HEALTH MONITORING MODULAR PANEL
Interface Design and Evaluation

by

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Original scientific paper
https://doi.org/10.2298/TSCI170531130V

In this paper we present a conceptual solution of modular panel for measuring health parameters of the elderly. The conceptual solution was followed by a study that analyzed the design and evaluated interface of the system. Modular panel contains sensors, processing unit, and interface enabling data acquisition and communication between the user and the medical staff. Positioning of the panel within the residential unit was determined by the categories of actions which it should provide and functional areas of typical housing unit. Interface design is based on a specific type of users and is on the basis of the type of data that should be collected and displayed. Evaluation of interface is conducted by using two user groups, where the first is made up of people older than 60 years and represents the interest group of the study, while the second group consisted of people younger than 60 years as the control group. The collected data were analyzed and the results indicate that the simplicity of the interface suits good to the users. Elderly users need more time to conduct certain commands, but most of them understood interface completely. The limitations of the system, such as lack of information provided for the users, will be considered in the future work.

Key words: *smart home, elderly, modular, human-computer interaction, assisted living*

Introduction

The study presents the conceptual solution of the interaction of a particular group of users with the smart house system by means of the design of a modular element and interface for communication with a system that is located within the element.

Adapting housing units for the elderly and introducing a smart home technology involves a multidisciplinary approach. By combining skills in architecture, mechanical engineering, automatic control, sociology as well as psychology it is possible to generate adequate solutions that can greatly improve the living space of the elderly. This paper deals with the question of the interaction of the elderly with the smart house system, using a modular element that contains certain smart features as well as an interaction tool – the interface. The modular element is an object designed so that it can be installed in existing residential units and in a simple way enables the introduction of smart functions. In addition, the solution is meant to provide the gradual adaptation of each room individually according to the capabili-

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ties of users. The element centralizes some of the basic smart home functions and represents the site of interaction with all the systems that are being introduced.

Smart home system designed for the elderly is a complex issue and covers many aspects that must be taken into account. The study aims to propose a solution that will try to cover the main functionalities and aspects of interaction with them. In other words, the concept being proposed, groups at one place several devices that enable older people to perform as many automatic activities as they need, which are adapted to their way of living. Additionally, the concept takes into account the economy as an important parameter. More specifically, a modular solution denotes the element's characteristic to adapt to different spaces. Dimensions are adapted to the dimensions of furniture and architectural elements characteristic to the context. In this way, the introduction of new functions would be simplified, as the modular element would have been installed as a finished product, and only necessary work would be done additionally.

The content of functions assigned to a modular element can be diverse, but the interaction issue should always be solved in a simple way. For the interaction design proposal, we selected an analysis of the use of a group of functions that can be placed in a modular element – measurement of medical parameters. In other words, we propose a specific solution for this specific function, but the concept can be applied to other functions such as the heating system, the lighting system, *etc.*

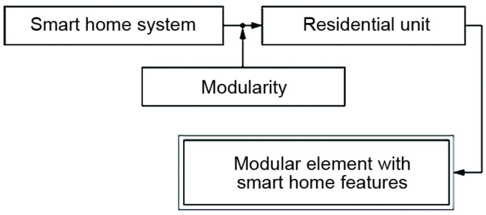

Figure 1. Concept for formation of modular element

The first step of this study was to form the principle, which possesses the characteristic of modularity. Setting this principle, is important in order to improve the way the system operates and make it applicable in various cases, before obtaining the final form of the element. The mentioned steps of concept formation are shown in fig. 1. The use of a modular panel requires a certain type of interaction which is achieved through the interface. Human computer interaction (HCI) with older users requires consideration of specific parameters to make the device available to as many users as possible [5]. While designing the interface, the system's architecture was taken into account as well as the requirements imposed by the user group.

