Interface design for a robot assisting the elderly with medication intake

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Abstract

Medication intake can prove a complicated task for the elderly. Since roughly 50% of all prescribed medication is taken incorrectly (MacLaughlin, et al., 2005), simplification of this task might have beneficial effects on this group's general health and society's healthcare costs. In response, Assistobot Corporation has commissioned the present study alongside its development of an assistive robot for the elderly, called RITA (the Reliable Interactive Table Assistant). The aim of this study was twofold: Firstly to develop a robot interface to assist the elderly with their medication intake. Secondly, to investigate whether the target group is willing to accept medication intake assistance from a robot.

In order to fully map the process involved and so prepare for the initial stages of development, caregivers were interviewed about the medication intake task. The responses were analyzed and served to guide the development of the robot interface. The caregivers indicated that it was important for them to check whether the elderly actually took their medication. Wireframes were created before the actual interface was developed. A focus group was asked to provide feedback on the clarity of the design, and whether it met their requirements. Our test group found that the font size should be increased for optimal utility.

The interface was developed in HTML5 and tested in a user study which consisted of a usability test and the post-study Usability Questionnaire (PSSUQ) (Lewis, 1992). The questionnaire was extended with an acceptance questionnaire to investigate whether elderly would accept a robot to assist them with their medication intake. This questionnaire was based on the ALMERE-model (Heerink, Krose, Evers, & Wielinga, 2010) (Xu, et al., 2014).

The usability test showed that the majority of participants in this study (17 out of 19) were able to take their medication with assistance of the interface. However, they found it difficult to work certain interface settings, such as those concerning the notifications interval or their pharmacy's contact details. Furthermore, on a five-point Likert scale, the PSSUQ resulted in a mean score of 3.9 (between 'Neutral' and 'Agree'); the Robot Acceptance Questionnaire scored a 3.5. Along with the results of the usability test, the questionnaire findings indicate that the interface could be used by the elderly for assistance with the medication intake task and that they are willing to accept assistance of a robot with this task in the future.

Contents

“I've come up with a set of rules that describe our reactions to technologies:
1. Anything that is in the world when you’re born is normal and ordinary and is just a natural part of the way the world works.
2. Anything that's invented between when you’re fifteen and thirty-five is new and exciting and revolutionary and you can probably get a career in it.
3. Anything invented after you're thirty-five is against the natural order of things.”

-Douglas Adams, 2002-

1. Introduction

The number of elderly is increasing considerably. The category “elderly” usually includes people aged 65 and older. In a survey of 2012, the number of elderly in the Netherlands was estimated to comprise around 2.8 million people. This equals roughly 17% of the country's population, with this percentage steadily growing (CBS, 2012). Considering the increase in life expectancy, it stands to reason that the Netherlands deals with a population ageing at a considerable rate. This trend is not expected to stop in the next decades. In 2040 the percentage of people older than 65 is estimated around 26% of the total Dutch population (Volksgezondheid, 2014). Current tendencies to cut healthcare costs and resources as a result of the current economic depression force senior citizens to look for alternatives to previous safety nets. Instead of reliance upon care homes, the Dutch government hopes for elderly to be cared for by their social network, e.g. their families, friends, and neighbors. Consequently, those without family and friends are left with great insecurity regarding their future care.

One of the most difficult things for the elderly to manage independently is taking their medication as prescribed. Those who are in need of care often use many different types of medication. Taking this medication as described is very important to stay in good health. Nearly half of prescriptions in medical care are taken incorrectly by elderly (MacLaughlin, et al., 2005). The extent to which the medication intake behavior matches the medical advice or prescription is called medication adherence. Medication non-adherence can lead to a weaker health, hospitalization and therefore to increasing healthcare costs.

A solution to aid the current healthcare system in tackling the challenges of providing care for the elderly with less budget and resources is to develop innovative technological products that support people in their daily lives. Developing technological products for this age category is challenging, because of the possibility of inexperience with technology. Also, elderly may suffer from age-related difficulties, such as perceptual, cognitive, and motor skill declines which increase the difficulty of working with these products. Age-related changes usually manifest themselves between 60-70 years of age and their severity may fluctuate or differ between different people (Rogers, O'Brien, & Fisk, 2013). Examples of these changes are a decline in memory or a decline in visual and hearing capacities (Boot, Nichols, Rogers, & Fisk, 2012). There are already some products available that focus on medication adherence for the elderly like smartphone applications and medication reminding devices. However, a technical solution that supports the elderly with medication adherence and other daily activities has not yet been widely available.

RITA

Assistobot Corporation proposes an assistive robot to address the current challenges in providing healthcare for elderly. Assistive robots are developed with the aim to serve their users. With their robot RITA (reliable interactive table assistant) (Figure 1), Assistobot Corporation aims to provide care to elderly in hospitals and care centers (care homes). However, RITA focuses mainly on personal activities of daily living (p-ADL) for elderly who live independently at home. RITA is designed to monitor the patient and learn from their behavior.

Via tele-monitoring, RITA or the user can contact caregivers or family and friends. The robot will be able to help with medication intake and bring drinks and food to the elderly.

Figure 1 Rita

Goal

This study aims to provide a solution for the design of an interface for RITA that can remind elderly of their medication intake, offer support in doing so, and document the intake for future reference. The goal is that the elderly should be able to take their medication with the robot without help from a caregiver. A second aim is to investigate whether the elderly are willing to accept medication intake assistance from a robot.

The next chapter provides a background about medication adherence, age related declines, interface design, human-robot interaction, and technology acceptance of the elderly. Chapter 3 introduces a field study to provide a detailed description of the medication intake task. Caregivers explained in interviews how they support elderly with this task and what they expected from the robot with respect to the medication intake procedure. These interviews were the basis for the first basic designs made with a wireframes tool ‘Balsamiq’. These designs were evaluated in two focus groups. To begin with elderly and secondly with their caregivers. Chapter 4 handles information about the process of the design and development of the medication intake interface for the RITA. In chapter 5, a user study is described and consequently results of this user study are presented. The interface of the current study was evaluated with a usability test and the post-study Usability Questionnaire (PSSUQ) (Lewis, 1992). The questionnaire was extended with an acceptance questionnaire to investigate whether elderly would accept a robot to assist them with their medication intake. This questionnaire was based on the ALMERE-model (Heerink, Krose, Evers, & Wielinga, 2010) (Xu, et al., 2014). This thesis will end with a discussion and recommendations.

2. Theoretical Background

The present study focused on developing a medication intake interface for an assistive robot which is developed to support the elderly in their daily living. Multiple aspects influence the success of this task and need to be considered before the interface can be developed. Prior to defining how exactly to support the elderly with their medication intake task we need to understand the process of medication intake, 'medication adherence' and age related declines that the elderly experience. In order to take these age-related declines into account specific interface design considerations for the elderly need to be determined as well as human-robot interaction design considerations. A brief overview is provided with past and more recent research on assistive robotics. Finally, the acceptance of the robot interface is of importance, therefore we need to take theories about technology acceptance into account.

2.1 Medication Adherence

Elderly in need of care often use different kinds of medication. Taking medication as prescribed is very important to stay in good health. The extent to which the medication intake behavior matches the medical advice or prescription is called medication adherence. Roughly half of the prescriptions in medical care are taken incorrectly by the elderly (MacLaughlin, et al., 2005). Examples of incorrect medication intake are skipping an intake moment or not taking the right dosage of medication. Erroneous medication intake is directly related to a senior patient's age, their decline in several cognitive processes, and the amount of medication prescribed (Botella, Borras, & Mira, 2013). Medication nonadherence can lead to a weaker health, hospitalization, thereby increasing healthcare costs. High medication adherence results in increased pharmacy costs, though saves in overall healthcare costs due to its preventative nature. (Roebuck, Liberman, Gemmil-Toyama, & Brennan, 2011).

We can distinguish two types of medication nonadherence: Intentional and unintentional. Unintentional medication nonadherence involves having the intention to take the medication as prescribed but in some way failing to do so. An example of this is forgetting to take the medication. Intentional medication nonadherence involves deliberately choosing not to take the medication. For instance, because the adverse effects of the medication are so high for the patient that it does not compensate for the benefits (Dayer 2013). A study of Lowe and Raynor (2000) investigated the number of elderly that intentionally did not take their medication as prescribed. They found that 35 percent of the elderly did not take their medication as prescribed as a consequence of an intentional decision (Lowe & Raynor, 2000). Many methods to decrease medication nonadherence have been studied. Common studied methods for medication adherence are counseling, reinforcement, education and reminding (Dayer 2013). One reason why it is often hard for the elderly to remember to take their medication is due to a decline in their prospective memory (Dayer 2013). Medication adherence improves when the time-based prospective memory task is changed into an event-based prospective memory task (Boot, Nichols, Rogers, & Fisk, 2012), for instance, by giving a memory aid in the form of an alert. This alert helps the elderly to remember their medication intake moments. Hayes, et al. (2009) studied the medication adherence with a medication reminding system. They compared medication adherence of a group of elderly who were reminded of their medication intake by an audio beep and visual alarm with a group without reminding. They found a significantly better medication adherence for the group who was reminded. Another interesting finding was that elderly in both groups had better medication adherence in the morning than in the evening. (Hayes, et al., 2009).

One solution for medication nonadherence amongst the elderly could be developing technological solutions. There are already applications or systems available which help people remind to take their medication. Most of these systems are designed to be used by the general public and are not tailored to the elderly in specific. Botella, Borras and Mira (2013) state that documentation of the medication intake is a vital task for this age group. This enables caregivers or family to keep track of the medication intake by the elderly. Many of the existing systems fail to document the medication intake Botella, Borras and Mira (2013) investigate in their study the requirements for a technological solution to solve medication nonadherence. Firstly, it should notify people of their intake moment. Secondly, it should register a patient's intake or rejection thereof. It should ensure the correct medication is taken at the correct time, and register changes in prescription. Finally, the medication intake schedule needs to be customizable so that the elderly or their caregivers can match it to their personal calendar. Botella, Borras and Mira (2013) translated these requirements into a virtual pillbox developed for a mobile device. They tested their application and their results showed that it resulted in higher medication adherence (Botella, Borras, & Mira, 2013). A possible downside of this application could be that the mobile device and the medication are not always located in the same place. A solution for this could be a material pillbox. Hayes, Hunt, Adami and Kaye (2006) present a pillbox (the Medtracker). Their device is a portable 7-day reminder system. The mean medical adherence measured during the experiment was 79% and was checked afterwards by pill count. This is a considerable increase compared to the 50% medication adherence measured without the system. (Hayes, Hunt, Adami, & Kaye, 2006). However the reliability of pill count is questioned in other studies (MacLaughlin, et al., 2005). Although these studies show great results, they only provide a solution for medication adherence, and fail to address age-specific issues such as special care and independence.

2.2 Age-Related Declines

As mentioned before the elderly may experience prospective memory declines which may cause medication nonadherence. Prospective memory decline is just one of the age-related issues that the elderly may experience. The elderly could be considered a separate category from younger adults due to these age-related issues (Boot, Nichols, Rogers, & Fisk, 2012). These changes usually manifest themselves above the age of 60. For instance, the elderly might suffer from perceptional changes. The visual and auditory system are often needed to receive information from products or systems. The elderly commonly experience a decline in visual and hearing capacities. For example, they might have problems with reading fine details because they are less sensitive to properties of the environment. These properties are in particular, luminance, contrast, color and motion. Hearing decline occurs most often at high frequencies, around 8000Hz. High-frequency sounds can be difficult to hear or to distinguish. Moreover these sounds are hard to localize because they enter both ears simultaneously (Boot, Nichols, Rogers, & Fisk, 2012) (Lorenzi, Gatehouse, & Lever, 1999). There are several cognitive processes that show age-related declines. For instance, selective attention which is the ability to focus on certain information and ignore remaining irrelevant information. Furthermore, the elderly could suffer from decline in attentional capacity as well as an increase in the amount of mental effort required to perform a certain task at a certain time. Both selective attention and attentional capacity may be affected with age. Memory is another problematic area. We can subdivide memory in three stages, namely, processing, storing and retrieving of memories. Multiple types of memory may experience age-related declines. First, working memory capacity might show declines in the elderly. This means that it is harder for the elderly to process information in an active manner. Second, it may also be harder for them to remember something that needs to happen in the future (prospective memory) and to memorize facts (semantic memory) (Boot, Nichols, Rogers, & Fisk, 2012). Third, motor skills may be affected by age. Some elderly might find fast movements difficult to perform. Younger generations perform movements around 1.5 times faster. People of a higher age often have less muscular strength, although this process could be delayed by training the muscles. Besides the decrease of muscular strength elderly also have less control over this strength. As a result they may experience problems with performing very precise movements. This is actually influenced both by perceptual and motor skill declines. That is to say, for very precise movements secure depth vision and muscle control is of the essence (Boot, Nichols, Rogers, & Fisk, 2012).

2.3 Interface Design

Two critical aspects of interface development are understandability and ease of use. The field of interaction design or human-computer interaction (HCI) deals with how to present information to the systems users in the most optimal way. Accordingly, the approach is to include the user in every step of the process of product development. This approach is called user-centered design. There are four basic steps that help to design and develop an interface with the user in mind (Preece, Sharp, & Rogers, 2007). First, identifying needs and establishing requirements, which is about exploratory work. Once an interface is going to be developed it is important to define the target group and what their needs are with respect to the system. Apart from defining the target group, one should also consider what help or support the system could provide them with. What kind of tasks the user could perform with the system. There are several ways to investigate the target group and their tasks, for example: interviews, questionnaires, focus groups and observations. Second, the creation of the designs. In this step the identified user needs and requirements of step 1 should be translated to one or multiple designs. These designs could be low or high fidelity prototypes and simple pen and paper could be used or a wireframe software tool. Presenting these designs to the target group could help discover if they match their needs and requirements. The third step is the development of the interface. In this step an interactive version of the interface is built. This could be an interactive high fidelity prototype or a first programmed version of the interface. The fourth and final stage is the evaluation of the interface At this point in the development process the usability and user acceptance of the system will be determined. Usability describes how easy to use a system or interface is. A usability test can determine if people understand how to use the system and if they are able to use it effortlessly. A usability test should be performed by people of the target group. In the past developers were less aware about usability and thought that if they could use it the target group would also be able to use it. Often this ended in a mismatch because developers or designers are rarely comparable to the target group (Preece, Sharp, & Rogers, 2007). Usability tests can be performed in the field or in a laboratory setting. A good score on usability of the system is no guarantee for actual system use. A prediction of the user acceptance can be done by using techniques based on a technology acceptance model, see 2.6 Technology acceptance. These four steps can be seen as a repeated cycle or in other words an iterative process.

Interface Design Guidelines

Usability can be seen as a quality attribute of interface design. An interface needs to be easy to use and understandable. Furthermore, it needs to support the user in their tasks and needs to have the right kind of functionalities. We can define the following usability goals (Preece, Sharp, & Rogers, 2007):

- Effectiveness investigates to which extent the interface is doing what it is supposed to do.
- Efficiency explores whether the interface supports the users with their task in the most optimal way.
- Safety focuses on the extent that the user feels the interface protects them from undesirable situations. In other words the interface prevents them from making errors with serious consequences.
- Utility is the extent to which the interface has the right kind of functionalities. And therefore, helps the user with what they need to do.
- Learnability investigates if the interface is easy to learn.
  Memorability describes how easy it is to remember how the interface works. For instance, when a user does not use the interface for a while, and it is easy for a user to remember how it works.

In his book "Designing Interactive Systems Benyon (2005) presents an overview of practical interface design guidelines which can help to meet the usability goals. These guidelines are based on a number of findings from the field of psychology (Benyon, 2005). The first few guidelines are based on some of the rules of perception. Proximity is the first perception guideline and states that items that are placed together tend to be perceived as together by people. This explains that in design two clearly distinctive items are better placed further apart to prevent people from choosing the wrong one by accident (perhaps even with disastrous consequences). The second guideline explains that similarity should be used for related items. The third perception guideline is continuity. This focuses on designing an item so that it helps to continue to another item.

It is easier for people to use an interface which does not asks much of their memory capacities. The next guidelines are based on knowledge about memory and attention. Working memory capacity is limited. Therefore, it is best to not require the user to memorize many details. Chunking is a way to decrease the demand on the users working memory. Chunking is grouping of related items into larger groups. Placing related items close together helps the user in finding the right information or item. Moreover, an interface should anticipate on the fact that recognition is less demanding on memory than recall. Recognition is the ability to recognize information as familiar. By recall it is needed to retrieve certain information from memory. Having these guidelines in mind during the design of an interface could enhance the usability and user experience of the interface.

Mobile interface design guidelines

Recent developments in the field of mobile interface design can give guidance in making design decisions for the system we wanted to develop for the elderly. Mobile devices are used widely and due to limited space smart design decisions need to be made.

Skeuomorphism is a term that refers to design elements which are derived from items from the real world. For instance, the envelope icon which is widely used to refer to email in interface design, this is a realistic representation of a real envelope. The term skeuomorphism is inferred from the ancient Greek language. Skeuo means tool and morphism means shape. Until recent years skeuomorphism was a generally accepted design guideline. Starting in the eighties, it was used to explain to novice uses the concept of how a computer works. In 2013, Apple released a new version of their operating system. IOS7 was released with a flat interface design (Figure 2) (Apple Inc, 2013), which started an ongoing debate in the field of mobile design. Contrary to skeuomorphic design, flat design is a more simplistic design approach. It removes 3D components like gradients and shadows.

