, the opened taps, the door-fridge, the house-appliances), then, if the user touches the screen and all warnings are addressed, then the following information may be shown (e.g., information concerning the forgotten objects such as keys, glasses, umbrella, phone, wallet, medicine). On the contrary, if the user touches the screen and there is some unsolved warnings, then the screen cannot scroll (e.g., if the screen shows the third function (forgotten object) and he/she touches the screen, then it cannot scroll to the fourth function).

This information structure enables the user to navigate easily between multimedia and ensures a failure-free experience.

In the event that the person approaches the door during the night (the second scenario), the system tell him/her not leave the house and provide reassuring messages. If the person leaves the home, the system alerts a family member or a caregiver. Therefore, in this case the system implements the following functions:

5) Get user's attention
6) Reassure to go to bed and alert familiar/caregiver if the person leaves the home.

In order to develop ICT product for people with cognitive dysfunction, design considerations should incorporate the following features [15]:

- Controls positioned at the bottom of the screen: reducing fatigue when users hold their arms out to press the screen.
- Large format screen and large font sizes: invites participation and provides easy to read prompts for those with visual impairments.
- Minimal use of text: although people with dementia may retain the ability to read and understand the text, their limited short-term memory can make difficult to remember long passages of text.

According with these rules, the interface was designed to provide only necessary information to the users. In order to gain the max-contrast, all icons have been designed with white background and black text. The font Verdana was chosen because it is one of the most easy to read.

Both 3-dimensional and 2-dimensional, as well as coloured and black/white images have been proposed to represent functions. All the images were collected from the web, and edited by Photoshop in order to achieve clear and understandable pictures. The choice to use square shapes is motivated on the findings that the square items are better operated on the computer screen than rectangular ones [16].

Fig. 3. The set of images that have been proposed to represent objects

Other fundamental interface design rules are the so-called Fitts'Law and Hick's Law. The Fitt's Law states that the time taken to move from a starting point to a target depends on two factors: the distance to and the size of the target [17]. This law provides not only design guidelines about the size of the icons, but also about their position on the screen. For example, buttons positioned on the corners of the screen are more efficient because it reduces the possibility of the user overshooting the target [17].

The Hick’s Law [18] states that choice-reaction time is related to the number of stimulus-response alternatives or to the amount of information that must be processed in order to respond. Consequently, a good approach would be to organize products into a hierarchy with a few high level categories: users will make a quicker decision from two lists of five options instead a list of ten options.

According to these rules, in each screen there is only a command button, which is placed in the bottom-right corner of the screen. Pressing this command button it is possible to stop the sound alarm and to scroll the screen. Despite the fact that the button is equipped with a text message (“Touch Here”), the entire screen is touch-sensible, and the user can stop the alarm by pressing anywhere on the device’s screen. This solution might avoid the apprehension some participants felt about where to press [15].

Finally, Michalski and Grobelny have demonstrated that organize target objects in horizontal menus improve usability [18]. This is why it was decided to place the longer side of the screen in horizontal position and to organize information items horizontally.

In order to implement the system interface, it was decided to adopt a touch-screen. In fact, it has been demonstrated that touch screens are suitable for people with dementia because there is a physical connection between the users and the display and users receive immediate feedback when they touch the screen [15].

An high-fidelity prototype was created using an interactive PowerPoint presentation, which reproduce the real user interface behaviour. Despite the PowerPoint presentation could run on Android operating system, the animations such as the voice recorders and the sound alarm cannot work. For this reason, a video was created using the software "iSpring Free" directly from PowerPoint presentation. It is run on Android using the free App "SmartSwf".

In fact, it has been demonstrated that the use of low fidelity prototypes (e.g. paper prototypes, or other simplified prototypes) is less effective with older people: such an effect indeed could be exacerbated by symptoms associated with dementia.

Fig. 4. The high-fidelity prototype

4 Evaluation method

In order to assess the usability of the designed interface, a proper experimental protocol was defined.

It is characterized by two analysis which respectively concerned the usability assessment of the icons and of the whole interface.

USABILTY DIMENTIONS		OBJECTIVE OF ANALYSIS	METRICS	INVESTIGATION TECHNIQUES: Structured interview	INVESTIGATION TECHNIQUES: VIA and direct observation	UNITS
				DESCRIPTION		
	Effectiveness	Icons	Understandability	% of correct recognitions	Comments of users	number
	Satisfaction		Preference	% of user's preferences		number
	Effectiveness	Whole interface (visual information, audible information)	Understandability	average of user's judgement related to the whole interface and to specific visual/auditive informations		1-3 Likert Scale
					median of expert's judgment about the user ability to understand product funtionalities	1-5 Likert Scale
	Efficiency		Learnability		median of expert's judgment about the user ability to understand product funtionalities	1-5 Likert Scale
			Ease to use	average of user's judgement to the whole interface		1-3 Likert Scale
					median of expert's judgment about the user ability to perform the task without external help	1-5 Likert Scale
	Satisfaction		Utility	average of user's judgement to the whole interface		1-3 Likert Scale

Fig. 5. Experimental protocol: metrics description, usability dimensions and data collection methods

The usability of the icons is measured by the number of correct recognition of the represented object. For some objects, different visual metaphors have been proposed: in this case, at the end of the test se

ssion, users are asked to express a preference.