Related work

Categorization within the smart home technology can be different. Demeris and Hansel [1] have defined six categories where they defined the categorization of the types of activities carried out by the elderly in their living space. The aforementioned categories are: physiological monitoring, functional monitoring, safety monitoring and assistance, security monitoring, social interaction, and monitoring assistance and cognitive/sensory assistance. Category aspects will be explained more in detail in the sequel of this paper. They have served as the basis for the formation of the concept of modular solutions for homes for the elderly. The same authors [1] show a number of examples that have already implemented smart home technology, where individual houses have been adapted to the elderly. It appears that these projects had a positive effect on the occupants and indicated the great benefit of this technology. The financial aspect that arises here as questionable of the question of how to form such solutions in the future, in a way that they are economical and accessible to a larger number of users.

Besides the economic aspect, there is the question the comprehensiveness of this technology. With the implementation of smart home systems in the homes of the elderly, it is important to include all activities that are carried out here and make them accessible. Raad and Yang [2] are in their work focused on the monitoring of physiological functions of the user. The principle of grouping several devices and the formation of the system described in their paper [2] in detail elaborates a large number of ways of monitoring the health status of the user. The emphasis is placed on portable devices that a user carries with him which enables the timely response of the competent services in emergency situations. This approach served as the basis for the understanding of monitoring the health status of the elderly within their housing units. Unlike Raad and Yang [2], in this paper, it is described a conceptual solution that due to its modularity, does not provide for devices that users carry with them, but are placed at a fixed place in the apartment. This difference represents an additional challenge, but the working principle is similar and the methods of measuring are the same.

Continuous monitoring of the living space of older people is of the equal relevance as well as the collection and further analysis of data [3]. A certain statistical data can be of great relevance for medical personnel who are assigned to help the elderly and for family members who take care of them.

In a study dealing with communication patterns in people over 65 who live in the New England region [4], it has been shown that this group of users most often use information technology to communicate with family members and friends as well as to get information on medical issues. In a given context, looking at the aforementioned group of users, two characteristic groups are distinguished, those who have accepted the use of information technologies in everyday life and those who are not. In the first group, interest in further learning evolved over time, while the other group is prone to anxiety and fear of contact with new information technology applications. The study [5] dealing with the use of computers and the Internet by older adults indicates that this group of users is the fastest growing. Because of cognitive and physical changes that occur during the lifetime, older adults use computer and the internet differently from younger users. Some of the differences are about vision, hearing and motor functions, which should be taken into account when designing an interaction between a user and a computer. The study points out that in addition to the physical changes that occur, there are also changes related to memory and attention, and we should pay particular attention to the ease of learning and understanding the interaction with the computer. The conclusion of the study is that the need for the use of information technologies in older adults occurs most often in a private context, while professional use is extremely rare. Interaction with technology should be motivational and should tackle the benefits of using information technology in everyday life, because there is a great need for future development of this field.

Considering the concept of a modular element and the interaction with the system contained within, we were partly guided by the study's findings [6] dealing with the use of affordable and robust smart home systems by elderly people. The results are encouraging and they show a wellness model that is constantly updated and predicts user behavior based on the patters that are obtained by analyzing the data. The results have shown that it is necessary to predict systems that are easy to install and robust. It should also be noted that there is a need for systems that can be continually upgraded in line with technology development and new needs arising from new knowledge acquired by users of this group. Monitoring systems [7] for people who depend on everyday care and help is a challenge of modern technology. The solution to these issues is in multisensory networks that are linked to a web application that medical personnel access remotely. The applied algorithm recognizes patterns of behavior in the users of this system, based on which timely support or assistance can be provided. In such systems, the economic aspect remains an open question and requires the consideration of concepts that are cost-effective so that mass production can be considered.

Research method

The study aims to address the issues that arose from the state of the art analysis, regarding the requirements placed on these systems. First and foremost, the concept responds to the question of robustness that repeats itself as the requirement of most previous studies. There is also an addressing the issue of ease of communication with the system. Our study aims to examine the concept from the point of view of the previously mentioned issues and to lay the foundation for further understanding of the concept.