Figure 2 Skeuomorphism(left) vs. flat design(right)

Currently flat designs are most used by designers in the field of mobile design. One important advantage of flat design over skeuomorphic design is its simplicity. The simplicity makes it easy to process. All the distracting aspects from the skeuomorphic designs are removed. A minimalistic design with less distracting elements makes it easier to focus on content, navigation and user goals (Hill, 2014). Not everybody is embracing the flat design trend. Nielsen calls it a usability threat and proposes to search for the middle between skeuomorphic and flat design (Nielsen, 2013).Often designers go too far with minimalistic flat design which results in less usable designs that are confusing. If flat designs can result in usability problems for the general mobile application use, this could also be of considerable influence on the elderly who might be less experienced with mobile application use. For the elderly it was found that they thought realistic or skeuomorphic design was more esthetically pleasing. However, a more abstract or flat design is better for understanding by the elderly. (Cho, Lee, Kwon, Suk, & Na, 2015).

Another important aspect of mobile interfaces is the design of the targets. To begin with the size of a target. The smaller the target, the harder it is for a user to touch. It requires more accuracy. In a worst case scenario the finger covers the entire target, which makes it impossible for users to see what they are aiming for. Moreover, small targets can lead to errors when other targets are located closely. In this case the wrong target can be triggered (Smashing Magazine, 2012). This is also influenced by which finger the user uses to locate a target. On a tablet most people use the index finger and on mobile phones the thumb is most used. MIT studied human fingertips to investigate the mechanics of tactical sense and found that the average index fingertip has a width of 1.6-2 cm, and a thumb 2.5 cm (Dandekar, Raju, & Srinivasan, 2003). The guideline for target size set at 2.2. cm in width. Although results show that a target with a width below 2.2 cm or below the index finger width works quite well, performance is affected when the target width is smaller than 1 cm (Lee & Zhai, 2009).

Besides target size, another important aspect of target design is the feedback that is presented to the user. Feedback helps the user to interpret the state of the system. For touch screen target feedback we can define visual, auditory and haptic feedback. Design guidelines state that visual feedback should be immediate to ensure the user that their action is processed (Pitts, et al., 2012). Examples of visual feedback are hovering effects or presenting the user with a modal (pop-up screen) after a button touch. Auditory feedback is often presented to the user by a small sound after target touch or a sound when the user needs to be notified. Haptic or tactile feedback is presented to the user by small vibrations. This type of feedback is mostly used for notifications. Research found that trimodal (visual, auditory and haptic) feedback can decrease subjective workload (Pitts, et al., 2012).

Nowadays we can see a huge trend in mobile navigation. The so called “hamburger menu” is used in many applications. This is a small three-layered button (Figure 3). When this button is pressed a menu fades in.

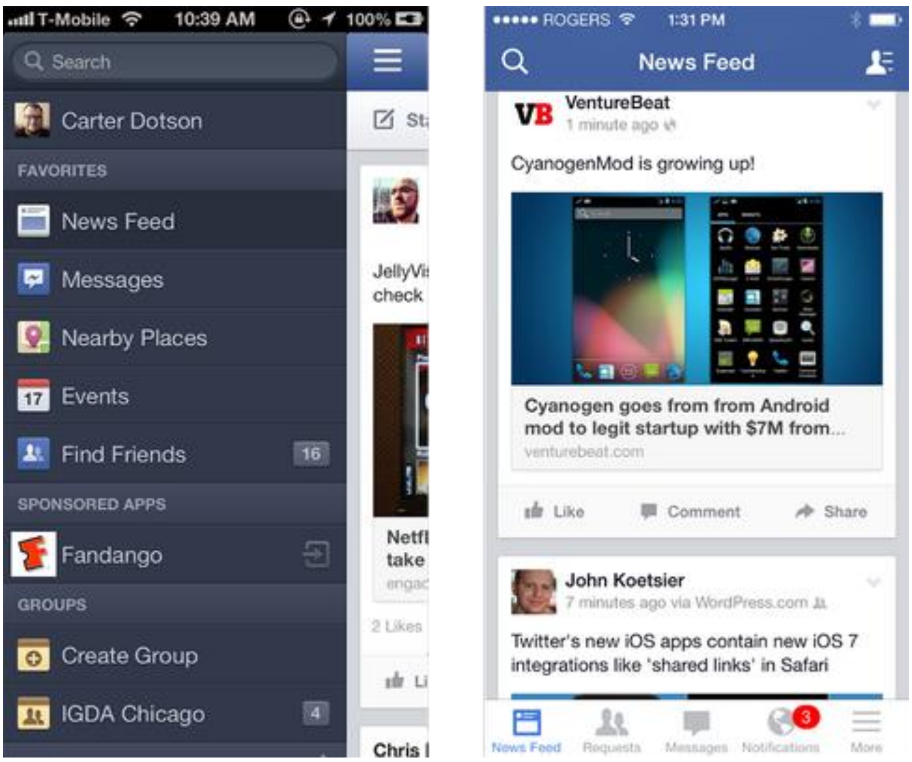

Figure 3 Hamburger menu versus bottom tab bar navigation

The main advantage of the hamburger menu is that is does not use much space of the small mobile screen when it is inactive. Many menu items can be stored out of sight. This advantage also results in a disadvantage. Users need to identify the hamburger icon as a menu. If the icon is not familiar for the users and all the available options are not showed, users might not discover its existence (Nielsen 2015). Another navigation type that is used in mobile design is tab bar navigation. In contrast to the hamburger menu the tab bar navigation makes the different menu items visible. As a consequence this menu type uses more screen space. Furthermore an accordion navigation can be used. It is called an accordion navigation because of its collapsible panels for menu items. This navigation type is especially useful for menus with many submenu items (Figure 4).

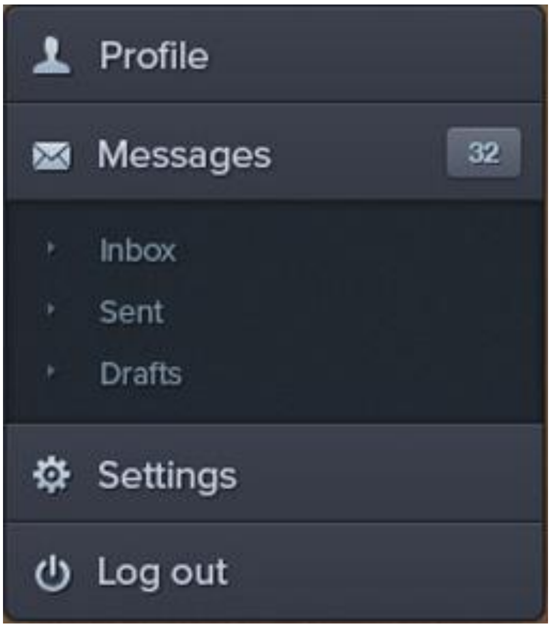

Figure 4 Accordion menu

Design Considerations for the Elderly

As discussed before, interface design for a senior target group requires a tailored approach because of their age-related declines. For instance, some elderly might have problems with reading fine details because they are less sensitive to properties of the environment. In particular, luminance, contrast, color and motion. It is therefore important to increase the size, brightness and contrast of items on screens. Moreover, a minimum of 12 point font size increases the chance that the elderly can read the text. The larger the font size the faster elderly may read the text (Bernard, Liao, & Mills, 2001). The best way to present text to read on a screen is black letters on a white background. (Boot, Nichols, Rogers, & Fisk, 2012). Furthermore for a coloring scheme the emphasis should be placed on the contrasting salient colors. (Rogers, O'Brien, & Fisk, 2013). Elderly people may experience some difficulties with focusing at different distances. If multiple displays are used they should be placed in closest proximity to the optimal reading distance which is around 40 centimeters (Boot, Nichols, Rogers, & Fisk, 2012).

High frequency sounds are hard to hear for the elderly so an alert should not exceed 8000 Hz and in some cases people already have a hard time hearing alerts of 4000Hz. The duration of alerts should be long enough to allow people to turn their heads and localize the sound (Boot, Nichols, Rogers, & Fisk, 2012). For this reason it is desirable to use low frequency alerts of long duration.

The control of movement often decreases with age so it is very likely that the elderly have difficulties with selecting small targets. (Rogers, O'Brien, & Fisk, 2013). Therefore, it is best to use large targets, which are not located too close to each other.

Elderly may encounter age-related declines in their selective attention. Consequently, task relevant items should appear prominent, and distracting aspects or stimuli irrelevant to the task at hand should appear as little as possible. Furthermore, elderly users should not be required to memorize too many details, and multitasking is not suitable for this target group.

Evaluation of a design through testing also asks for some specific considerations with this particular target group. First of all, computer jargon should be avoided because elderly could have little experience with the use of computers and this jargon. Secondly, instructions should be repeated if necessary throughout the study. Finally, a user study with elderly should be planned time wise with a wide margin. The Elderly often need more time to perform tasks than younger age groups. (Dickenson, Arnott, & Prior, 2007).

2.4 Human-Robot Interaction

Human-Robot interaction (HRI) is an emerging field of study related to human-computer interaction and Artificial intelligence and focuses on the interaction/communication between robots and humans. Activities in the field of HRI are understanding, designing, developing and the evaluation of HRI. Two types of interaction can be defined in this field: Remote and proximate interaction. Proximate interaction happens when the human is in the same area as the robot. For remote interaction this is not necessary, the robot can be controlled remotely (Goodrich, 2007). The current study focuses on proximate HRI.

In the early days a major goal of artificial intelligence was to develop a fully autonomous robot. From 1966 through 1972 the Artificial intelligence center of Stanford Research Institute (SRI) International (a non-profit research center in Silicon Valley) worked on one of the first autonomous robots called “Shakey” (Nilson, 1984) (Figure 5). This robot was able to autonomously navigate through an area with obstructions, although it needed strict lighting conditions and was very slow. The research on Shakey was of great influence for future work in this area. After the development of Shakey there were two major breakthroughs in the research field of robots. The first one was in behavior-based robotics when it became possible for robots to make a response to external stimuli instead of planned behavior. The second one was the development of hybrid architectures. This architectures uses a combination of a top-down approach (hierarchical) and sense-act approach (reactive). These two findings were of importance for future complex interactions between robots and humans (Goodrich, 2007).

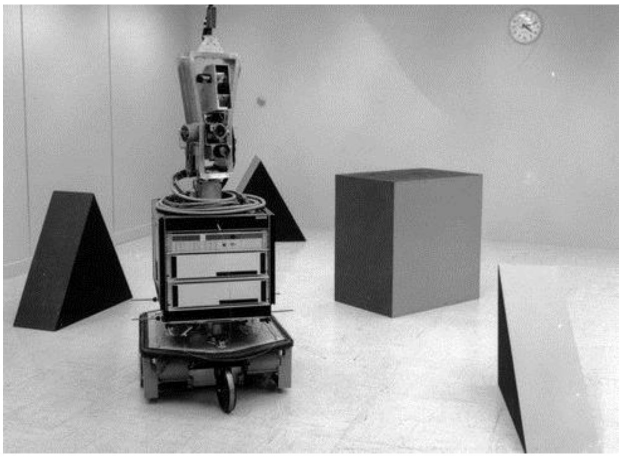

Figure 5 Shakey the robot (Nilson, 1984).

In 1990 scientists from different scientific fields such as robotics, psychology, and human-computer interaction came together, upon realizing that it was important to work in tandem, because of overlap in their research, and so the field of human-robot interaction emerged. As a consequence we can define human-robot interaction as a multidisciplinary field of study with as its main goal to understand, design, and evaluate robotic systems that are used by humans (Goodrich, 2007). There are different aspects of a robot that influence human-robot interaction. Of particular importance is the level of autonomy. Autonomy is determined by the tasks a robot can perform, the level of interaction with its users and finally, on the reliability of the robot (Beer, Fisk, & Rogers, 2014). A way to measure autonomy is through the robot's neglect tolerance. When a robot is "neglected" by its user we can measure if the robot's effectiveness in performing its tasks declines over time (Goodrich &Olsen 2003). A second aspect that influences human-robot interaction is the way information is exchanged between the robot and the user. We can distinguish a variety of ways. For instance, Waldherr, Romero and Thrun (2000) developed a gesture based robot interface. The interface uses a camera for gesture recognition. They use arm motions for gestures and in this study a high classification accuracy was found (Waldherr, Romero, & Thrun, 2000). Lazewatsky and Smart (2014) used a framework that lets people interact with the robot without any intermediary devices. The interface is projected in the environment, for example on a surface. Because of the input by simple motions they found that the interface could be used by people with motor disabilities (Lazewatsky & Smart, 2014). Another type of interface is the speech command interface. Panek and Mayer (2014) evaluated HOBBIT, a mobile assistive robot that uses a speech command interface. The main challenge of the HOBBIT project is to achieve a high level of automated speech recognition in far field recognition (Panek & Mayer, 2014). Often robots use multiple of these ways to exchange information. For instance, Tiwari, et al. (2011) developed a robotic platform for assessing medication adherence in elderly. Their platform combines a touch screen with a voice-based interface. Using multimodal robot interfaces might decrease cognitive workload and make interactions more natural (Granata, Chetouani, Tapus, Bidaud, & Dupourque, 2010)

Another aspect apart from level of autonomy and information exchange that influences the interaction between human and robot is the degree of adaptiveness. A very important element in the relation that the robot and user can build together is how the robot learns from and adapts to its user. In human-human interaction people also adapt to each other to enhance the relation.

On the other hand is it important to keep the degree to which the user has to learn to interact with the robot and adapt to it to a minimum.

In the field of human-robot interaction robots are often developed in multidisciplinary teams in which knowledge of different fields is combined to develop a robot in a most optimal way. Another method is to develop a prototype of the robot and evaluate it with subjects from the future user group. Sometimes this evaluation is performed early in the development process with a robot simulation. A third area is one whereby common human-robot interaction metrics are used. These metrics measure the degree of effort that both the user and the robot must contribute in order to effectively achieve the common objective (Steinfeld, et al., 2006).

2.5 Assistive Robotics

Assistive robotics have been proposed and developed as a solution to serve their users in multiple ways, for instance, educational robots for children and robots for people in need of care (Goodrich, 2007). Two types of assistive robots can be defined; a companion type, and a service type. The first one is focused on social support and the second one performs service tasks, for instance, assisting people in their daily activities (Heerink, Krose, Evers, & Wielinga, 2010). Besides having a distinctive type of task, these robots also differ in their physical appearance/design. A companion robot usually has a physique which invites people to have peer-to-peer interaction. A service robot in contrast usually has a more functional design.

Wada and Shibata (2007) conducted a study with a companion type robot called Paro (Figure 6). It is a robot with an embodiment of a seal and is developed with therapeutic purposes. Paro adapts its behavior to its elderly users and it was found that after some time strong ties with the users were established. Physiological analysis of urine levels of Paro’s users revealed a decrease in hormones which are related to stress (Wada & Shibata, 2007).

Figure 6 Paro

An anthropomorphic appearance reflects positively on the robot and on its social interaction with people, in contrast with Paro who resembles an animal. (Walters, Koay, Syrdal, Dautenhahn, & te Boekhorst, 2009) (Choi & Kwak, 2015). One of the best known examples of a robot with a anthropomorphic appearance is Kismet (Breazeal and Scassellati, 1999). Kismet uses facial affective cues for interaction which are based on human facial expressions. Kismet can interact in a complex social environment and give a human social cues an expressive feedback by facial affective cues (Breazeal &Scassellati, 1999) (Braezeal, 2003).

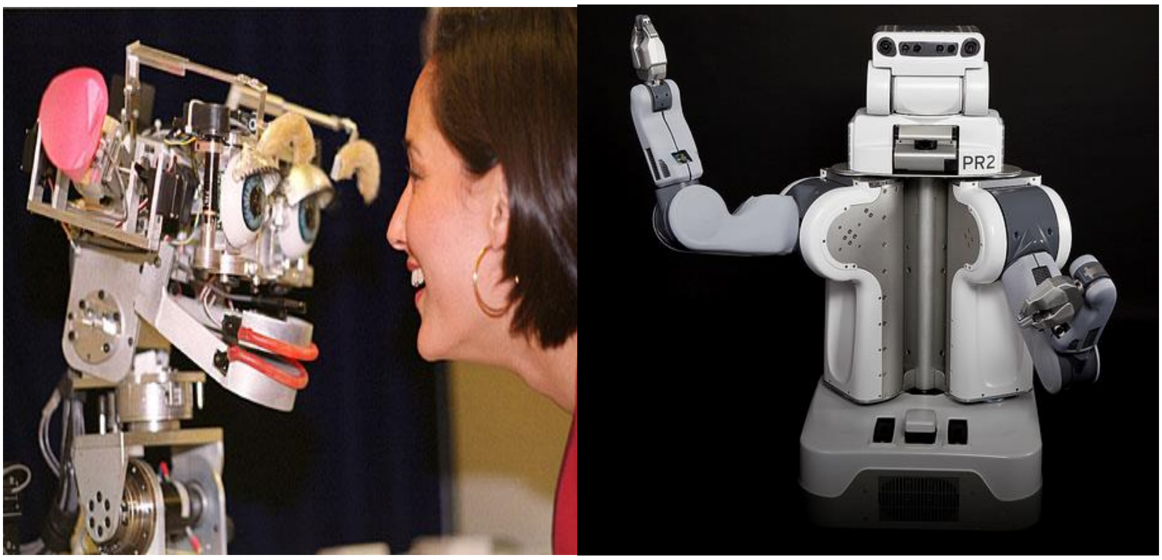

Figure 7 left:Kismet (companion type) right:PR2 (service type)

Contrary to companion-type assistive robots, service robots usually have a functional embodiment. Research shows that a serious appearance could enhance robot acceptance in service robots. Chenet al. (2014) proposed a robotic system (PR2) see figure 7 which gives assistance to people with severe motor impairments. PR2's main goal is to assist people with self-care, household activities and social interaction at a distance with other people. Consequently, the PR2 has a functional embodiment to be able to perform these functions. The development of the PR2 is a long-term project but it is currently able to shave and scratch a person with severe motor impairments (Chen, et al., 2013).