The usability of the whole interface is evaluated by task analysis. In order to collect data, both structured interview and behavioral analysis were used.

According respectively with the two use case scenarios, each screen is shown to the users. Users are asked to interact with the device in order to stop the notification of audible information feedbacks and to report what the device tells them to do. Then the users are asked to evaluate the understandability of the provided information by using a 1-3 Likert scale (1 = difficult to understand, 2 = neither easy or difficult to understand, 3 = easy to understand).

At the end of the test, user are asked to evaluate the ease to use and the utility of the device, by using similar 1-3 Likert scales.

Behavioral analysis is performed by using a pre-defined observation form. In particular, the following aspect are evaluated:

- Understandability ("the user is able to understand product functionalities);
- Learnability ("the user has learnt easily to use the product");
- Ease of use ("the user is able to start and execute a task by himself/herself").

A total of three experts (two behavioral psychologists and one cognitive psychologist) are involved. They are asked to observe the user's behavior during the execution of each task and to express their judgments on a Likert 1-5 scale.

4.1 Experimental session

Tests with users were carried out in one of the rooms of the Daily Activity Unit of I.N.R.C.A Centre of Ancona.

INRCA is the only institution officially recognised by the Italian Ministry of Health as "Scientific Institute for Residential and Hospital Care". It pursues its goal mainly in an interdisciplinary way, through clinical and translational research, training in the bio-medical field as well as in the organization and management of health care services, in particular by means of highly specialized hospitalization and health care.

The selection of people with dementia for the test was based on their MMSE score. The MMSE (Mini Mental State Examination) is the most commonly test used for complaints of memory problems. The lower the score on the MMSE, the more severe the cognitive impairment. A score between 24 and 21 indicates mild dementia. A score between 20 and 11 indicates moderate stage of dementia. A score lower than 10 indicates severe dementia. Because only people with mild or moderate dementia could be able to live alone, only these people were involved in the test.

A total of 20 persons have been involved in the tests. The following table shows the participants' profiles.

GENDER	AGE	PAST PROFESSION	LIFESTYLE	MMSE
Male	77	Municipal clerk	Living with his wife	23
Female	78	Worker	Living with formal caregiver	19
Male	84	Salesman	Living with his wife	23
Female	84	Teacher	Living alone	23
Male	67	Tradesman	Living with his wife	18
Female	85	Bank clerk	Living with her sons	22
Female	86	Knitter	Living alone	19
Female	77	Dressmaker	Living alone	21
Male	84	Official	Living with formal caregiver	28
Female	90	Cleaning leady	Living with her son	22
Male	78	Building carpenter	Living with his wife	27
Female	76	Head nurse	Living with formal caregiver	13
Female	87	Cleaning leady	Living alone	19
Female	91	Garment factory worker	Living alone	16
Male	89	Buildings constructor	Living with his wife	17
Female	78	Bookkeeper	Living alone	28
Female	72	Children's nurse	Living alone	20
Male	83	Chief designer	Living alone	20
Female	84	Cleaning leady	Living alone	15
Female	81	Bank clerk	Living with formal caregiver	17

Fig. 6. Users' profiles

The tests were carried out with the cooperation of four person:

Three test observers: they observe the test session without any interaction with the user and take note about the participant's performance and reactions;

Test moderator: the person who interacts with the participants and asks questions. Moreover, the moderator introduced the objectives of the test to the participants.

At the beginning of the session, the test moderator introduced the objectives of the test. After this, the actual test might start: the first step is the icon recognition.

The icons were shown to the user one by one. A question regarding the icon's meaning ("what is the object represented in this picture?") was asked at the same time as each icon was shown. Similarly, a question regarding the preference between the different way to represent the same object was asked at the same time as both icons was shown. For each icon, the participant's comments, (i.e., "think aloud" comments) were pinned, thanks to a Video Interaction Analysis (VIA).

Once this first test is finished, a short demonstration of the functional behaviour of the device is shown to the subject. Then, the two scenarios are simulated: the user has to tap on the interface in order to interrupt the audio feedback and to scroll the screens. Once the user has tapped the screen he/she is asked to answer two question: "What do you have to do?" and "Is the provided information easy to understand?"

At the end of the five tasks, two question regarding the ease of use and the usefulness of the whole device are posed to the user.

The mean time used to perform the whole test is about 18 minutes. During the whole time, the care centre responsible was present at the test.