Methodology of the design consists of a series of steps that generate the solution. The first step is the analysis of segments of ambient assisted living (AAL) systems, such as residential unit as part of smart home system. The functional units are analyzed and on this basis, we consider adequate zones for positioning the modular element and define its parts according to the role they should perform. After setting up a modular element in the space, we started developing detailed design of communication process that is achieved between all the users of the device. The communication interface is a key part of this device, because it provides data and visualizes information so that the users understand and properly use it.

Prior to the formation of the conceptual solution of the modular element and interface, we laid the foundation in the analysis of the housing unit as a set of functional units, in order to form a generic approach, applicable in different environments. In addition, defining the functional units ensures the clarity of the system that we want to examine. Simplicity and generic characteristics are principles that directly match the characteristics of a group which are insufficient knowledge of technology, fear of using unknown systems*, etc.* A system that is clear and easy to use will be better accepted and will rapidly evolve into an element that represents everyday life.

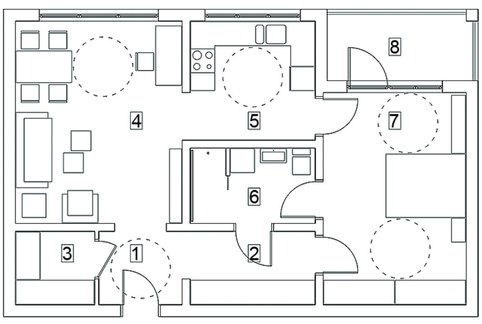

Figure 2. Residental unit used as basis for modular solution; *1 – entrance hall, 2 – corridor, 3 – wardrobe, 4 – living room, 5 – kitchen, 6 – bathroom, 7 – bedroom, 8 – balcony*

System design

The AAL for elderly (categories of functions)

Residential unit

A residential unit, fig. 2, can be analyzed with all the parts that generate it. In terms of spatial-program organization of architectural objects, residential unit is characterized by the fact that each room work as a separate function. Regarding this feature, different functional units (rooms) will be shown as categories, like it was the case with categories of smart home system. Thus there are living room, bedroom, kitchen, bathroom, *etc.* where all functional units in one apartment serve as a base point for smart home system structure.

Smart home for elderly principles

In order to generate a conceptual solution of modular elements that are installed in an existing residential units and that contain integrated technical smart home systems, it is necessary to provide an overview of the system by categories. Categories of functions that occur in the smart home system for residential units where elderly live can be divided into six groups [4], namely: functional monitoring, safety monitoring, physiological monitoring, cognitive support or sensory aids, monitoring security, and social interaction, fig. 3.

Functional monitoring is monitoring the performance of activities within the residential units, which require the participation of elements such as lighting, use of water, electrical appliances, *etc.* These activities are monitored in order to gain data on the uses of space and to facilitate the performance of certain activities. Automatic lights or heating as well as the control of these functions by users are some examples of the application of functional monitoring. *Safety monitoring* refers to the monitoring activities that may endanger the safety of the user. The presence of gas or smoke in the area, which can be spotted late, poses a serious threat to the elderly, if they do not have time to react. Data from sensors for gas, smoke, water, as well as the camera can serve for automatic notification of service for assistance. *Physiological monitoring* refers to the monitoring of vital functions of residents [2]. Blood pressure, pulse or blood sugar levels are data that can be entered into a database where doctors get informed about the patient's condition. Sensors that measure the aforementioned vital functions need to be located in residential units, at the places where they are available and easy to use. *Cognitive support and sensor aids* serve to help users who suffer from difficulties in the functioning, and facilitate the daily activities such as grocery shopping, paying bills and the like. Devices that would be associated with keys for example or other objects can provide information on the location of the same. Also, the system can provide notification about taking medication or other therapies. *Monitoring security and social interaction* is a function that primarily provides security for users of the residential unit and informs the centers for assistance if necessary. Also provides communication with family members and friends through devices intended for it.