Acceptance of the robot is actually the main challenge to tackle during the development of an assistive robot (Robinson, MacDonald, & Broadbent, 2014). Research has shown that the more socially intelligent a robot is the better it is to interact with (Robinson, MacDonald, & Broadbent, 2014). In their research Broadbent, Tamagawa, Kersh, Knock, Patience and MacDonald (2009) investigated what the elderly want from a robot. They mostly indicated that they want the robot to react when they fall, assist with cleaning, remind them of medication tasks and track their location (Broadbent, et al., 2009).

Robotic healthcare solutions to assist the elderly

In order to address issues related to a cuts in healthcare budgets and resources and an increase in elderly in need of care, researchers have been working on robot healthcare solutions. There are multiple ways a robot can support the elderly. Mann et al. (2015) found that for receiving healthcare instructions people prefer a robot over a tablet. The elderly in this study thought that it was fun to use the robot. The results of Mann et al. (2015) suggest that using robots for healthcare support can be enjoyable for their users (Mann, MacDonald, Kuo, Li, & Broadbent, 2015). Tiwari et al. (2011) propose a robotic platform for assessing medication adherence in the elderly. They state that a robotic platform can assist the elderly with their medication intake via personalized and social interaction. They combine a touch screen with a voice-based interface for their robotic platform (Tiwari, et al., 2011). However, a literature review on automatic speech recognition applications for the elderly, by Young and Mihailidis (2010) showed that ambient voice recognition is not optimal for the elderly. It is error prone and evokes feelings of irritation by the elderly (Young & Mihailidis, 2010). Despite the automatic speech recognition, the elderly could complete their task successfully with the robotic platform of

Tiwari, et al (2011). Furthermore the elderly explained they felt comfortable using the robot and that it was easy to use. Rudzicz, Wang, Begum and Mihailidis (2015) developed a mobile robot “ED” for elderly with Alzheimer’s disease. Their robot assists with activities of daily living and also uses speech based interaction. They found that elderly with Alzheimer’s disease ignored the robot when the speech interaction was confusing. This accounted for 40 percent of the robot behavior (Rudicz, Wang, Begum, & Mihailidis, 2015). Data, et al (2012) propose a stationary medication management system to monitor elderly for pain and adverse side effects of their medication. This static robot was primarily designed to track the elderly’s side effects when a doctor prescribes medication dosage. Their experiments showed that their robot could enhance a cost-effective relationship between the elderly and the prescriber of medication (Datta, Yang, Tiwari, & MacDonald, 2012). Another monitoring robotic system is RoboCare (Cesta, et al., 2011) this system actively monitors elderly and detects exceptions in behavior and proactively responds to these exceptions. All these robotic systems helped the elderly directly or indirectly to cope with their age-related declines.

A different way to deploy a healthcare robot is to focus on the delay of these age related declines. iRobiS is a healthcare robot that has brain training games installed. A usability study for the application of these brain training games revealed that the elderly were willing to use the robot for these games and indicated to have fun during the use of the system (Ahn, Santo, Wadhwa, & MacDonald, 2014).

2.6 Technology Acceptance

Technology acceptance in general is a topic that is studied widely, however technology acceptance by the elderly in specific has been studied far less. It is a sub-category which so far has been largely neglected and is an important part of this study because we would like to investigate whether the elderly are willing to accept assistance from a robot with their medication intake. It is important to make a distinction between adoption and acceptance. When a user adopts technology, he or she uses it to its full extent, and is likely to replace or update it when required. Technology acceptance, however, describes an individual's more general attitude toward technology of a particular type (Renaud & Biljon, 2008). A model that describes the constructs of influence on technology acceptance is the technology acceptance model (TAM) and is first proposed by Fred Davis in 1985. Figure 8 shows an updated version (Davis, Bagozzi, & Warshaw, 1989). This model is the basis for many studies in the field of technology acceptance.

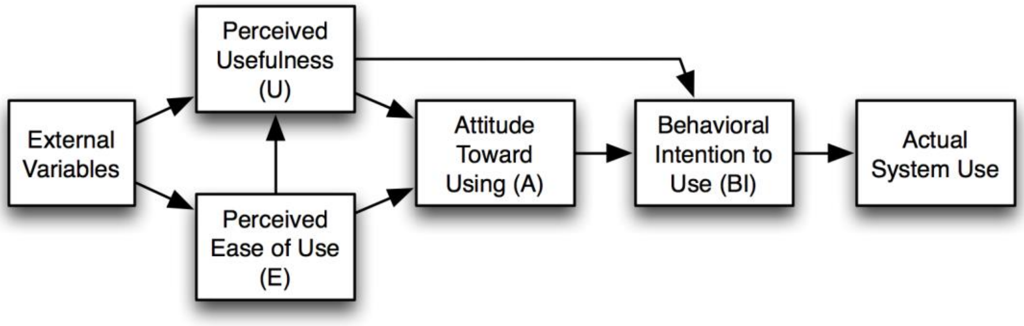

Figure 8 Technology acceptance model (Davis, Bagozzi, & Warshaw, 1989).

As can be seen in figure 8 the TAM includes a few factors that influence attitude towards technology acceptance. External variables are the first factors in the model. External variables could be for example age, or level of education. Perceived usefulness and perceived ease of use are influenced by external variables. Perceived usefulness is the belief that a user has that the system enhances his task performance. Perceived ease of use can be defined by the extent to which a user believes the system can be used without effort. Attitude toward using depends on perceived usefulness and perceived ease of use together. The Attitudes are positive or negative feelings towards using the system. Behavioral intention to use is predicted by attitude toward using and perceived usefulness. The final factor of the model is the actual system use and is predicted by behavioral intention to use. The actual system use is the expected use of the system for a longer period of time in the future.

A limitation of the TAM is that it does not account for social influence. It is believed that technology acceptance is influenced both by personal as social influences (Renaud & Biljon, 2008). Not including social influence as a factor might result in a less reliable prediction. A model that does include social influence is the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, Morris, Davis, & Davis, 2003) (Figure 9). The model combines the best constructs of all models that are presented in research after presentation of the TAM into one unified model.

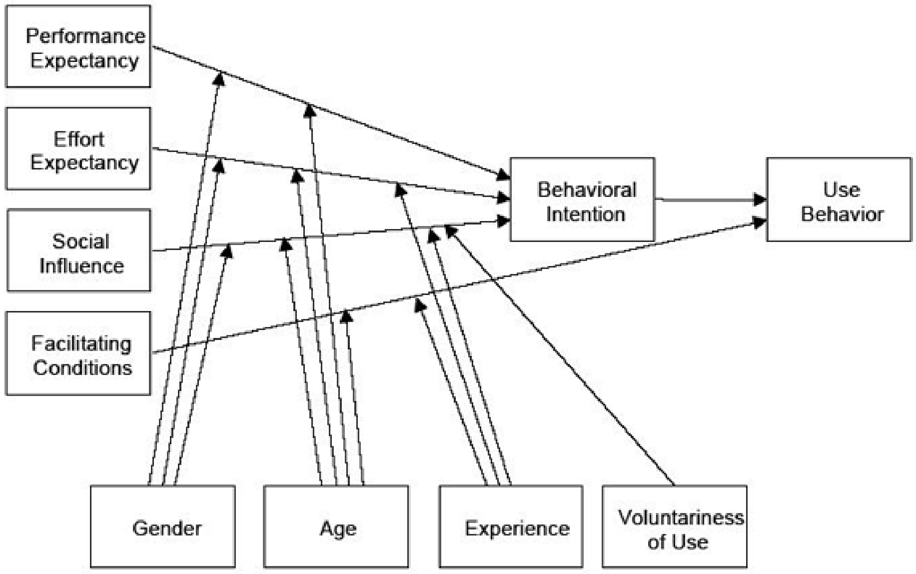

Figure 9 The Unified Theory of Acceptance and Use of Technology (Venkatesh, Morris, Davis, & Davis, 2003).

In the UTAUT the topic of perceived usefulness (TAM) is extended and renamed with performance expectancy (Figure 9). Perceived ease of use is also extended and renamed, which is now called effort expectancy. Another factor that is added is facilitating conditions, which are environmental factors. These different factors are influenced by gender, age, experience and voluntariness of use.

Robot Acceptance of Elderly

As may be seen in Figure 9, age, experience, and voluntariness of use are all aspects that influence use. These aspects also mark the elderly as significantly different from younger generations, as was discussed in terms of age-related decline and lack of experience. For example, the elderly people make three times less use of computers than younger age groups (Mitzner, et al., 2010). However, research shows that the elderly might be willing to use technology if they have access to information about the benefits, and if these benefits are of use to them (Rogers, O'Brien, & Fisk, 2013). The ALMERE-model is a model of technology acceptance which is developed to investigate the acceptance of assistive robots by elderly and is based on the UTAUT-model discussed before (Heerink, Krose, Evers, & Wielinga, 2010). Traditional technology acceptance models are not specific enough to also apply to assistive robots and do not focus on elderly particularly.

The ALMERE-model consists of four categories which consist of several constructs.

- General Attitude
    - *Attitude* investigates the feelings of the elderly towards the robot.
    - *Intention to use* is the prediction that someone is going to use the robot for a longer period of time.
- Instrumental Aspect
    - *Perceived usefulness* investigated if the robot is expected to be assistive.
    - *Perceived adaptability* investigated the extent to which participants expected that the robot could adapt to their needs.

    - *Perceived ease of use* can be explained by how effortless people expect the robot to be.
- Emotional aspect
    - *Perceived enjoyment* focused on the enjoyment that people thought they would experience while using the robot.
    - *Anxiety* questioned via the statements if using the robot for medication intake could evoke feelings of anxiety.
    - *Trust* investigates whether the elderly trust decisions of the robot.
- Social aspect
    - *Perceived sociability* can be explained by the fact if people expect the robot to perform social behavior
    - *Social influence* focuses on whether the elderly think that people in their near environment want them to use the robot.
    - *Social presence* investigates whether the elderly could see the robot as a social entity.
    - *Facilitating conditions* was a topic that focused on things in the environment that could influence using the system.

All together these constructs help to make a prediction of the use of the robot by the elderly, in other words, the expected use of the robot by the elderly for a longer period of time in the future.

3. Field Study on Medication Intake

Before we can start to develop a robot interface for a robot assisting with medication intake we need to understand what the target group needs from the robot. We therefore performed a field study on medication intake to obtain an overview of the medication intake task and to define the needs of the elderly and their caregivers concerning a robot which assist with medication intake.

3.1 Introduction

The main goal of this field study was to discover as much as possible about the medication intake task. What kind of action do caregivers perform to assist elderly with their medication intake? What are the rules and regulations that caregivers manage concerning medication intake? What functionality does the robot need to do to support elderly with their medication intake? We conducted interviews with caregivers and a medication expert to answer these questions. The received data was input for the design of the wireframes, which are low fidelity prototypes of the interface. The wireframes were discussed with a group of elderly and caregivers in focus groups.

3.2 Interviews with caregivers and medication expert

The first part of the field study consisted of three interviews with caregivers and a medication expert from Zorggroep Oude en Nieuwe Land. The interviews were held to discover how caregivers assist elderly with their medication intake and what they thought the robot needs to be able to do to give assistance to elderly with medication intake.

Two caregivers were interviewed; one working in a senior healthcare center and one that works as a district nurse. The healthcare center caregiver works for elderly who could not live independently because they suffer from physical or cognitive age-related declines and has over 15 years of experience in this field. The district nurse works for elderly who live independently but need assistance for medical issues and has over 5 years of experience in this field. Another interview was conducted with a medication expert of a large healthcare organization. She manages all rules and regulations concerning medication for the healthcare organization. We choose to conduct the interviews with these three people to approach the medication intake task from three different angles and collect a clear view of the complete task.

The interviews were semi-structured. A topic list was used with the following topics:

Current medication task:

- Medication storage.
- Refill medication
- Checks before giving medication
- Medication timing
- Documentation
- How to act after missing an intake moment
- What can go wrong

Medication task by robot:

- What does the robot need to know to assist with medication?
- What should the robot check?
- Video recording
- Alarmsystem/Notifications for caregiver
- What information does the robot need to give to the caregiver? (documentation)
- How to act when a client refuses the medicaton?

Although this topic list was prepared, it was also possible to discuss subjects that were not on that list but brought up by interviewer or interviewee during the interview. First, the participants were asked if they could give a detailed description of how they assist the elderly with their medication intake. Second, this task was discussed in detail by the separate subtasks. The interview ended with questions focused on what the robot needs to assist the target group with the medication intake task. What does the robot need in the caregivers opinion to be able to assist with medication intake?

The interview with the medication expert was mostly intended to check if the collected data were in accordance with the rules and regulations concerning the assistance of medication intake. The robot needs were also addressed with the medication expert.

Results

The caregivers explained that the task of medication intake starts at the pharmacy. People who need multiple medications, multiple times a day often receive their medication in a so-called medical pouch roll (figure 10). This is a roll of medical pouches containing the correct dose for every medication intake moment. The transparent bags have personal information, the intended intake date and time and information about the medication (for instance, color or shape of the pills) printed on them. The bags are transparent so that its content is always visible. The bags are filled by a computer-controlled machine and checked by the pharmacy staff, this means that the medical pouch roll contains the medication exactly as prescribed. This way of packaging is widely used by pharmacies although different pouch roll suppliers are used. The use of medical pouch rolls make it unnecessary for the elderly or the caregiver to check if the bags contain the prescribed medicine. They just have to check whether the content is taken at the prescribed time. The medication expert explained that caregivers are only allowed to hand out the medication to the elderly per intake moment. They are not allowed to change the quantity without consent of the pharmacy or doctor.

Figure 10 Medical pouch roll.

In some cases people need to take medication which are not included in their pouch roll. This occurs when medication is added from the prescription. It takes some time for the pharmacy to process changes in prescribed medication and for example, certain medication cannot be included in the pouch roll. When this occurs the caregivers receive a copy of the medication prescription which explains what they should give to the elderly and at what time. They need to check the expiration date on the package of the medication at all times.

For some medication the intake time is of vital importance. Both caregivers and the medication expert explained that for this medication the directive is that patients take their medication within half an hour of the prescribed time. When the medication is taken too late it is the caregiver who decides how to act. In these cases the caregivers always fill in a “client incidents report” in which they document which medication was taken too late, as well as the date and time and an explanation. In some cases they notify the doctor. The same procedure is performed when a medication intake moment is for some reason skipped by the elderly.

After the medication has been given to the elderly the caregivers document this in a ‘client dossier’. They only document if they actually saw the elderly take their medication. The district nurse explained that in some of her cases people are officially responsible for their own medication. In these cases she may prepare the medication but there is no regulation to be present during the actual intake.

Robot functionality

A schematic representation of the medication intake task can be seen in figure 11. The task of the robot can be divided in three main stages: Reminding, intake and notification. These three stages in turn cover subtasks of the medication intake task. The green line represents a successful medication intake moment. The elderly accepts the medication intake moment, the robot checks the pouch roll and documents the intake. The intake moment recording is saved so the caregiver could check the intake moment afterwards.

The robot needs to give the elderly the opportunity to postpone their medication for a maximum of 30 minutes. This gives the elderly the time to finish or stop their current activity and move on to medication intake. The elderly should also be able to cancel the medication intake moment. Although this is an undesirable action, the elderly should be able to decide whether to take their medication. In the case of cancellation the robot should notify the caregiver immediately, so they can respond to this situation.

An important distinction that is of influence to the robot requirements is; who responsible is for the medication intake. This could be the caregiver as well as the elderly themselves. If the caregiver is responsible it is important to be aware that the elderly should not be able to change robot settings.

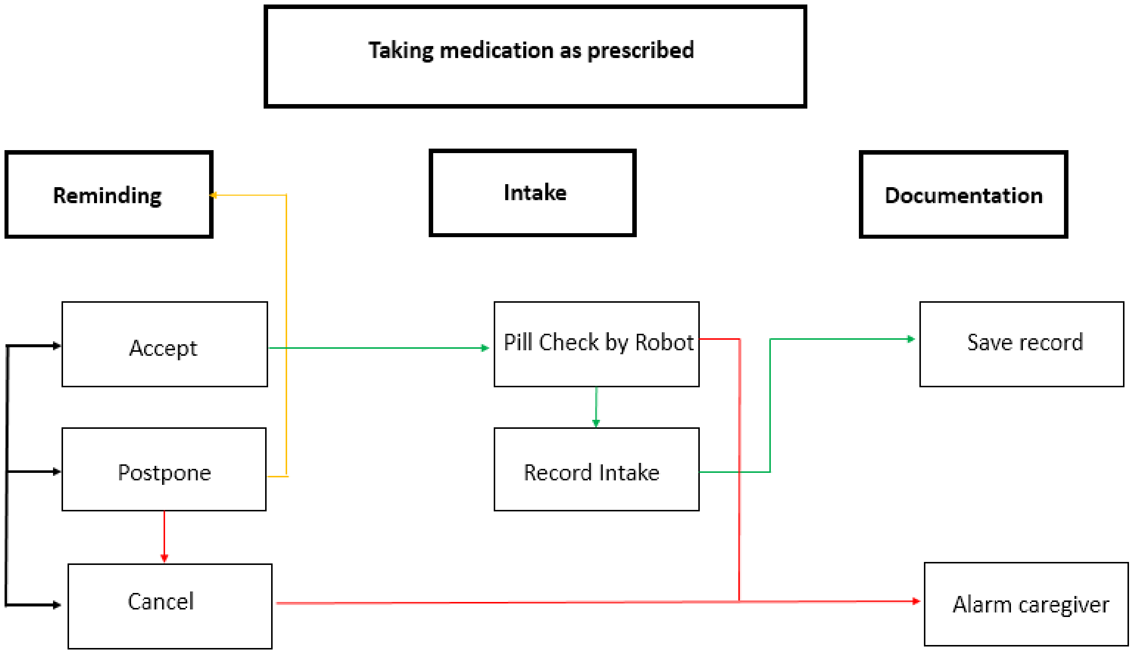

Figure 11 Schematic representation robot tasks for medication intake.