5 Experimental Results

The Figure 7 shows the recognition rate of the icons which have been proposed. In particular for images that have received the highest number of preferences, the percentage is represented in black.

These results provide clear indications as to which icons should be improved. For example, it appears clear that the images used to represent the fridge and the bed are not sufficiently clear. It should also be noted that only one third of the subjects involved in the test has a mobile phone. This may have a negative impact on the result for the proposed images to represent the object.

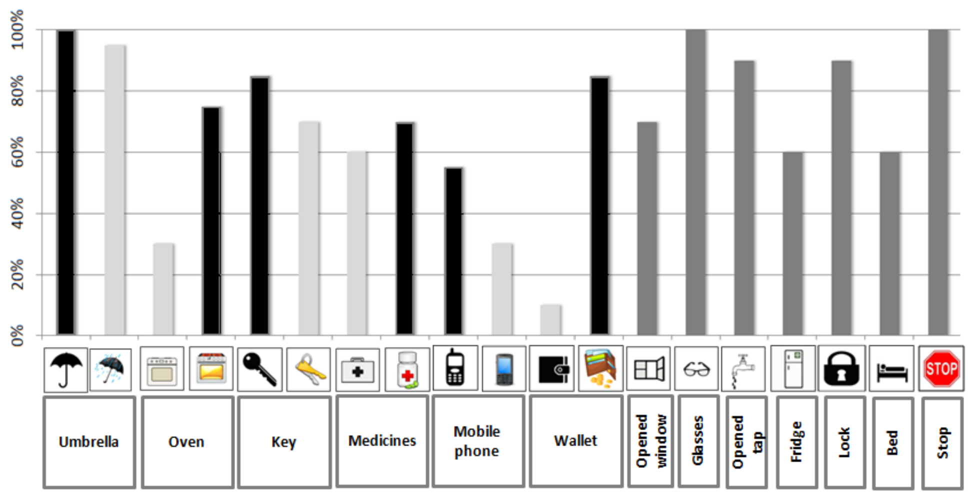

Fig. 7. Icons recognition rate and preferences (in black)

	Normal			Mild dementia						Moderate dementia										
	U9	U16	U11	U1	U3	U4	U6	U10	U8	U17	U18	U2	U7	U13	U5	U15	U20	U14	U19	U12
MMSE	28	28	27	23	23	23	22	22	21	20	20	19	19	19	18	17	17	16	15	13
Understandability	5	4	5	5	5	5	4	5	4	4	5	4	4	5	5	4	4	3	2	3
Learnability	5	5	5	4	5	5	3	4	4	5	4	5	3	5	4	3	3	3	2	3
Ease to use	5	4	5	4	5	5	3	3	5	4	4	4	4	4	4	2	3	2	2	2

Fig. 8. Medians of the judgments expressed by experts for each metric

The Figure 8 shows the values for the medians of the judgments expressed by experts for each metric, by using a 1-5 Likert scale.

These results show that the information provided by the system are easily understood by people with mild and mild to moderate dementia. However, the system does not seem to be suitable for people with moderate to severe dementia (i.e. MMSE <17).

The following figure reports the average of users' judgments about the understandability of the various screens. only the opinions of users who have earned a median value of expert judgments greater than 3 in all the metrics have been taken into account. Regarding to the "ease of use", only two users have found difficult to use the device.

In the end, although a total of 9 users considers that the device is useful, about a third of them has answered by saying that: "*it is not useful for me, maybe it could be useful for someone else*".

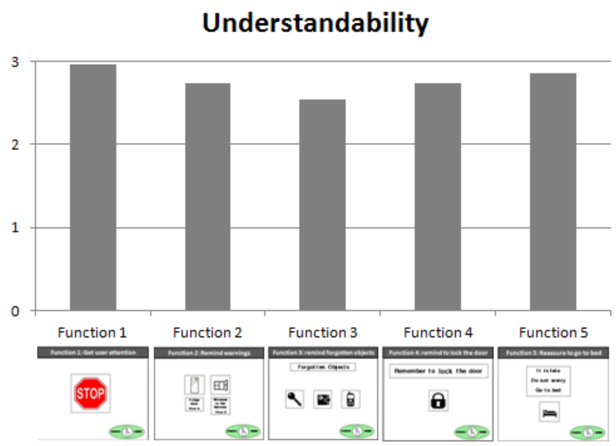

Fig. 9. Understandability levels of the five screens

6 Conclusion

A user-centered design method to support the design of people with dementia has been presented. This methodology has been applied to develop a novel user-interface. Usability analysis have been carried out according to a proper experimental protocol which has been specifically defined. Results showed that the designed interface is usable by people with mild and mild to moderate dementia.

In order to determine if the system is able to improve independent living of such people over a longer period of time, more pilot studies should be conducted. To this purpose a full-functioning prototype should implemented in order to simulate realistic situations.

Acknowledgement

The authors wish to thank I.N.R.C.A of Ancona for the support during the experimentation.

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