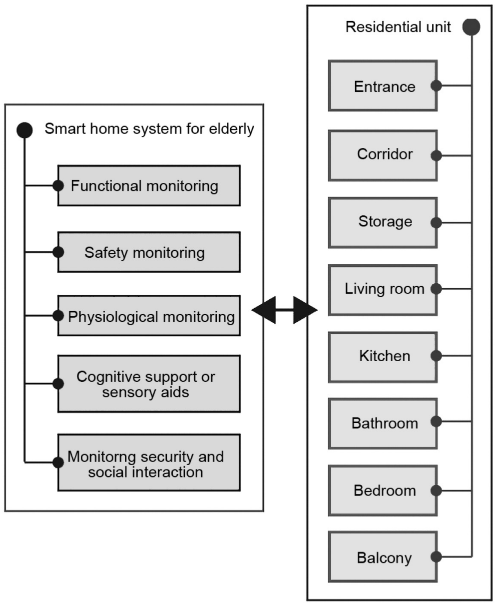

Figure 3. Constitutive parts of smart home system and residential unit

The concept of modularity

The biggest problem with elderly is the lack of understanding of this technology and fear that they can spoil something or make a mistake that will later jeopardize their safety or health. On the other hand, there are also frustration and anxiety, as the elderly were placed in situations where they are not able to understand the technology that is in front of them. Besides they encountered some inconveniences with young people who are trying to give them instructions. This problem greatly complicates the integration of smart home systems in homes for the elderly, which is why it is necessary to offer a solution that to the least possible extent endangers users [5]. The modularity of the system is based on the functions of residential unit in which the smart home system is integrated. Each functional unit of the apartment is treated as a separate entity and it is assigned with smart home features. The table will clearly show in what way is assigning of features done to each room of the apartment. This is the first step in the formation of modular solutions, because grouping of functions and devices at the rooms simplifies their subsequent merge into a single architectural element.

Table 1. Assigning smart home features to adequate rooms

	Monitoring security and social interaction	Cognitive support and sensor aids	Physiological monitoring	Safety monitoring	Functional monitoring
Entrance	x	x		x	x
Corridor				x	x
Storage		x		x	x
Living room	x	x	x	x	x
Kitchen		x	x	x	x
Bathroom		x	x	x	x
Bedroom	x	x	x	x	x
Balcony	x			x	x

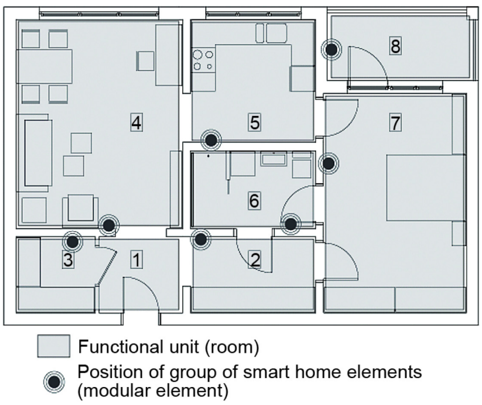

Figure 4. Functional zones and positions of modular elements; *1 – entrance hall, 2 – corridor, 3 – wardrobe, 4 – living room, 5 – kitchen, 6 – bathroom, 7 – bedroom, 8 – balcony*

The process of introducing the smart home features and assigning them to each room, is shown in the housing unit that is defined in the first section, tab. 1. Housing unit is made up of the main functional areas (entrance, corridor, storage, living room, kitchen, bathroom, bedroom, and balcony) and in accordance with the activities the smart home system is assigned to them, fig. 4.

Modular panel for health monitoring

Modularity as a principle explained in the previous section serves as the basis for the formation of the modular smart home element. In order to fully implement modularity in the functional sense, it is necessary for the form to be adequate and that the physical installation of a new element possesses the character of modularity. If we look at a unit measurement that is present in the design of buildings, characteristic dimension is 60 cm, adopted width on the basis of shoulders of man ad in accordance to it all in the inner space is sized. In addition to the sizing the area towards this unit, furniture is also made to these measures. The proposed element can be treated as an architectural element or as a piece of furniture.