3.3 Wireframe design

Next we will discuss the design of the wireframes for the medication intake interface and we explain the design decisions made. The designed wireframes are low fidelity prototypes of the interface. Images of the wireframes can be found in Appendix D. The design decisions are based on literature on interface design, design for elderly and the outcomes of the interviews. Main goal was to design the wireframes in such a way that it fits the elderly's needs and that they are able to use it without help.

First of all we used as little text input in the designs as possible. Apart from the credentials of the caregivers no additional text input from the interface users is needed. During the design process we removed text input to keep the tasks with the interface as simple as possible. Furthermore we expected that it would be hard for the elderly to use a keyboard on such a small screen because of the possibility of decreased precise motor skills (Boot, Nichols, Rogers, & Fisk, 2012).

The interface gives a visual notification at every medication intake moment. Research has showed that medication adherence may improve when the time-based prospective memory task is changed into an event-based prospective memory task (Boot, Nichols, Rogers, & Fisk, 2012). Because of this reason the notification is included to help to remind the elderly when to take their medication.

Taking the medication as close to the exact prescribed intake time is preferable although the interviews revealed that the elderly should have some freedom in their medication intake time so that it is not interfering with their current activities. For instance, when someone is having a phone conversation it should be a possibility to postpone the notification and therefore the medication intake. Caregivers explained in interviews that medication needs to be taken within 30 minutes of the prescribed intake moment, therefore we chose to let the caregiver receive a notification after 30 minutes which says that the elderly postponed their medication for too long. There is also a third option which is for skipping the medication. In that case the caregivers receives a notification immediately.

The medication intake is recorded with the purpose that the caregiver can check if the elderly actually did take their medication. After finishing their medication intake the elderly presses 'done', this triggers a pop-up which asks them to confirm that they really took all their medication. After the confirmation they return to the homepage. In the wireframes this function was presented by showing an avatar on the screen.

Apart from the part of the interface which helps people with their medication intake there is a settings part. In this part the elderly or their caregivers can change the notification, medication or personal settings. Elderly who are not responsible for their own medication do not have access to this part of the interface due to safety reasons. In that case the caregivers need to give login credentials to proceed to the settings part.

The functionality located at the settings part is divided in a side tabbar navigation. The notifications tab gives people access to setting that has to do with the notifications. The notifications interval can be changed (the interval of receiving new notifications after postpone or ignoring). It is also possible to set the maximum amount of time to postpone the notifications. This is standardly set at 30 minutes because caregivers explained that the elderly could not take their medication any later without consideration of a caregiver. The medications tab stores information about the medication; when the intake moments are, what way of medication storage is used and if there is any medication prescribed apart from the storage system. The final tab with personal information gives the option to set who is responsible for the medication: Elderly or caregiver.

Most of the text used in the interface is drafted in the first-person. The main reason to for this was to give the robot/interface personality. Although it is not an intention of RITA to be a companion-like robot, giving the interface personality and communicating in the first person could enhance the user experience (Robinson, MacDonald, & Broadbent, 2014).

3.4 Focus groups with elderly and caregivers

The outcomes of the interviews were input for the design of wireframes. Wireframes are low-fidelity prototypes of the interface. The actual design of the wireframes will be discussed in chapter 4. The wireframes itself can be found in Appendix D. The wireframes were evaluated in focus groups with elderly as well as caregivers. The first goal of the focus groups was to discover if the wireframes covered the complete medication intake process. The second goal was to see if we could find usability issues that need to be solved.

Focus group elderly

The focus group with elderly consisted of 5 people with an age range of 77-84 and a mean age of 79.8. Three of them lived in a healthcare center. Two of them lived on their own but received daily care and attended occupational therapy at the same healthcare center. The elderly were recruited via the healthcare center. All the participants gave informed consent for participation in this focus group and for audio recordings of the focus group.

The session started with an explanation of this study, which it is about a robot which assists elderly with medication intake. It was explained that the robot has a computer screen and that during the focus group was going to be discussed what will be presented on that screen. This explanation was supported by a picture of the RITA. The elderly were provided with a paper copy of the wireframes and the wireframes were also presented on a tablet computer. The first wireframe showed a medication alert which asked if the user would take, postpone or skip the medication intake moment. The second and third wireframes both showed a confirmation modal which asked consecutively if the user was sure to postpone or skip the medication intake moment. The fourth, fifth and sixth wireframe showed the intake moment. The wireframes showed that the intake is recorded, give options to leave the screen, for help and finish the intake moment. The seventh, eighth and ninth wireframe showed the settings. These wireframes were used to show how settings concerning notifications, medication and personal information can be changed. It consists of back, save and help functionality.

Every wireframe was explained in its context and discussed separately with the elderly. The elderly were asked to explain what they thought they could do with that certain wireframe and if they understood the items displayed. Furthermore, it was also free for them to come up with suggestions for changes.

After all the wireframes were discussed the readability was checked and the elderly were asked if they could distinguish the different items on the wireframe from a distance of 1 meter. This would be approximately the distance between the user's eyes and the screen on the robot. We measured this to determine if we used the right font sizes in the wireframes.

The focus group ended with time for questions and remarks and a discussion about what their opinion was of a robot which helped them with their medication intake.

Focus group caregivers

The focus group with the caregivers consisted of three district nurses and one healthcare center caregiver all working for the same healthcare organization. One of the district nurses also gave an interview earlier in this study.

The group session started with an explanation about the procedure and information about the study supported with a picture of RITA. The wireframes were presented on a tablet. The wireframes were interactive because they were presented on a tablet so it was possible for the participants to go through the different parts of the interface by clicking on the wireframe buttons. Per wireframe it was discussed if the different items were clear to the caregivers. Furthermore, it was discussed whether the wireframes included all the necessary subtasks of the medication intake task. And whether it was possible in their opinion for elderly to take their medication with support of this interface independently. It was made sure that all the wireframes were discussed but for the remainder this group session was unstructured.

Results

Although they were able to read the original text, 3 out of 5 of the elderly participants preferred bigger fonts. Apart from the size of the text they stated that they could differentiate the different items on the wireframes.

The first wireframe that was discussed with the elderly showed the medication notification. One participant did not understand the 'cancel' option. She mentioned that she never skipped her medication and that she would never intentionally skip her medication. Three of the other participants agreed with her. One participant explained that he sometimes skipped medication when he went out and did not want to take a diuretic.

The participants did not understand what to do with the wireframe which showed them that they had to take the medication in front of the camera (figure 12). They did not understand how to use this screen or the help button in the upper right corner.

Figure 12 Medication intake wireframe

The caregivers expected that it is possible for elderly to take their medication with this design. However, they had some suggestions for improvements.

The first suggestion was about the modal that presents the option to take, postpone or skip the medication. The choice to postpone or skip is undesirable so the caregivers stated their doubts about the similar levels of intake, postpone and skip in the notification modal.

The second suggestion was to add an emergency option in the interface. They wanted an option for the elderly to notify them directly if something went wrong. They gave the following scenario as an example. "The elderly by accident drop all their pills on the floor and are not able to pick them all up". In such a case they stated that they want to be notified so they can make sure that the elderly still take the medication in time.

A final suggestion had to do with the scenario that anything goes wrong with the medication or if a mistake is made with the medication pouch roll. In such a scenario the pharmacy or doctor needs to be contacted. The caregivers explained that it would be useful to have pharmacy and doctor contact information presented in the interface.

4. Interface Design and Development

The research described in this thesis involves the design and development of the interface of the medication intake task in which the robot will assist. In this section we give an overview of the assistive robot of this study. Furthermore, we give background information on the development of the interface and explain the design decisions made based on the theoretical background (chapter 2) and field study on medication intake (chapter 3).

4.1 RITA

The robot of this study is called RITA. RITA is an abbreviation for Reliable Interactive Table Assistant. Assistobot is currently developing the fourth prototype of RITA (Figure 13). Although Assistobot Corporation aims to provide care to elderly in hospitals and care centers (care homes), RITA focuses mainly on personal activities of daily living (p-ADL) for elderly who live independently at home. RITA is designed to monitor the patient and learn from their behavior. Via tele-monitoring, RITA or the user can contact caregivers, family or friends. The goal is for the robot to be able to help with medication intake and bring drinks and food to the elderly.

Figure 13 RITA

RITA has a functional embodiment with a classic wooden exterior to fit in the elderly’s home interior. It has a red button on top to stop the robot entirely in case of emergency. The large screen as shown in figure 13 can be used for presentation purposes. The smaller screen is a touch screen used for controlling and interacting with the robot. RITA also has two depth sensors, one on the top and one beneath the touch screen. Rita contains a laser at the bottom of the robot for localization as well as sonars for obstacle avoidance. The robot is adjustable in height.

The assistive robot RITA runs on ROS, a robotic operating system, to manage hardware and software resources (Quigly, et al., 2009). The developers of Assistobot mainly use Python for the back-end development of the different robot functions (behaviors). For the front-end development of the robot interface we choose to work with HTML5.

4.1 Interface

The creation of the interface consists of two parts; prototyping and developing. We started with wireframes prototypes because they are quick to make and easy to adjust. Developing a working interface costs more time and it is more difficult and time consuming to make adjustments.

Prototyping

Interviews with caregivers (chapter 3) gave input for the first designs of the interface. With a wireframe computer program "Balsamiq" wireframes were made. Balsamiq is a software tool for the creation of wireframes with its main focus on usability (Balsamiq Studios, 2014). Balsamiq has functionality to make different wireframes interactive. The wireframes are therefore very useful for collecting feedback on designs. We chose to create low fidelity sketchy wireframes (Figure 15) (Appendix D). We made that decision because we hoped on receiving content focused feedback rather than on minute details which are not of high importance in this stage. Feedback on the wireframes was collected from elderly in a healthcare center and caregivers as described in chapter 3.

Development

For the actual development of the robot interface we chose to work with HTML5. This is the latest version of HTML and combines the functionality of HTML and XHTML. With the introduction of HTML5 it is possible to play interactive content without an installed flash player. One advantage of an interface developed in HTML5 over Python is that it can easily run on other devices than the robot (mobile phone, PC or tablet).

We made an external CSS (cascading style sheet) file supported with a Bootstrap plugin (Github, 2014) for styling purposes. Bootstrap is a collection of tools which provides a basic style for the most commonly used HTML elements. Using bootstrap helps to create a consistent design over all interface elements.

JavaScript with the jQuery library plugin (The jQuery foundation, 2014) was used for the interactive part of the interface (for example manipulation and event handling). With the jQuery library it is possible to create more functionality without writing many lines of code. Using jQuery is very efficient and decreases response times.

The interface records the medication intake. A diagram of this process can be seen in figure 14. This process starts when the elderly press the 'intake' button at the medication intake modal. This action triggers a JavaScript function which sends a HTTP get request to the GNUI server. The GNUI server is a Django webserver (Django Software Foundation, 2015) which is started by the ROS environment. This webserver hosts an HTML5 admin interface (GNUI) which is used to control some ROS nodes. One of the ROS nodes controlled by the GNUI server is the ROS USB Cam node. This node is able to capture images from the webcam and the GNUI server can be used to access these webcam images. The medication intake interface uses a HTTP GET call to the GNUI sever to get these images. For the interface to be able to show moving images this process is repeated every 250 Ms. The process stops when the elderly press 'done' on the medication intake screen.

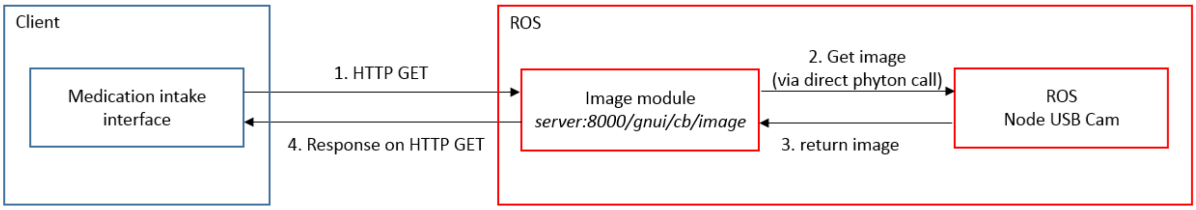

Figure 14 Medication intake recording diagram

Figure 15 shows the structure of the ROS environment. The USB Cam node is a ROS node. A ROS node is a process that performs a certain computation and ROS consists of several nodes that communicate with each other. To host the HTML5 medication intake interface on the RITA it needs to have a webserver. A Django webserver is used since it is written in Python and can communicate seamlessly with the ROS nodes. Assistobot developed a custom module (image module) which runs on the webserver and links the GNUI server to the ROS node. This module is used by the medication intake interface to receive the webcam images.

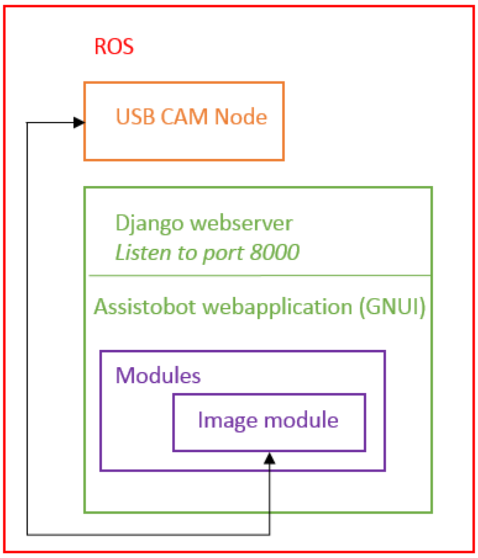

Figure 15 ROS structure

To save the changes that are made with the interface HTML 'Local Storage' is used. We chose this solution for saving changes for experimental purposes. Eventually this will be resolved by the robot itself. Local storage stores data locally in the used browser. An advantage is that there is no expiration date for the data storage and it is possible to store large amounts of data (W3Schools, 2015).

4.3 Design details

Style

The font size used in the interface had the CSS property ‘large’. Originally we chose a smaller font-size but as a result of feedback from the elderly during the focus group the font-sizes were increased. Larger fonts are used for page headings. The highly contrasting combination of black text on a white background is used throughout the interface. These considerations were necessary to make sure that most of the elderly are able to read the text on screen despite of age-related visual declines (Rogers, O'Brien, & Fisk, 2013).

We choose a simplistic design guide in the form of flat design for this interface. This means we do not use 3D components like gradients and shadows. A minimalistic design makes it easier to focus on content, navigation and user goals (Hill, 2014). For the elderly research found that a more abstract or flat design is better for understanding (Cho, Lee, Kwon, Suk, & Na, 2015).

The color scheme of the interface consists of a type of blue for buttons. This color matches the corporate identity of Assistobot and blues are often associated with calmness, reliability and friendliness (Chapman, 2010).

Interface changes with respect to the wireframes

We have made some changes to the medication intake modal. As can be seen in figure 16, the elderly are now prompted to choose the left blue button which says ‘intake’. Taking the medication as close to the exact prescribed intake time is preferable although the field study revealed that the elderly should have some freedom in their medication intake time so that it is not interfering with their current activities. For instance, when someone is having a phone conversation it should be possible to postpone the notification and therefore the medication intake. This is the middle option of figure 16 and is designed to be less outstanding than the intake button. Caregivers explained in interviews that medication needs to be taken within 30 minutes of the prescribed intake moment, therefore we chose to let the caregiver receive a notification after 30 minutes which says that the elderly postponed their medication for too long. There is also a third option which is for skipping the medication. In that case the caregivers immediately receive a notification.

We choose to support the medication intake modal with an audio notification. This audio notification could notify the elderly when they are not focusing on the robot interface. For the sound of the notification we chose a lower frequency sound because this increases the chance that elderly can hear it. Age related declines make it harder for them to hear high frequency sounds.

Figure 16 Medication Notification

Pressing the ‘intake’ button triggers the robot camera and a recording is started. The interface displays a message which tells the user to stand in front of the robot for recording the medication intake. This message is included due to feedback during the focus group with the elderly and disappears after 5 seconds.

Furthermore we have changed the side tabbar navigation into a top tabbar navigation because that resulted in more space in the width.