Element is a panel made from gypsum attached to a structure, fig. 5. On the back of the panel, or in the other words in the space between the wall and the panel, the components of the smart home system intended for the current room are placed. From that place, networks are spread through which sensors and actuators are connected with the central unit. On the panel there is also an interactive display, alerts, display sensor for physiological data*, etc.* In addition, there are also panic button, camera, *etc.*

More specifically, the modular panel is composed of three segments which are connected to one another. Each segment has dimensions of 850 × 600 mm and it is made of gypsum boards at the front and aluminum carriers on the back. Aluminum carriers are mounted on the wall and provide distance to form a space to store the devices of smart home system. On the front panel, the plaster, all the sensors that can be grouped and instruments for communication are installed. They are placed at appropriate heights, all in accordance with the function they perform. Other sensors are placed on appropriate places around the rooms and connected to the central control unit. Between modular wall panels, the cables connecting all devices with a control unit are placed.

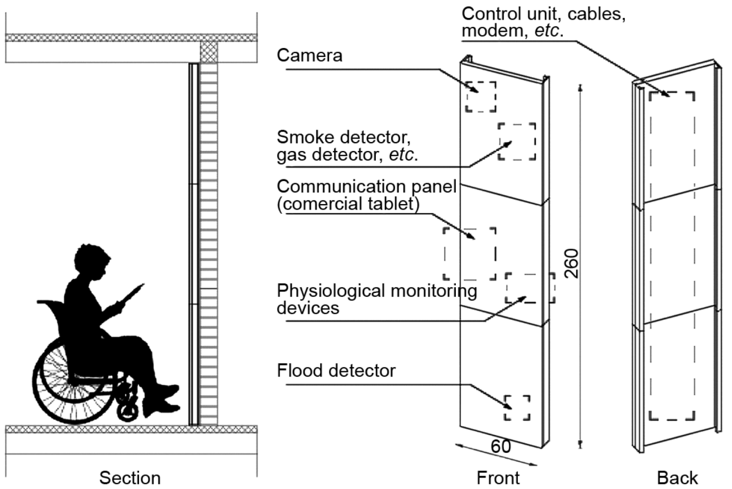

Figure 5. Some of the components of modular panel

Panel is brought in segments brings to the place of assembly and mounted on the existing wall. The height of the unit is set so that the users can use them regardless of whether the user is in a wheelchair or can stand upright. Subsequent adjustments, replacements or repair of the devices or complete modular panel is simple thanks to the easy way of mounting.

Human computer interface

With AAL system, interaction between humans and computers should be clearly defined in order to avoid for the AAL systems to remain unused. For users with special needs, there is a large variety in levels of computer technology knowledge, which implies that the interfaces have to adapt to a wider range of capabilities and skills [8]. The interfaces in AAL systems can be divided in two groups, explicit and implicit [9]. Explicit systems require direct interaction where the user must contact the system in order to obtain specific feedback. With AAL this characteristic can present difficulty due to the very nature of such systems which implies certain intelligence and independence in relation to the user inputs. Implicit HCI implies natural interaction where the monitoring of user activity and the various parameters that are obtained from the wearable and environmental sensors generate a specific output. This output is always at the service of the user, but does not require the user to communicate directly with the system and system operates independently.

In our study, the aim is to measure and gather physiological parameters, where the user is not required to have access to the values measured. The values obtained are sent to the database or to the person responsible for monitoring the state of the user in order for the feedback to be formed. This feedback information can be in the form of changes of patient's therapy, but if necessary it can involve the intervention of the doctor, alerts on certain conditions, *etc.*

Communication with computer, as opposed to communication between people means the possibility for errors that occur due to insufficient awareness of the context and the inability to achieve visual contact, which often has a big influence to communication [10]. The design of interfaces for communication, especially when it comes to persons who do not have enough knowledge of computer technology, should minimize the error. During the design it is necessary to conduct testing in order to identify common errors. The system for interaction should be established so that errors and inconsistencies are minimized.