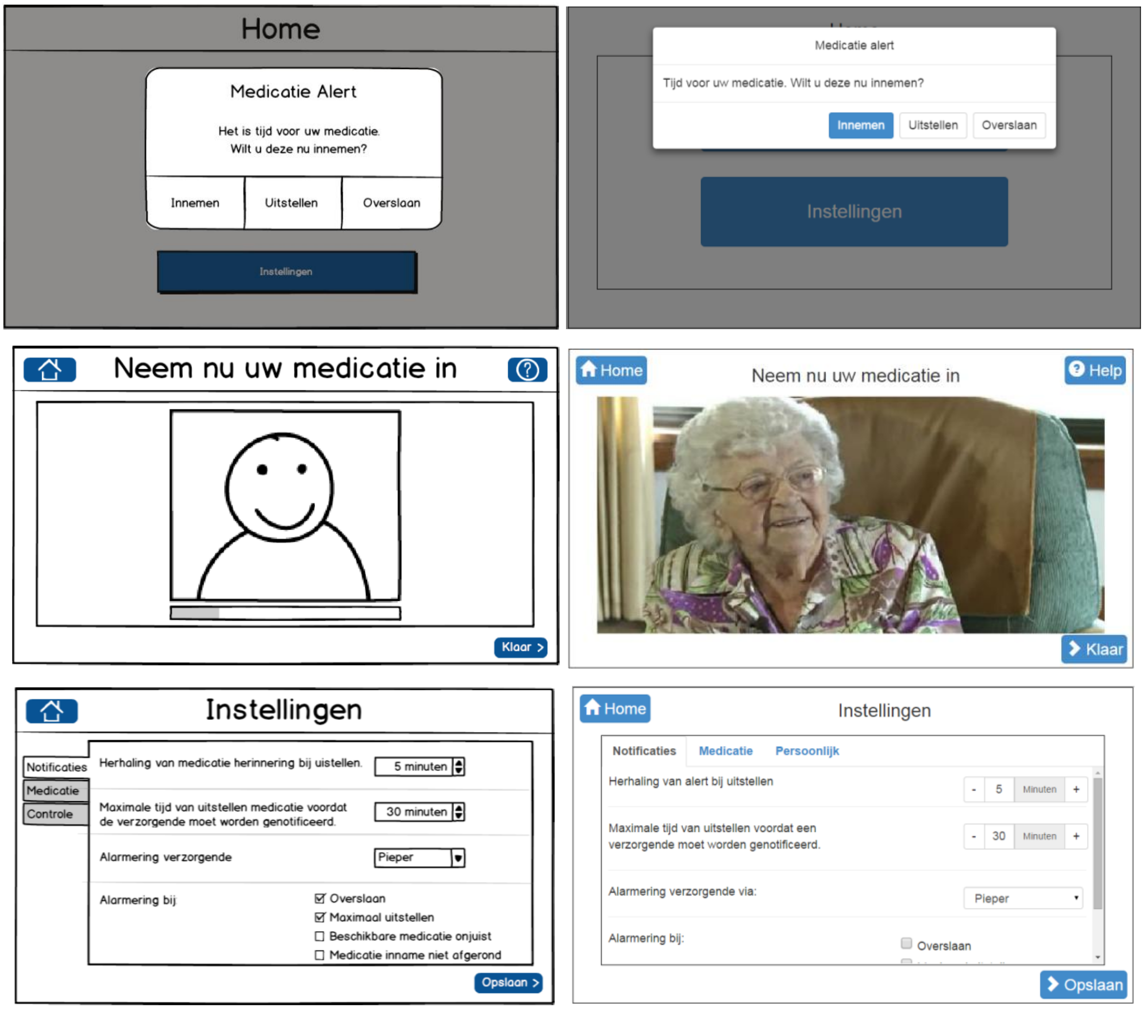

Figure 17 Left: A selection of the wireframes. Right: A selection of interface screenshots.

5. User Study

5.1 Introduction

To investigate whether the developed interface could be used by the elderly without help, whether there were any usability issues and whether the elderly were willing to accept an assistive robot to help them with their medication intake we performed a user study. In contrast to the focus group session (discussed in chapter 3) the participants individually performed scenarios with the developed interface instead of wireframes which were used during the focus groups. The entire user study consisted of a usability test, usability questionnaire and acceptance questionnaire. To investigate the usability issues, a combination of a usability test and a usability questionnaire was used. The reason for this combination was to combine the elderly's opinion on the usability (usability questionnaire) with aspects that were discovered by the experimenter during the elderly's use of the interface (usability test). The usability test consisted of 4 scenario assignments which had to be performed by the participants. The usability questionnaire used in this user study was the post-study Usability Questionnaire (PSSUQ) (Lewis, 1992). This questionnaire was developed by Lewis (1992) to measure user satisfaction after participating in a usability test. The last part of this user study was an acceptance questionnaire based on the ALMERE-model (Heerink, Krose, Evers, & Wielinga, 2010) (Xu, et al., 2014). This questionnaire has been especially created to measure user acceptance of assistive robots by elderly people.

5.2 Method

5.2.1 Participants

19 Elderly voluntarily participated in this experiment (11 female, 8 male; age range: 65-88; mean age = 75.4). We were looking for an even spread of elderly people from this age group. We defined two inclusion criteria for this study. First, people could only participate if they were 65 or older. Second, the participants could not suffer from severe cognitive age declines. Three of the participants lived in a healthcare center and sixteen lived on their own. This imbalance can be explained by the fact that within the timeframe of this study we were unable to find more healthcare center residents that matched our inclusion criteria. Seven of the participants received care in some form. The elderly were approached for participation at Lentis (a healthcare organization in Groningen) and Zorggroep Oude en Nieuwe Land (a healthcare organization in Emmeloord.) All participants gave informed consent before the user study started.

5.2.2 Materials

Usability Test

During the usability test the participants used the interface on a tablet because the robot development had some delay and it was not possible to use it for testing. The tablet used was an 8 inch Sony Xperia. The size of this tablet is slightly larger than the size of the screen of the robot. Mozilla Firefox was the web browser used because of the full screen functionality. The tablet ran the interface by a network installed on a Dell Latitude laptop. A JavaScript function switches on the webcam of the Dell laptop and shows the webcam image in the interface. This is used to simulate the medication intake recording. During the experiment audio recordings were made with an Iphone5 microphone. The usability test consisted of four scenarios (Appendix B) which were printed in paper and handed out to the participants.

Usability Questionnaire

The user study finished with a questionnaire (Appendix C) which consisted of two parts. The first part focused on the usability of the interface and was composed of a set of 21 statements. The first three statements focused on the appearance and readability of the interface. The other 18 statements were part of the post-study Usability Questionnaire (PSSUQ) (Lewis, 1992). This questionnaire was developed to evaluate user satisfaction after participating in a usability test. We chose to divide the statements of the (PSSUQ) in subscales. The following usability goals are used as subscales (Sharp, Rogers, & Preece, 2006).

- *Effectiveness* investigates whether the participant thinks the interface is doing what it is supposed to do.
- *Efficiency* explores whether the participant feels that the interface supports them with their task.
- *Safety* is a subscale that focuses on the extent that the participant feels the interface protects them from undesirable situations. In other words, the interface prevents them from making errors with serious consequences.
- *Utility* is the extent to which the interface has the right kind of functionalities. So this subscale investigates if the participants believe that the interface can help them with what they need to do.
- *Learnability* investigates whether the participant believes the interface is easy to learn.
- *Memorability* describes how easy it is to remember how the interface works. For instance, when a user does not use the interface for a while, is it still easy to remember how it works?
- *Enjoyment* focuses on the enjoyment the participant feels while using the interface.

Robot Acceptance Questionnaire

The second questionnaire focused on robot acceptance and was based on the ALMERE-model (Heerink, Krose, Evers, & Wielinga, 2010) (Xu, et al., 2014). This questionnaire is especially created to test the user acceptance of assistive robots by elderly people. We used this questionnaire to assess whether the elderly were willing to use an assistive robot to support them with their medication intake. The questionnaire consisted of 37 statements. The 37 statements covered the following factors.

- *Attitude* investigated the feelings of the elderly towards the robot.
- *Intention to use* is the prediction that someone is going to use the robot for a longer period of time.
- *Perceived usefulness* investigated whether the robot is expected to be assistive.
- *Perceived adaptability* investigated the extent to which participants expected that the robot could adapt to their needs.
- *Perceived ease of use* can be explained by how effortless people expect the robot to be.

- *Perceived enjoyment* focused on the enjoyment that people thought they would experience while using the robot.
- *Anxiety* questioned via the statements whether using the robot for medication intake could evoke feelings of anxiety.
- *Trust* investigates whether the elderly trust decisions of the robot.
- *Perceived sociability* can be explained by whether people expect the robot to perform social behavior
- *Social influence* focuses on whether the elderly think that people in their near environment want them to use the robot.
- *Social presence* investigates whether people could see the robot as a social entity.
- *Facilitating conditions* was a topic that focused on things in the environment that could influence using the system.

All together the results of these constructs help to make a prediction of the use of the robot by the elderly.

5.2.3 Procedure

The experiment took place in the participant's living room or the common area of a healthcare center. The experiment started with a brief explanation about the study and the robot. We explained to the participants that the data of their participation would be processed anonymously and that they could stop their participation at any time. The participants signed a consent form and gave permission to make audio recordings. Thereafter, the participants were asked if they received care in any form because this influenced the assignments they had to perform with the interface. Next they watched a 2 minute marketing movie made by Assistobot. In this movie, Assistobot outlines a scenario of a man who is in need of care. The movie shows how this man uses the robot for activities of daily living. Coupled with a voice-over explaining RITA's functionalities.

Usability test

After watching the movie the participants sat behind a laptop with a tablet in front to operate the interface. This experimental setting can be seen at figure 18. The participants received a paper with a description of the scenarios (Appendix-B). These assignments were expressed as scenarios. The participants were instructed to think aloud during the assignments. This means that they were asked to say everything they saw, what they were doing and how they were feeling. We used this method to learn why participants experience usability issues in some parts of the interface.

Figure 18 Example of the experimental setting with a model participant.

The first scenario explained that it was morning and time for their medication. The elderly received a notification on the interface which told them that it was time for their medication and asked them if they would: take, postpone or skip their medication. The assignment asked them to take the medication. Table 1 presents the different steps that had to be run through to finish the first scenario. These steps were not presented to the participants.

Step 1	Respond to medication intake notification and press “intake”
Step 2	Read pop-up with explanation
Step 3	Finish medication intake by pressing “done”.
Step 4	Confirm that all medication was taken by answering confirmation modal.

Table 1 First usability test assignment

The second assignment explained that it was afternoon and they were calling with a family member and taking the medication at this time was not convenient for the participant. The two steps of this assignment can be found in table 2.

Step 1	Respond to medication intake notification and press “postpone”
Step 2	Confirm postponing medication intake

Table 2 Second usability test assignment.

After these two assignments the participants who did not receive care performed two extra assignments concerning the settings part of the interface. Only this group gets access to the settings part eventually. The third assignment was a continuation of the second assignment. It explained that people received medication intake notifications every 5 minutes during their phone call. They wanted to receive the notifications with more time in between. Table 3 shows the different steps of this assignment.

Step 1	Go to settings part of the interface
Step 2	Change notification interval
Step 3	Save changes by pressing “save”

Table 3 Third usability test assignment

The fourth assignment asked people to find contact information of their pharmacy in the system. The steps that needed to be performed to successfully finish this assignment are shown in table 4.

Step 1	Go to "personal" tab
Step 2	Find contact information pharmacy

Table 4 Fourth usability test assignment.

The scenarios were used to measure in which parts of the interface the participants experienced usability issues. We documented whether participants finish a step. In some cases participants received help, this was also documented. Participants received help when they gave up trying to finish the scenario by themselves. We chose to give participants help because performance on remaining steps of a scenario could still be insightful.

Usability and Acceptance questionnaire

The experiment finished with a questionnaire which consisted of two parts (Appendix C).The first part focused on the usability and the second part on the robot acceptance. The researcher called out the statements, after which the participants responded with a Likert Scale score ('strongly agree', 'agree', 'neutral', 'disagree' and 'strongly disagree') that matched their opinion. The participants received the instruction to answer to a statement with an exact item of the likert-scale. The answers were subsequently noted by the researcher on the questionnaire form. The participants received an instruction before the acceptance part of the questionnaire started that they should answer the statements with the robot from the instruction movie in mind. They were instructed to answer to the statements like if it was possible to use this robot for medication intake at this moment.

5.2.4 Data-analysis

The usability test measured whether the participants completed the scenario steps. Furthermore, it was measured if they received help. These measurements were combined with the qualitative data of the think-aloud method. Bar plots were used to graphically analyze this data. The data of the questionnaires was analyzed with the software environment and programming language R. A regression analysis was used to examine the effect of age on robot acceptance. We used a two sample t-test to analyze a difference in means between groups with and without care. Moreover, boxplots and scatterplots were used to graphically analyze this data.

5.3 Results

In this section the results of the user study are presented. First the results concerning usability will be discussed. We will end with the results of the acceptance questionnaire.

Usability test

To assess the usability issues of the interface we conducted a usability test. The results of the usability test will be discussed per scenario. The participants who received care only performed the first two assignments.

Seventeen out of nineteen participants were able to finish the first scenario assignment without help. This stands for 89.5 percent. Two females aged 83 and 84, both receiving care, were unable to perform this task without assistance. The think-aloud method revealed that the pop-up faded out too fast for elderly to read it carefully. This pop-up was used to explain to the elderly that they were recorded and instructed them to stand in front of the robot camera.

Seventeen of the nineteen participants were able to complete the second scenario which asked them to postpone the medication intake. Two males aged 78 and 88, and one female aged 83 encountered problems during this scenario. After a few attempts they finished with help from the experimenter. The 84 year old female who was not able to complete the first assignment on her own was able to finish this second assignment successfully.

After these two scenarios the participants who did not receive care performed two extra assignments concerning the settings. Three of the twelve participants who carried out this assignment were able to complete it without help. Four participants were able to find the “settings” part of the interface but encountered problems during step 2 or 3.

This assignment was completed by two of the twelve participants. The other participants did not switch between the different tabs and searched in vain for the contact information under the tab “notifications”. Some of the participants did not scroll with their finger to find information that was presented off screen.

Usability Questionnaire

After they performed the usability test, participants answered the usability questionnaire. In figures 19-21 bar plots are shown of the first three statements which focused on interface appearance and readability. The mean scores of the participants for these statements reflects agree and strongly agree (Table 5).

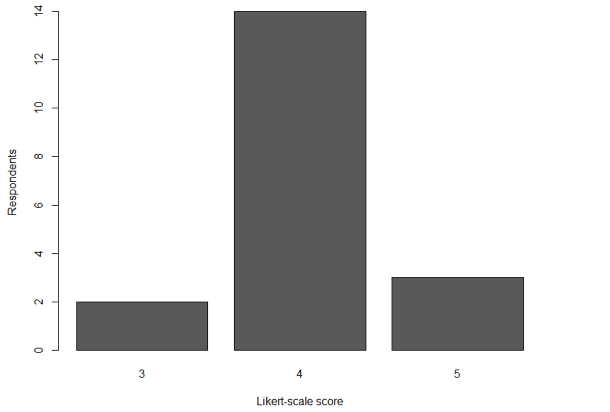

Figure 19 General statement1: I think the use of colors in het interface is pleasant.

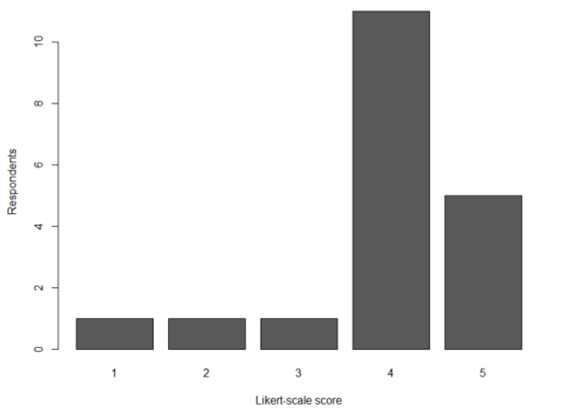

Figure 20 General statement 2: I can read the text on the screen clearly.

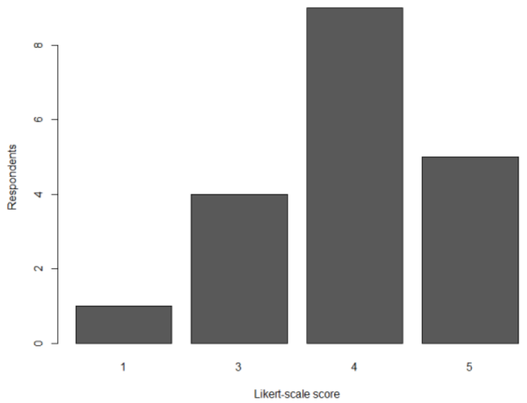

Figure 21 Statement 3: I can clearly distinguish the different items on the screen.

General statement	**Mean**
I think the use of colors in het interface is pleasant.	4.1
I can read the text on the screen clearly.	4.0
I can clearly distinguish the different items on the screen.	3.9

Table 5 First three usability statements with mean over 19 participants.

The remainder 18 statements were all part of the PSSUQ. The mean score for all items is 3.9. Apart from one, all participants gave a mean overall score of 3.6 or higher on the 5 point likert-scale. An 81 year old man who lives in a health care center gave an overall usability score of 2.2. An overview of the mean scores on all subscales is presented in figure 22.

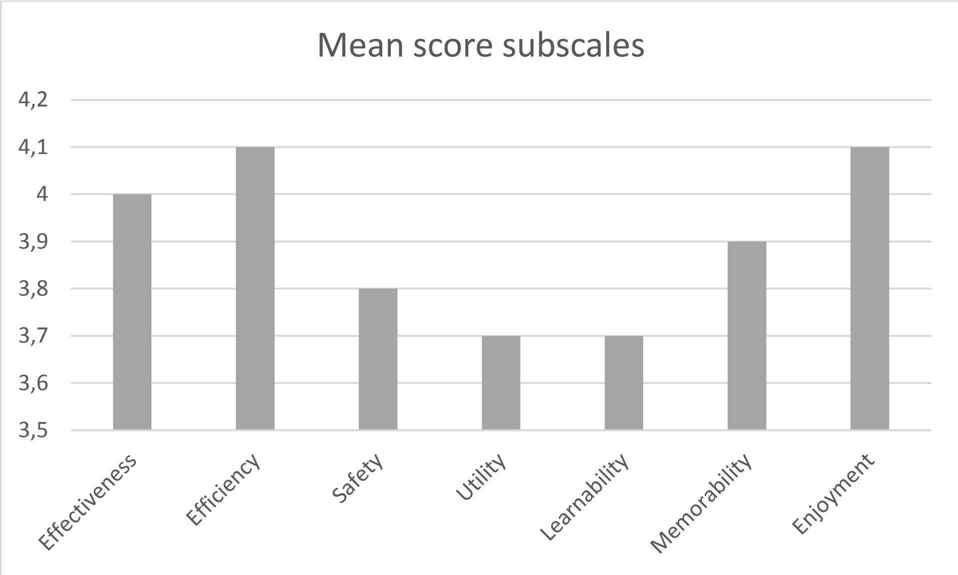

Figure 22 Mean scores subscales PSSUQ

As can be seen in figure 22 the subscales 'efficiency' and 'enjoyment' received the highest scores from the participants. On the other hand, the lowest scores were given to 'utility' and 'learnability'. On a 5-point scale the variation of the different subscales is not large. The subscale 'memorability' received a higher score than 'learnability'. This statement focused on the extent that it is easy to remember how the interface works, once it is learned. Furthermore the statement that focused on the notifications of the interface received a mean score of 3.8.

In order to find out if there exists a linear relationship between mean usability and age the correlation coefficient was calculated. The correlation coefficient between the mean usability score and age is -0.02.

Robot Acceptance

The second part of the questionnaire focused on robot acceptance and was based on the ALMERE-model (Heerink, Krose, Evers, & Wielinga, 2010) (Xu, et al., 2014). The statements in this questionnaire, dealing with a variety of topics, sought to predict the potential 'use' of the robot. The mean score for 'use' over all the participants was 3.5 on the 5 point Likert-scale. Use can be seen as a prediction of the actual use of the system over a longer period of time. With this factor we can make a prediction over the acceptance of RITA for medication intake by the elderly.

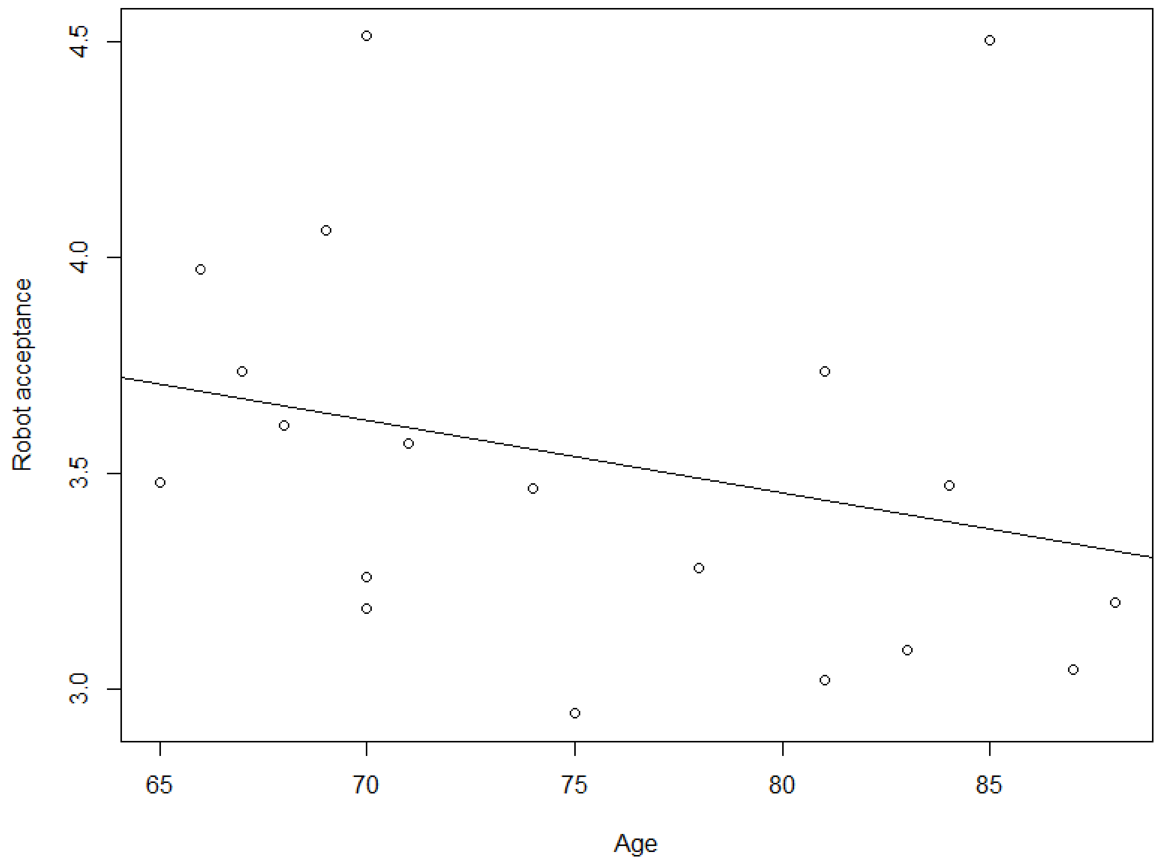

Figure 23 Correlation between robot acceptance and age.

To check whether there exists a linear relationship between robot acceptance and age the correlation is calculated. In figure 23 a plot of the correlation between acceptance for medication intake with a robot and age is shown. The correlation coefficient is -0.28. This correlation is considered a small negative strength of association.

Furthermore, whether or not participants already receive care could be of influence on robot acceptance. While analyzing our acceptance questionnaire data, it should be noted that our test group consist of two unequal sub-groups: 7 with care, 12 without. Figure 24 presents boxplots of the two groups. As can be seen the median of use for the group with care is lower than the median of the group without care. The group without care has a larger spread. Moreover, the boxplot of this group is skewed, with scores concentrated at the lower end.

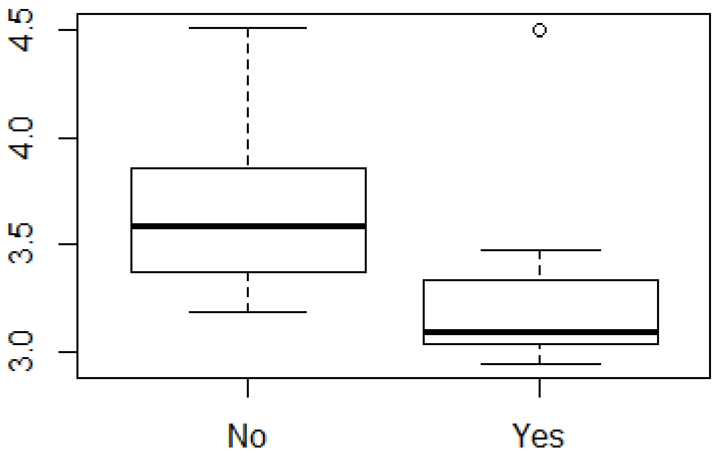

Figure 24 Boxplot of difference in score on Use between people groups who do receive care and who do not.

The two means of the groups are 3.3 for the groups with care and 3.6 for the group without care. A two sample t-test is not significant (t (17) = -1.409 p=0.19).

Subscale	**Mean score**	**Correlation age**	**Care**	**No care**
Anxiety	3.8	0.1	3.6	3.9
Attitude	3.7	-0.22	3.6	3.8
Facilitating conditions	3.5	-0.34	3.2	3.7
Intention to use	3.8	-0.63	3.2	4.0
Perceived adaptiveness	3.7	-0.43	3.6	3.8
Perceived enjoyment	3.5	-0.40	3.8	3
Perceived ease of use	3.4	-0.01	3.2	3.5
Perceived sociability	3.5	-0.009	3.3	3.6
Perceived usefulness	3.8	-0.21	3.6	3.9
Social influence	3.4	-0.07	3.4	3.5
Social presence	2.5	-0.14	2.4	2.6
Trust	3.8	0.21	3.8	3.8

Table 6 Overview results Acceptance questionnaire.

The statements of the questionnaire could be divided into different subscales which together estimated the predicted use of the robot. Table 6 presents an overview of all the scores on the different topics. Figure 25 and 26 present bar plots of mean scores on all subscales and the mean scores for the groups with and without care on all subscales. As can be seen in figure 24, the means of the group without care are slightly higher for all but one subscale.

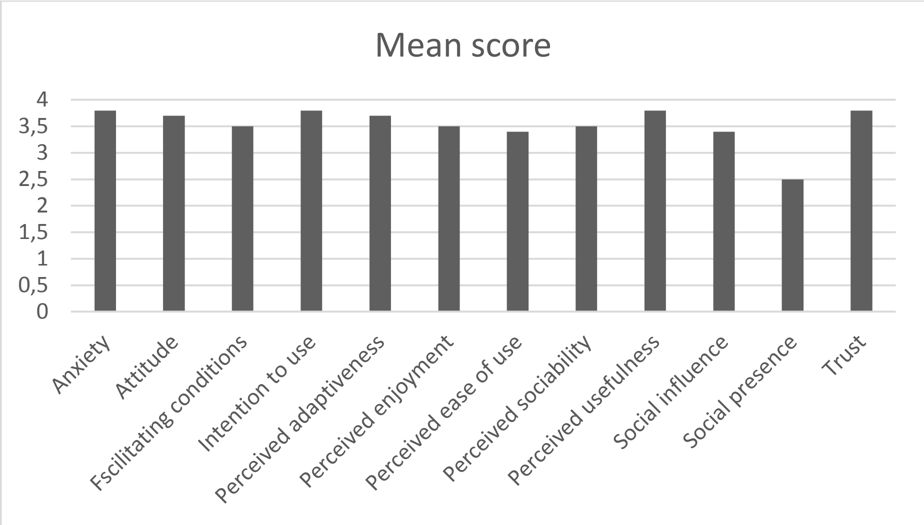

Figure 25 Mean scores on subscales

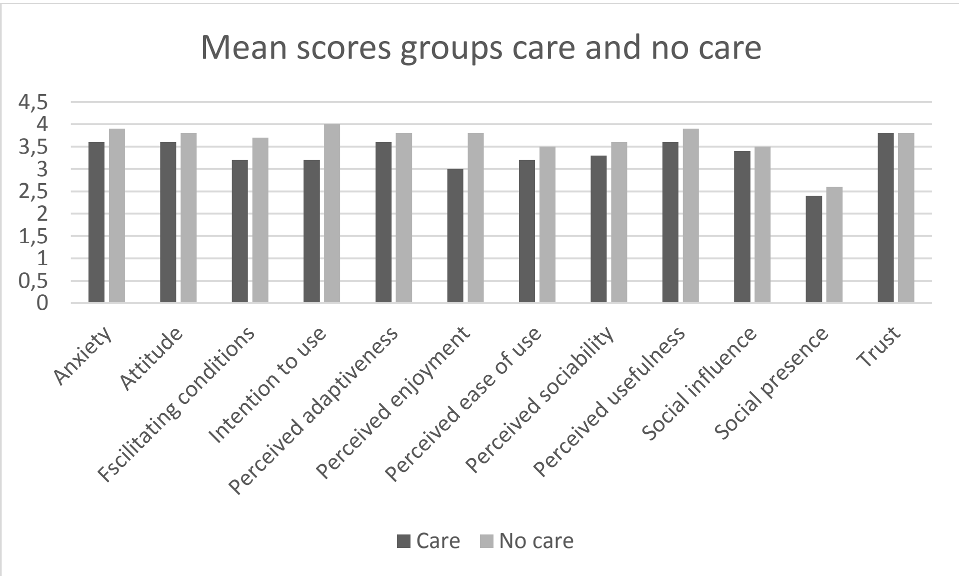

Figure 26 Mean score groups care and no care

The most relevant results are presented more extensively below. Perceived usefulness is the topic that investigates if the robot is expected to be assistive. Mean score over all the participants for 'perceived usefulness' is 3.8. This was the highest overall score of all the topics.

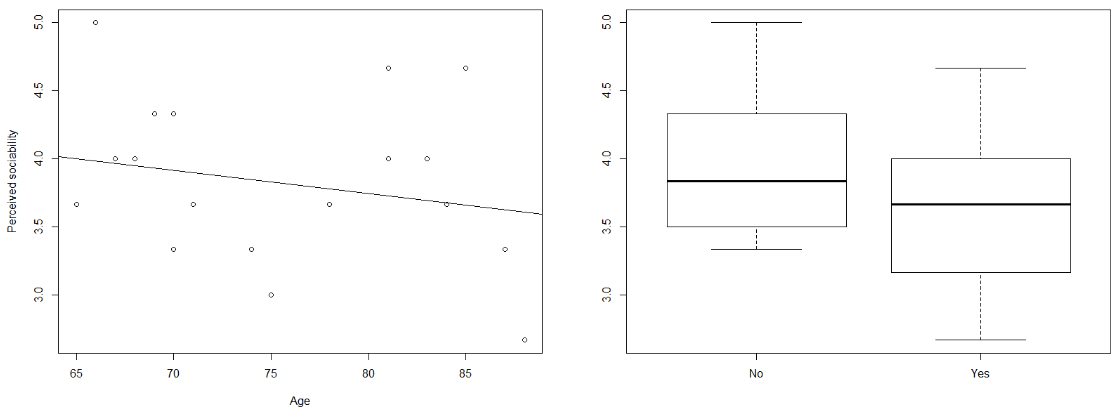

Figure 27 Left: Correlation Perceived usefulness and Age. Right: Boxplot Perceived usefulness score in care-groups.

The correlation coefficient between ‘perceived usefulness’ and ‘age’ is -0.21. This coefficient is considered a small negative strength of association. On the right side of Figure 27 it can be seen that the boxplots for the groups with and without care do overlap. The median of the group without care lies a little bit higher and the boxplot of that group is skewed. Mean score for this group was 3.9. For the group with care this was 3.6

Social presence is the topic of the questionnaire with the lowest mean score over all participants. The mean score is: 2.5. This topic investigates if people could see the robot as a social entity.

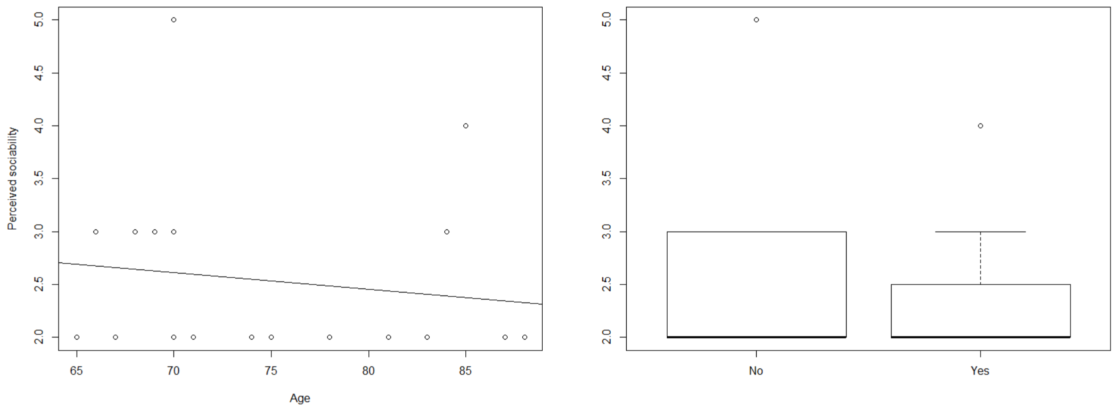

Figure 28 Left: Correlation Social presence and Age. Right: Boxplot Social presence score in care-groups.

This topic was assessed by one statement: “I could see the robot as a living creature”. As can be seen in the left part of Figure 28 most of the participants answered this statement with disagree. The correlation coefficient of ‘social presence’ and ‘age’ is -0.14 and can be seen as low strength of association. The boxplots of the groups with and without care show that both groups have the same median and are skewed towards the lower side. The group without care has a mean score of 2.6 and the group with care has a mean score of 2.4.

Another topic of the questionnaire was ‘Intention to use’. This is the prediction that someone is going to use the robot for a longer period of time. Mean score of the participants of this study on this topic was 3.8.

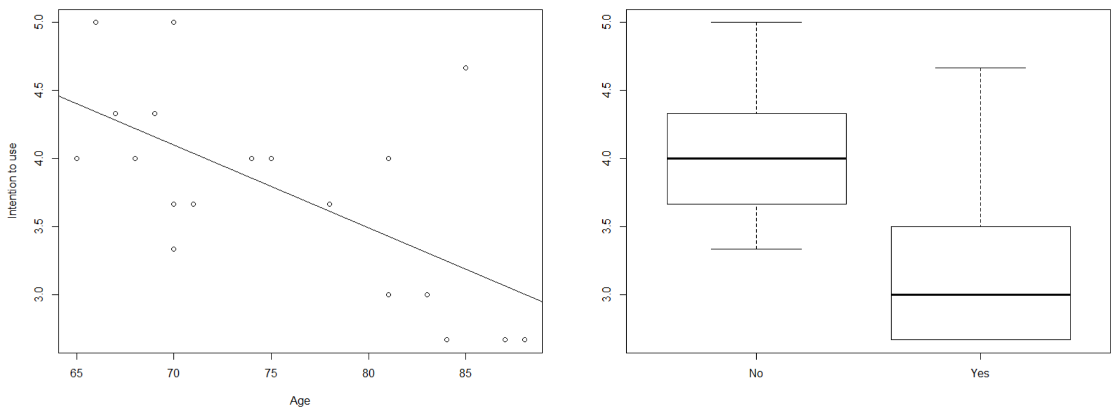

Figure 29 Left: Correlation Intention to use and Age. Right: Boxplot Intention to use score in care-groups.