At the proposed system, in accordance with the physical structure, the interface also has certain functional features which are consistent with the functioning of the device. Communication is first established between the user and the interface. In addition to the measurement of certain physiological parameters, the user enters the data through the interface and the entire data packet is forwarded on. Processing of data is not in the scope of the study, but the medical staff provides a new data packet which is returned as a new input to the device and to the interface. Feedback comes to user in the form of data or in the form of new therapy, interventions, *etc.*

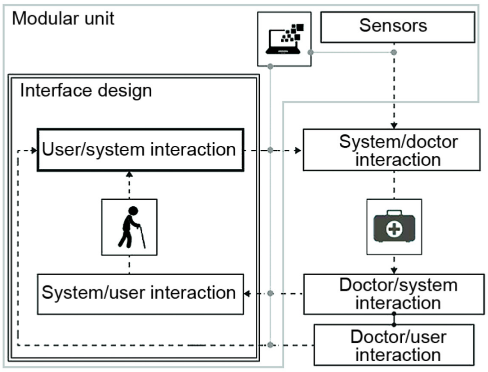

Figure 6. Functional structure of the system

Interface design should be accompanied by a certain method and in this paper is presented the one where the visual structure of the interface should follow the functional structure. Mirroring these two things should not be direct, but more in the form of interpretation. First, the functional structure is presented by using the graph that clearly shows the procedure of the information flow, fig. 6. Based on this, an intuitive interface is formed which, in addition to the user friendly graphical interface takes into account the specificity of the target group to which it is intended. These specific characteristics are imposed by disabilities which range from inadequate knowledge of technology, difficulties with cognitive abilities, dementia, *etc.*

Interface design

Translating functional structure of the system in the structure of the interface should be conducted according to a specified procedure [11]. Functional blocks of the scheme, such as communication between a user and a computer or computers, and medical personnel, would be represented as either active or passive interface elements.

The problem in communication between human and computer still exists with the elderly, and any further development of the interface for this specific group of user's needs to consider this. The gap between man and technology has reduced [12], but still, this problem has to be carefully addressed.

A study concerning the interface design for people with special needs, proposes the introduction of a virtual character [13] whose role is to communicate with the user and the smart home systems. It includes a large number of units within a single home, and among others there is a system for monitoring health parameters.

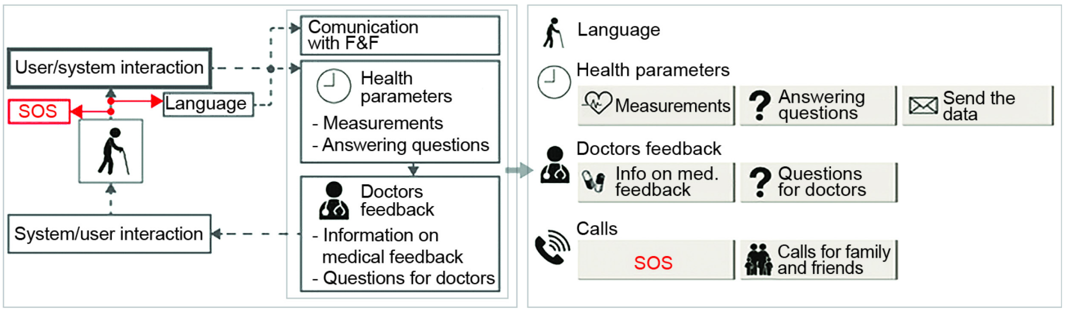

Figure 7. Gradual shift from the functional scheme of the system to HCI interface