The correlation coefficient of the ‘intention to use’ topic is significant (r(17) -0.63 $p<0.01$). This is a large association strength. The boxplots of the two groups with and without care show that the interquartile ranges of both boxplots do not overlap (Figure 29). A two sample t-test has a significant result (t (9.06) = 2.54 p=0.03). There is a significant difference in means between the two groups. As can be seen in the figure the mean for the group without care is higher than the group with care and for the second group the boxplot is skewed to the lower side.

Perceived enjoyment focused on the enjoyment that people thought they would experience while using the robot. The mean score of the elderly who participated in this study was 3.5.

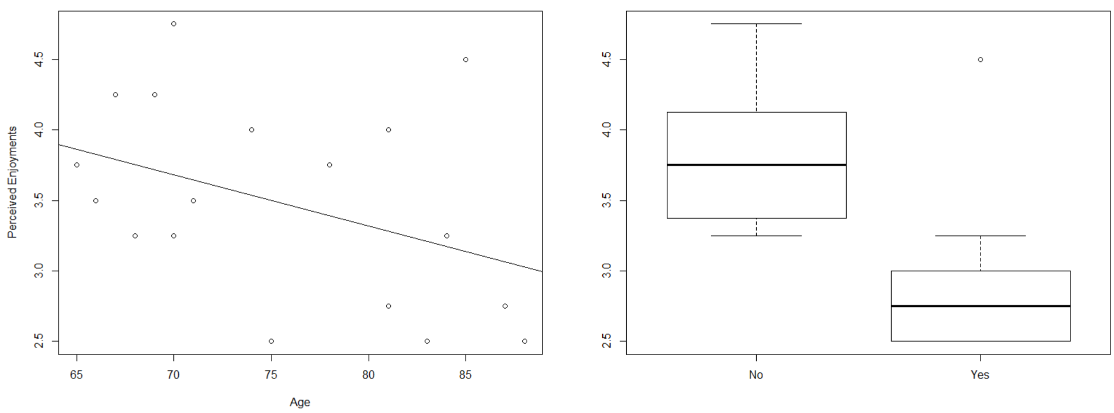

Figure 30 Left: Correlation Perceived Enjoyment and Age. Right: Boxplot Perceived Enjoyment score in care-groups.

The linear association between ‘Perceived enjoyment and ‘age’ has a correlation coefficient of -0.4, which is a medium strength. The boxplots of the two groups with and without care show that the interquartile ranges do not overlap (Figure 30). A t-test reveals that the mean for the two groups do significantly differ (t(9)=2.69 $p<0.05$). The mean for the group that does not receive care is: 3.8. The mean for the other group is 3. Both boxplots are skewed, which means that the answers of the participants are concentrated at the lower part.

6. Discussion and conclusion

This study aimed at developing a robot interface with three main functions, namely reminding the elderly at their medication intake moment, checking whether they took all the medication of a certain intake moment, and documenting the medication intake process. The elderly need to be able to independently take their medication with the robot without help from a caregiver. Furthermore, we measured user acceptance of an assistive robot that supports the elderly with their medication intake. This chapter discusses the main findings of this study, starting with the results in light of research objectives. Next, the recommendations are discussed and we will end with a general discussion.

Introduction

This study can be divided into four parts. The first part focused on how to design a medication intake interface for an assistive robot RITA. The second part investigated if elderly could use the interface and if there were any usability issues. The third part focused on the fact if elderly were willing to accept an assistive robot for their medication intake. Finally the fourth part focused on using an assistive robot with touch screen interface assisting elderly with activities of daily living.

Robot interface design for a medication intake task

A field study on the medication intake task served as input for the first concept designs of the robot interface. This study consisted of interviews with caregivers and focus groups with elderly and caregivers. The conducted interviews gave insights in the medication intake task. This information is important for the requirements of the interface. The interviews revealed that the medication intake task of the robot consists of three main subtasks. These are reminding, intake and documentation. Furthermore, the elderly should be able to postpone or reject a medication intake moment. However, in that case the responsible caregiver should be notified. In a study of Botella, Borras and Mira (2013) the requirements for a medication intake mobile interface were researched. They found that it should notify the elderly, register the intake, and should match the elderly’s schedule. The results of the interviews are in line with the results of Botela, Borras and Mira (2013).

The findings of the interviews were input for developing wireframes of the robot interface. These wireframes were evaluated with the elderly and caregivers in focus groups. Both the elderly and the caregivers did not mention many large issues in the way the wireframes were designed. We found that half of the elderly preferred larger fonts for the smallest fonts used in the wireframes. Thirteen point font sizes were used for the smallest fonts. Research states that twelve point fonts are the minimum for the elderly users (Bernard, Liao, & Mills, 2001). The buttons for intake, postpone and reject were designed as similar (same shape and colour) in the wireframes. Caregivers explained that although postpone and reject should be possible, intake is preferred. In the final interface design a more clear distinction was made between these three options, we prompted on intake by giving that option a different colour than postpone and reject. Furthermore, the font sizes used in the interface were increased.

Usability evaluation of the interface

A usability test was conducted in order to investigate whether the elderly experienced usability problems during the use of the interface. Nineteen elderly participated in the usability test which was part of the user study. The elderly performed scenario-based tasks which asked them to simulate medication intake with the interface, postpone the intake and change some of the settings. The participants performed the tasks with a tablet connected by a local network to a laptop. The results of the usability test were completed with the participant's subjective response to usability with a usability questionnaire.

The usability test showed that 90% of the participants in this study were able to perform the scenario which asked them to simulate their medication intake moment with the support of the interface. This indicates that the interface which supported them with the medication intake task was designed in an understandable manner and did not require much training of prospective first-time users.

Performance results concerning the scenario-based tasks focusing on the interface settings indicate that this part was unclear to the participants. Participants were supposed to navigate to the notifications settings and change the notification interval. Seven out of twelve participants were able to find the settings section. They could not, however, distinguish the different parts (notifications, medication and personal) which were distributed among a tab bar navigation. As a result, they navigated to the medication tab when the assignment asked them to change the notification settings. This outcome might indicate that the participants placed a link between the label "medication" and the fact that they were using an interface for a medication intake task. Secondly, the tab 'notifications' contained all features concerning the notifications that the interface gave to the users. The term for notifications is often used in computer interfaces. Hypothetically, it is possible that some of the elderly might have little to no previous experience with computers. This might explain their failure to recognize the functionalities commonly associated with this word. Unfortunately, this study did not measure computer experience of the participants. But research shows that the elderly make three times less use of computers than younger age groups (Mitzner, et al., 2010). Finally the meaning of the tab 'personal' was also not clear to the elderly. All things considered, the labeling of the settings tab bar should be improved.

Apart from the tab bar in the settings part, people often did not discover that by using a swipe gesture they could scroll to off-screen information. In touch screens this is often used to present off-screen information but again, we speculate that due to possible lack of experience in this age group, seniors might not be able to discover off-screen information without a visible clue.

The usability questionnaire showed that the participants were in general positive about the usability of the interface. For example, they indicated that they could clearly distinguish the different items on the screen. We use a flat design to distinguish the different items of the interface. For the elderly it was found that they thought of a realistic or skeuomorphic design as more esthetically pleasing. However, a more abstract or flat design is better for understanding (Cho, Lee, Kwon, Suk, & Na, 2015). Furthermore, they indicated that the use of colors in the interface was pleasant. We used blue as a main color. Research shows that blues are often associated with the following positive characteristics, calmness, reliability and friendliness (Chapman, 2010).

The fact that participants experienced some issues with the assignments that focused on the settings part of the interface is not directly reflected in the scores on the usability questionnaire. The mean score of the total usability score for all participants is 3.9 on a maximum of 5. The statement that focused on the findability of information did not receive a low score. This high score can be explained by the following reasons. A first possible explanation could be that during the questionnaire the elderly reflected on the first few assignments with the interface more than on the second part. Secondly, it could be that they felt that the problems they encountered with the settings part would not occur again if they would use the interface a second time as a result of retention (learnability). Furthermore, a high score on the statement that asked the elderly if they thought they would become productive quickly with the interface supports this. We also found a rather high score for the subscale ‘memorability’ which describes how easy it is to remember how the interface works. For instance, when a user does not use the interface for a while, is it still easy to remember how it works? Another reason for the high scores on usability might be that the scores were affected by the acquiescence bias, which is the effect that people tend to choose ‘agree’ with statements more often than ‘disagree’ (Sauro & Lewis, 2011). Another reason for positive rates could be that people do not want to give the impression that they are a ‘negative person’. We expect that all these speculations could contribute to the positive score.

One of the highest mean scores on the post-study usability questionnaire was given by the participants to the statement: “I liked using the interface of this system”. The fact that this statement received such a high overall mean score shows that despite of the elderly’s performance on the usability test they liked using the system.

In general these results indicate that elderly could use the interface for the medication intake task without usability problems. This indicates that this part of the interface was designed in an understandable manner and did not require much training of prospective first-time users. Although the settings did reveal usability problems which should be improved in future versions. Nonetheless, the elderly gave a high rate for usability of the interface.

Acceptance of an assistive robot for medication intake

While developing a new product, it is not only of importance to develop it in such a way that users understand how to use and enjoy it. It should also be investigated whether people will accept the technology and will continue to use it in the future. The results of this part of the study are explained by the outcomes of the robot acceptance questionnaire. This questionnaire is based on the ALMERE-model and gave some insights in the use of the robot interface, in other words the expected use of the system for a longer period of time in the future (Heerink, Krose, Evers, & Wielinga, 2010). This questionnaire was conducted after the usability test and the usability questionnaire. We asked the participants to imagine that they could use the RITA for medication intake assistance.

The mean score on the subscales of this questionnaire was 3.5 on a maximum of 5, which is between ‘neutral’ and ‘agree’. The subscale ‘perceived usefulness’ received the highest mean score over all the participants. This subscale focused on the degree that people expected the robot to be assistive. People often complemented their answer with the remark that they could see the use of the robot, but that they did not require its help at this moment. The lowest mean score was given to the subscale ‘social presence’. This subscale consisted of just one statement: “I could see the robot as a living creature”. The low mean score is not a surprise because the

RITA's embodiment is not developed to give the feeling to be a living creature. However, this score was expected to be even lower. We expect that the interaction in the first person that we used for the usability test of the interface was of influence on this score.

Besides the scores on this robot acceptance questionnaire it was of interest to see if a correlation between acceptance and age could be found. Age is negatively correlated with acceptance: people tend to slightly score lower on the robot acceptance questionnaire when they have a higher age. For the subscale 'intention to use' a considerable significant correlation was found between the subscale and age. This subscale investigated if people have the intention to use the robot for their medication intake for a longer period of time in the future. A possible explanation for this significant effect could be that the younger seniors positively considered the use of RITA due to the uncertainties of future care given the current economy and ageing population. Furthermore, using a robot for a period of time in the future helps them to stay independent. In addition, it could be that they have the intention to use the robot for a longer period of time in the future because they have experience with using different kinds of technology. For this reason the elderly could have less resistance in the future with unknown technologies. These speculations could explain the significant difference in means between the groups with and without care of this subscale.

We found a slight difference between the participants who received care and the participants who did not. That is to say the participants who did not receive any care had an overall higher score on the acceptance questionnaire. A possible reason for this could be that the people who do receive care from caregivers are satisfied with the current situation. People who do not receive care possibly think that in the future there are not enough resources for personal care. This could indicate why they are more willing to accept a robot for medication intake.

The subscale 'Perceived enjoyment' showed a significant difference between the means of the groups with and without care. Perceived enjoyment focused on the enjoyment that people thought they would experience while using the robot. We expected a significant correlation between age and this subscale because of technology experience. However this was not the case.

Using an assistive robot with touch screen interface assisting elderly with activities of daily living

Assistobot proposes an assistive robot (RITA) to assist elderly with activities of daily living. RITA should enable the elderly in the future to live independently. Although results of this study revealed that the elderly were able to run through the medication intake task with the interface we should question if this functional interface with a touch screen is the most optimal interaction type. The touch screen is rather small and this makes it hard to read from a distance. The most optimal reading distance for the elderly is 40 centimeters (Boot, Nichols, Rogers, & Fisk, 2012). The RITA does have an extra presentation screen although it is advised against using multiple screens at different distances at the same time for the elderly (Boot, Nichols, Rogers, & Fisk, 2012).

Implications

Developing a robot is a long process and generations expire. This makes it hard to define the to study target group of the RITA. Today's theoretical robot user group likely consists of different individuals than its equivalent in five to ten years. Furthermore, people who are in their eighties now are often less experienced with computers, touchscreens and robots. The ‘younger elderly’ who are around 65 probably have more experience with computers and touchscreens. Many studies in assistive robotics include the elderly who could need the robot at this moment as participants in their research. In contrast, this study included both ‘younger elderly’ and ‘older elderly’. We included the ‘older elderly’ who in all likelihood experience age-related declines and the ‘younger elderly’ who are possibly going to use the robot when it will be available for in the future.

Many studies just focus on the fact if the elderly are able to use the robot and if their ideas match the elderly’s needs. This study also took the robot acceptance in to account. The predominantly positive results we found concerning the acceptance of a robot assisting with the medication intake task, indicate that the elderly are open towards alternatives for their daily care.

Limitations

One limitation of this study was that the interface was not tested on the RITA itself. This was impossible due to developmental delays. Therefore we chose to evaluate the interface on a tablet and simulate the medication intake recordings with a laptop camera. Using the interface on the robot touch screen instead of on a tablet might yield different results for both the usability evaluation as the robot acceptance. However, Xu, et al (2011) found in their study that scenario-based evaluation is an effective way to measure acceptance of an assistive robot.

Next to age and receiving care there is a moderating factor that we left untouched. We did not measure the participants experience with technology and computers. This measurement might give support by interpreting the results and finding future directions for the usability issues found.

During the usability test the tablet did not react properly to some of the elderly’s touch. The experimenter herself did not encounter any problems with this. This issue might have influenced the results of the usability test. Some elderly explained that they encounter this problem more often while using touchscreens. This raises the question if a touch screen is the most optimal interaction type for the robot.

Future interface developments

The usability test revealed some issues concerning the interface settings which could have been implemented differently knowing the results of this study. For example, the participants did not understand what information they could find at the different tabs. A recommendation to begin with to address this problem is to change the terminology of the tabs to labels that are more familiar to the elderly. Options for this different terminology is showed in figure 22. The first label for notification is a term that is used more often in Dutch language. The second and third label both have an additional word ‘information’. Another improvement could be to add icons to the tab bar navigation. Icons for notifications, medication information and personal information might support the understanding of the labeling.

Figure 31 Recommendations Settings page.

A third improvement for the settings part of the interface is a more clear distinction between the different tabs as showed in figure 31. Instead of only having a difference in text color and hovering effect, the not selected tabs now have a grey background.

Basic design considerations of this interface, in this case, font size and the color scheme, did not result in usability issues. Therefore, these design considerations could also be included for future development of interfaces of other functionalities of the robot.

Future work

Seventeen out of nineteen participants in this study were able to take their medication with the interface. Unfortunately, this was not tested on RITA itself. Although this study shows a good insight in the usability of the first developed version, for future work it should be tested if people are also able to use the interface when it is presented on RITA instead of on a tablet. Preferably, this would be in a natural setting. For example the robot should be placed in the elderly's home. Their normal medication routine should be replaced with medication intake with assistance of RITA. It would be interesting to see if this yield different results.

Furthermore, it would be interesting to analyze if the design of RITA's embodiment as can be seen in (figure 1) is of influence on the medication intake task usability. To put it differently, the position and the way the touchscreen is mounted on the robot could give the elderly a different experience. For instance, this might influence the elderly's subjective responses to the usability. Moreover, using the interface on the robot instead of on the tablet could also influence the outcome of the acceptance questionnaire. Because working with the robot could give the elderly a realistic view of how it would be to have the robot in their house to help them with their medication intake.

We chose not to include measurements of the time that a participant needs per assignment during the usability test. In case of a repetition of this study, this measurement should be considered. In order to compare these measurements between the different participants, the execution of the usability test needs to be in a strictly controlled manner. However, we chose to use the think-aloud method during the usability test. In essence this means that the elderly were asked to say everything they saw, what they were doing and how they were feeling. The way in which participants engage in the think-aloud method could influence the time-measurements. For this reason these measurements were not included in this study.

We did not measure the elderly's experience with technology, computers and touch screens. This measurement could help to find an explanation for some of the results we found. For future work this measurement should be included in the experimental measures.

The number of elderly who participated in the user study was 19. In case of the usability test this number was sufficient to find usability issues. A minimum of 5 participants is considered acceptable in a usability test (Sharp, Rogers, & Preece, 2006). Although for the questionnaire it would be interesting to redo this part with a larger number of participants to have more statistical power.

General perspectives

The RITA is a service robot and does not focus on possible companion type functions that robots could have. Research has shown that the more socially intelligent a robot is, the better it is received by its users (Robinson, MacDonald, & Broadbent, 2014). We should ask ourselves if providing elderly just with assistance of activities of daily care covers everything caregivers are providing them with right now. Caregivers also provide elderly with care in a social form. RITA is currently not able to do that. A combination of a companion type and service type of assistive robot could address to both age-related declines and social isolation (Granata, Chetouani, Tapus, Bidaud, & Dupourque, 2010).

From an HCI perspective the overall embodiment of the RITA raises some questions. At this moment the RITA does not have functionality to grasp objects. Many elderly people experience age related declines in their motor capabilities. With an increasing age they often get less mobile and in some case cannot walk independently. To provide the care they need the RITA needs to be able to grasp objects and bring them to the elderly. The stop-button of RITA is located at the top. For immobile elderly this is a very impractical location.

The current embodiment of the RITA is not able to walk the stairs. It is likely that there are elderly who live in houses with multiple floors. In absence of an elevator the RITA cannot change floors. For the RITA to assist the elderly they need to be at the same floor.