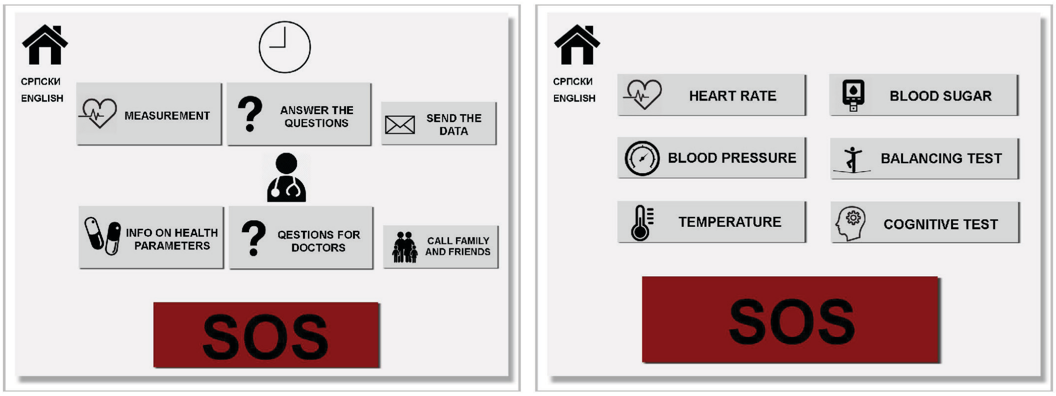

Figure 8. Design of the interface

When it is referred to smaller systems such as the proposed modular panel, it is necessary to establish a simpler interface that can later be developed in a much more complex structure. The proposed solution is based on simple geometrical shapes, and a simple path of movement through the measurement process and acquisition of medical parameters. Figure 7 shows a gradual shift from the functional scheme of the system to HCI interface. When communicating, user primarily has to choose the language that will be used. Also, the emergency call button should always be available on every page. Thus, the first pages provide primarily these two options, select the language and call the emergency services. When the user selects a language he is taken to the menu, which allows him to choose the measurement procedure or answer questions about his/her condition. Both procedures should be conducted, and the user can choose which by order to would happen. Also, users can communicate with friends and relatives via interface. In short, the interface involves three groups of commands. The first relates to the measurement and collection of data about the health of the users. The second is a communication with the medical staff. The third relates to communication with emergency services and relatives and friends. Each group has its own sub-commands and those are related to the new list of options. The design is simple and user friendly with large buttons and font size, fig. 8.

Evaluation of interface

A case study for the preliminary evaluation of the interface has been prepared. Two groups of participants have been established where the first group consisted of five participants older than 60 years, with different levels of knowledge in regard to the technology. Without previous explanations, they were asked to use interface and to answer the questionnaire. In addition, they were asked to choose the one option from the menu, specifically the command for blood pressure measurement. While conducting the task, time was measured for later analysis. This same task was performed with the second group that consisted of twelve adults younger than 60 who had to conduct the same task of finding the command for measuring blood pressure. The questionnaire consisted of seven questions for participants to assess the degree of clarity of the questionnaire, and the adaptation to their level of knowledge of the technology. The questionnaire consisted of seven statements, which were evaluated with grades 1 to 5. Score 1 means that the user was completely disagreeing with the statement, while five signified total agreement. The questionnaire referred to how easy and convenient the system is using the displayed interface, how fast the user can learn to use the system, can a user easily correct the error he makes during the use of the system, and whether the information obtained is clearly displayed and whether the system has everything that a user expects from it. They also had the opportunity to point out the shortcomings of the interface and to make suggestions on how to improve the current design.

Results

The questionnaire was completed by participants of the case study which showed that the three questions received average ratings less than 5. As described in the previous paragraph, statements rated with 5 signified total agreement, as opposed to statements rated with 1. The lowest grade (3.5) was given to the question that deals with the simplicity of the command for returning to the previous step after making a wrong selection. Questions related to whether users can receive all the information and functions they considered necessary got average grade of 4. From this it can clearly be concluded that users consider that these issues need to be improved. A number of users felt that the size of the letters should be bigger, and that different colors can signify differ commands.

Each of the participants from the case studies and from the control group measured the time he/she needed for selecting the command for measuring blood pressure. Participants had a time to familiarize themselves with the interface, but they were not familiar with the task. Time is measured in seconds. Figure 9 shows the results for 5 case study participants (users over the age of 60) which are marked CS1, CS2, CS3, CS4, and CS5, and 14 participants from the control group that have been labeled from U1 to U14. We presented two average values – the average value for the case studies control group (16.9 seconds) and the average value for control group (8.50 seconds).

Discussion and limitations

Lower grades of certain questions indicate that it is necessary to pay more attention to the easier way of returning one step back if the user makes a mistake. Due to the simplicity of the interface, only home button is provided, but the participants indicated that it is necessary to introduce additional *back* button.

Adding *back* button can have simple design like the other commands which will not further complicate the design of complete interface. It may also be considered to keep only

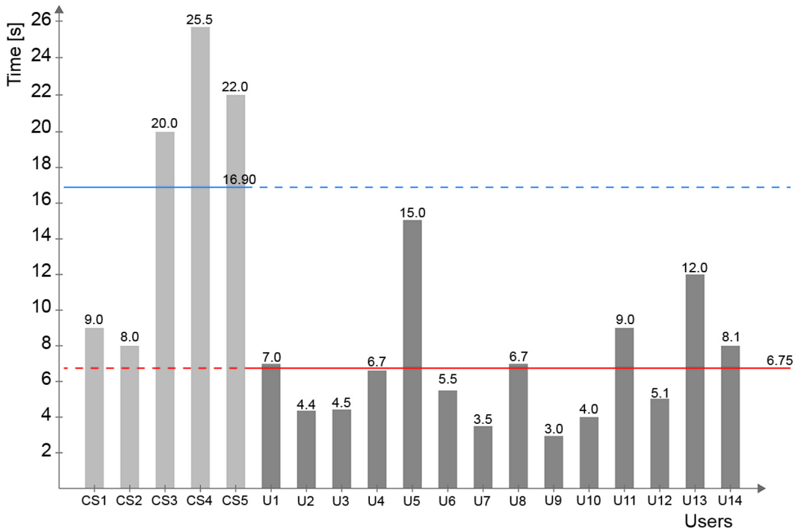

Figure 9. Results of the study

one button, but it could be the *back* button instead of the *home* button. Involvement of medical personnel was not in the scope of this study, it is included as a part of the system. Also, with the information provided by medical personnel, the history of patient's data could be formed where users can see the change of the measured parameters in a certain period of time. This information should be informative, but also it would be good to examine which of the data should be available to the patient in order not to cause further distress by misinterpretation of data. A possibility that the medical staff decide which data should be available to users should be considered. The involvement of medical personnel does not belong to the scope of this study, but is considered to be an integral part of the system. We include this in the interface design and remains an open question for further development of the system for future work. Although at this moment we are not dealing in detail with this aspect, it has to be included from the very beginning, because it is an essential part of the assistance as the output system for which we propose the concept.

The task that required finding the command for measuring blood pressure showed that case study participants, on average, need more time than the participants of the control group. Some of the control group participants needed more time than case study participants, which depended on the familiarity with technology. Differences of test results between the participants in the case studies suggest that knowledge of technology and ease of use of the interface is crucial.

Analysis of the interface points out the advantages and disadvantages of the entire system of modular panel. The information that patients want to obtain should be included from the very beginning of the design. Storage and display of the data, which is shown to be a necessary accessory, should be planned in advance in order to adjust the overall system architecture.

Conclusions and future work

The modular system designed for measuring and monitoring health parameters for elderly is a solution that should provide users with new opportunities within their home. These new opportunities are related to the monitoring of health status and a constant connection between the user and the medical staff. The system offers two benefits that relate to simplicity and robustness, as features that prove to be necessary, following a state of the art analysis. We focused on an interface design that displays system functions and enables good communication with the user. This concept supports add-ons in later phases of system development.

The architecture of the whole system is interpreted through the interface that is designed to have simple commands and allows users, without special knowledge in the field of technology, to measure health parameters. An analysis was conducted, which showed that the interface design is suitable for specific user group for which it is intended. There are limitations and drawbacks of the system that can be eliminated and which are related to the way information is presented.

Future work would involve testing of the entire system. The testing of interface is the first step, which showed that the connection between the system and users can easily be established. Further development of the interface and its prototype could enable system testing in a real environment. Further steps also include the involvement of medical staff in order to elaborate in more detail the aspect of providing support to users and monitoring their condition. This would demonstrate the efficiency of all system functions and examine its justification.

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Paper submitted: May 31, 2017
Paper revised: December 18, 2017
Paper accepted: January 21, 2018