Conclusion

With the increasing number of elderly in society and the current tendencies to cut healthcare costs and resources as a result of the current economic depression it is hard to present them with the care they need because of a lack of resources. The development of technological solutions that support the elderly with care in their daily living could meet this problem of deficiency. With RITA, Assistobot Corporation proposes such a technological solution. Main goal of RITA is to support the elderly to live independently without help of a caregiver. This thesis proposed an interface design which reminds people of their medication intake moment, checks if they took all the medication of a certain intake moment and documents the medication intake process. We evaluated the usability of this interface design. Furthermore, we investigated the extent to which elderly would accept a robot to support them with their medication intake.

To conclude the outcome of this study that the majority of the participants could take their medication with the interface and the results of the acceptance questionnaire imply a positive picture about the future of a robot which assists with medication intake. Although the RITA is not yet ready to take in to use by the elderly. A lot of research and developmental work still needs to be done.

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Appendix A - Topic list Interview caregivers

- Could you describe how you assist a client with their medication intake? Please be as detailed as possible.

Current medication task:
- Medication storage.
- Refill medication
- Checks before giving medication
- Medication timing
- Documentation
- How to act after missing an intake moment
- What can go wrong

Medication task by robot:
- What does the robot need to know to assist with medication?
- What should the robot check?
- Video recording
- Alarmsystem/Notifications for caregiver
- What information does the robot need to give to the caregiver? (documentation)
- How to act when a client refuses the medicaton?

Appendix B - Assignments Usability Study

Voor u ziet u een tablet, hierop ziet u de interface. Dit is het kleine scherm wat u zojuist in de video heeft gezien. Dit systeem zal uiteindelijk op de robot komen. Dit scherm helpt u om uw medicatie in te nemen. De volgende opdrachten kunt u met de tablet uitvoeren. Lees ze goed door voordat u begint.

1. U gebruikt de tablet zodat u uw medicatie niet vergeet. Stelt u zich voor dat het 8 uur ’s ochtends is. U krijgt zo een herinnering om uw medicatie in te nemen. Doorloop de stappen met de tablet om uw medicatie in te nemen. Probeert u hierbij hardop uw gedachten uit te spreken.

2. ’s Middags is het weer tijd om uw medicatie in te nemen. U bent op dit moment echter aan het bellen met een familielid. Doorloop de stappen met de tablet om de medicatie op dit moment niet in te nemen. Spreek uw gedachten hardop uit.

3. U heeft zojuist de medicatie uit gesteld. Op dit moment zou u na 5 minuten een nieuwe herinnering krijgen. U heeft liever dat deze herinnering om de 10 minuten komt. Pas met de tablet de tijd tussen de herhalingen van de herinnering aan. Spreek uw gedachten hardop uit.

4. U heeft een vraag over uw medicatie. Zoek met de tablet het telefoonnummer van uw Apotheker op zodat u deze kan bellen. Spreek uw gedachten hardop uit.

Appendix C - Usability and User Acceptance Questionnaire

Vragenlijst

Respondentnummer:

Leeftijd:

Woonsituatie:

Zorg: Ja/Nee

Stelling	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik vind het kleurgebruik van het systeem prettig.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik kan de letters op het scherm goed lezen.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik kan de verschillende items op het scherm duidelijk onderscheiden.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens

Over het algemeen ben ik tevreden over hoe gemakkelijk het systeem in gebruik is.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik kon de taak goed uitvoeren met alle aanwezige informatie.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik denk dat ik snel uit de voeten kan met dit systeem.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik kon mijn taak snel af te ronden met het systeem.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Het systeem heeft alle functionaliteiten en mogelijkheden die ik nodig heb.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik voelde mij op mijn gemak tijdens het gebruik van het systeem.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik vond het gemakkelijk om te leren hoe ik het systeem moest gebruiken.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik kon mijn taak effectief afronden met dit systeem.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens

Ik kon fouten die ik maakte tijdens het gebruik gemakkelijk herstellen of oplossen.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
De informatie die de interface gaf (meldingen) waren duidelijk.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Het was gemakkelijk om de informatie te vinden die ik nodig had.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
De informatie die het systeem mij gaf was gemakkelijk te begrijpen.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Het systeem is gemakkelijk te gebruiken.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
De organisatie van de informatie op de verschillende pagina's was duidelijk.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik vind het systeem prettig.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik vond het leuk om het systeem te gebruiken.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens

Ik was in staat om mijn taak efficiënt af te ronden met dit systeem.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Over het algemeen ben ik tevreden met het systeem.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens

Stelling	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik denk dat het een goed idee is om de robot te gebruiken bij medicatie-inname.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik denk dat de interactie met de robot plezierig is.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik denk dat de robot gemakkelijk is in gebruik.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik vind de robot intimiderend.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik weet genoeg van de robot om er goed gebruik van te kunnen maken voor medicatie inname.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik vind de robot eng.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik denk dat de robot me alleen zou helpen op de momenten dat ik dat nodig vind.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens

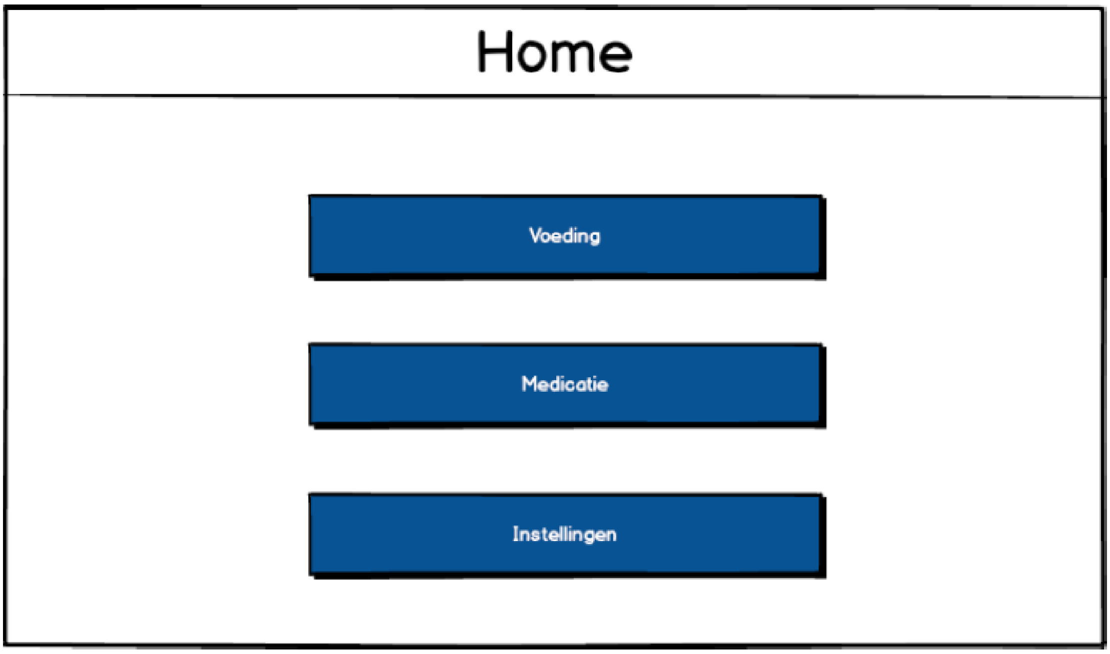
Ik zou het advies dat de robot me geeft opvolgen.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Als ik de robot zou gebruiken bij mijn medicatie inname zou ik bang zijn om er fouten mee te maken.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Als dat zou kunnen zou ik denk ik de robot de aankomende paar dagen wel gebruiken voor mijn medicatie inname.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik denk dat de robot zich kan aanpassen aan wat ik nodig heb.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik vind de robot fascinerend.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik denk dat ik de robot kan gebruiken voor het innemen van mijn medicatie mits er iemand is om me te helpen.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik denk dat mijn familie zou willen dat ik de robot gebruik voor medicatie inname.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik vind de robot plezierig.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens

Ik heb het gevoel dat de robot me begrijpt.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik vind de robot saai.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Het is goed om gebruik te maken van de robot voor medicatie inname**.**	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik ben er zeker van dat ik de robot de aankomende paar dagen zou gebruiken voor mijn medicatie inname als dat zou kunnen.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik denk dat ik de robot kan gebruiken voor het innemen van mijn medicatie mits ik een goede handleiding heb.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik vind de robot aardig.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik denk dat ik een goede indruk maak op anderen als ik de robot gebruik.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Het zou handig voor me zijn als ik de robot zou hebben om me te helpen bij het innemen van mijn medicatie.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens

Ik vind de interactie met de robot plezierig.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik denk dat ik zonder hulp de robot kan gebruiken voor het innemen van mijn medicatie.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik denk dat mijn verzorgenden/mantelzorgers willen dat ik de robot gebruik voor medicatie inname.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik denk dat de robot mij kan helpen bij veel dagelijkse handelingen.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Als ik de robot zou gebruiken bij mijn medicatie inname zou ik bang zijn om iets kapot te maken.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik denk dat de robot nuttig is.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik denk dat de robot mij helpt wanneer dat noodzakelijk is.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik zou de robot vertrouwen als ze me advies geeft.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens

Ik vind het leuk om mijn medicijnen in te nemen met de robot.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
De robot zal het leven interessanter maken.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik zou de robot kunnen zien als een levend figuur.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik heb alles wat ik nodig heb om de robot te kunnen gebruiken voor medicatie inname.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik denk dat ik snel begrijp hoe ik de robot moet gebruiken bij het innemen van mijn medicatie.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Ik denk dat het een goed idee is om de robot te gebruiken bij medicatie inname.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens
Als dat zou kunnen zou ik de robot in de toekomst gebruiken.	Helemaal eens	Eens	Neutraal	Oneens	Helemaal oneens

Appendix D - Wireframes



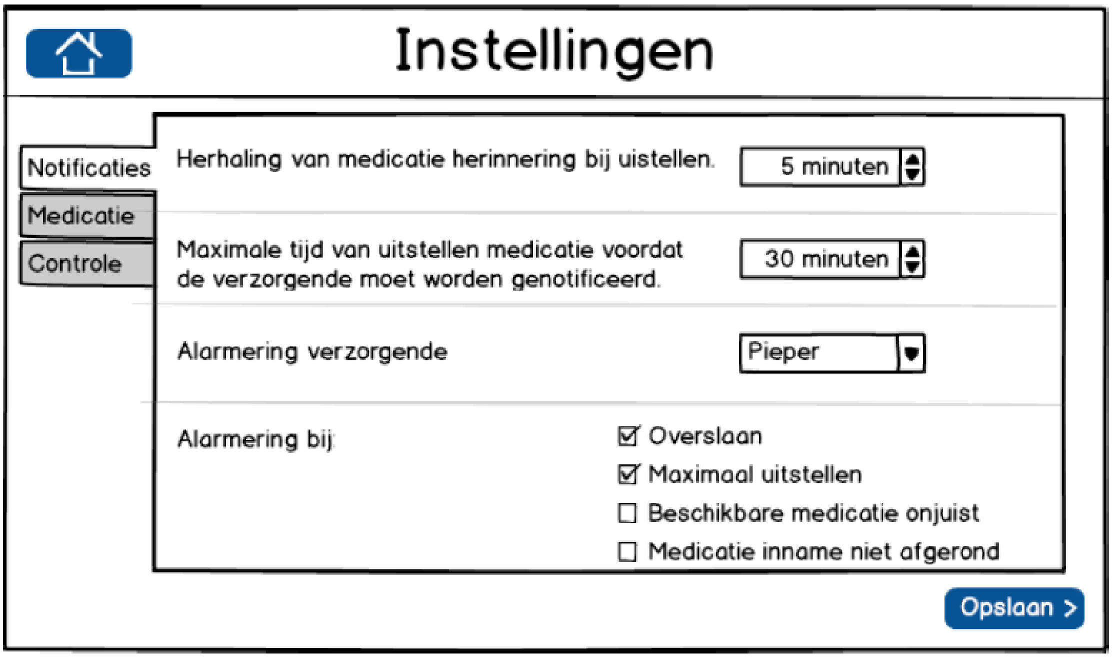
Home
Let op!
U heeft ervoor gekozen uw medicatie
inname uit te stellen.
Weet u het zeker?
Ja
Nee
Instellingen

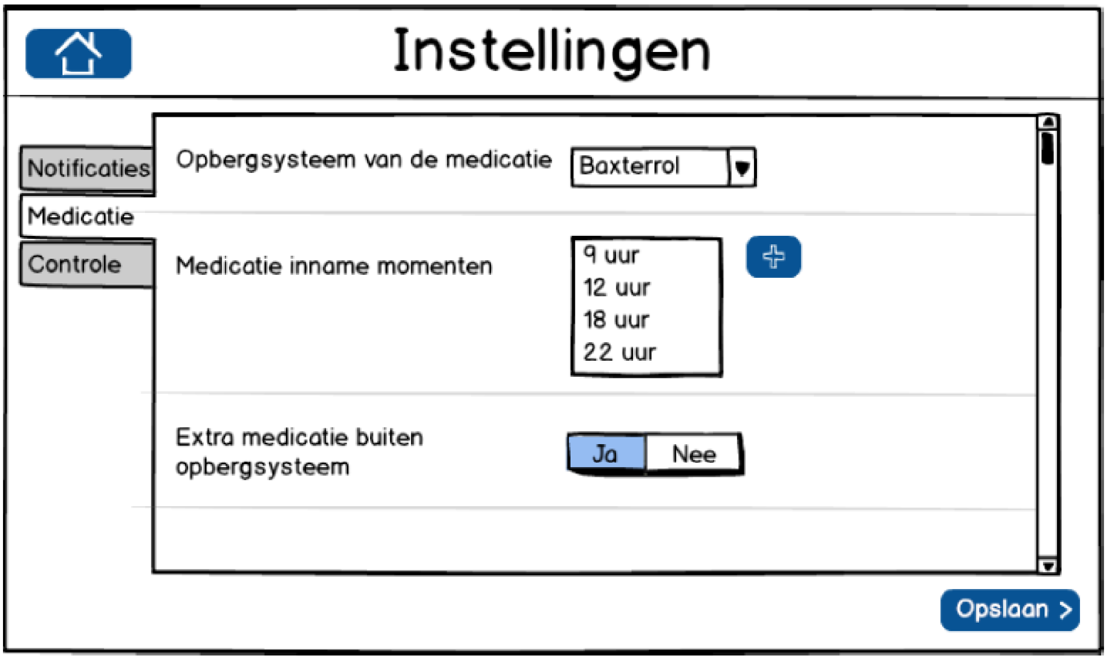
Home
Let op!
U heeft aangegeven de medicatie over te slaan.
Ik stuur uw verzorgende een berichtje waarin
staat dat u ervoor hebt gekozen de medicijnen niet
in te nemen.
Weet u zeker dat u de medicatie wil overslaan?
Ja
Nee
Instellingen


Neem nu uw medicatie in
Klaar >


Medicatie inname
Er wordt nu een opname van uw medicatie inname gemaakt. U kunt de opname op het beeldscherm zien. Probeer goed voor me te staan zodat ik u goed kan zien. De opname kan later worden teruggekeken door uw verzorgende.
Ok
Klaar >

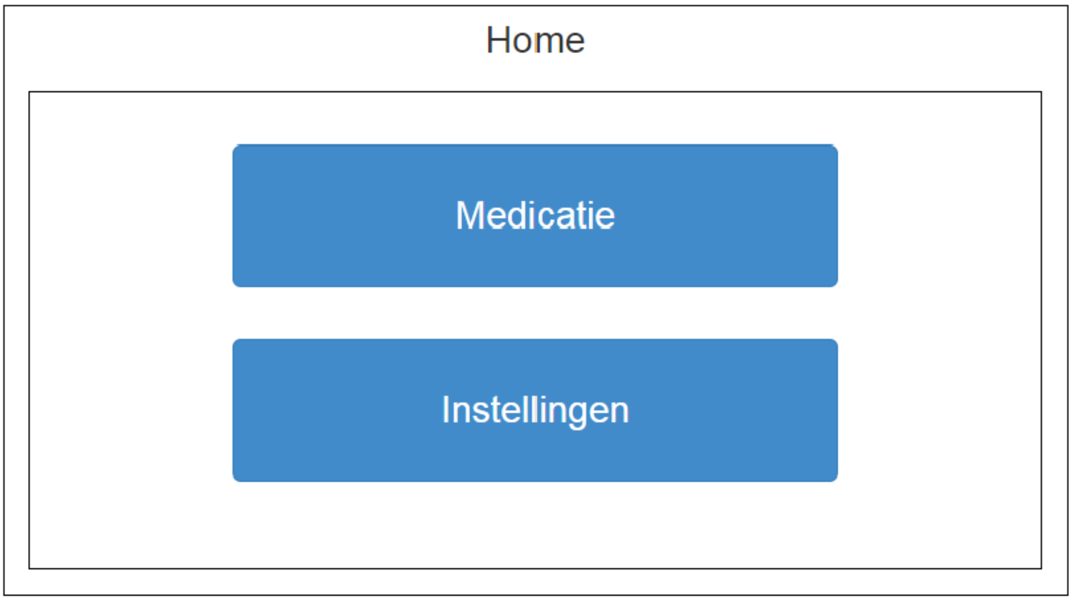

Neem nu uw medicatie in
Let op!
We zijn bijna klaar met de medicatie inname. U wordt zo terug geleid naar het home scherm.
Heeft u al uw medicijnen ingenomen?
Ja
Nee
Klaar

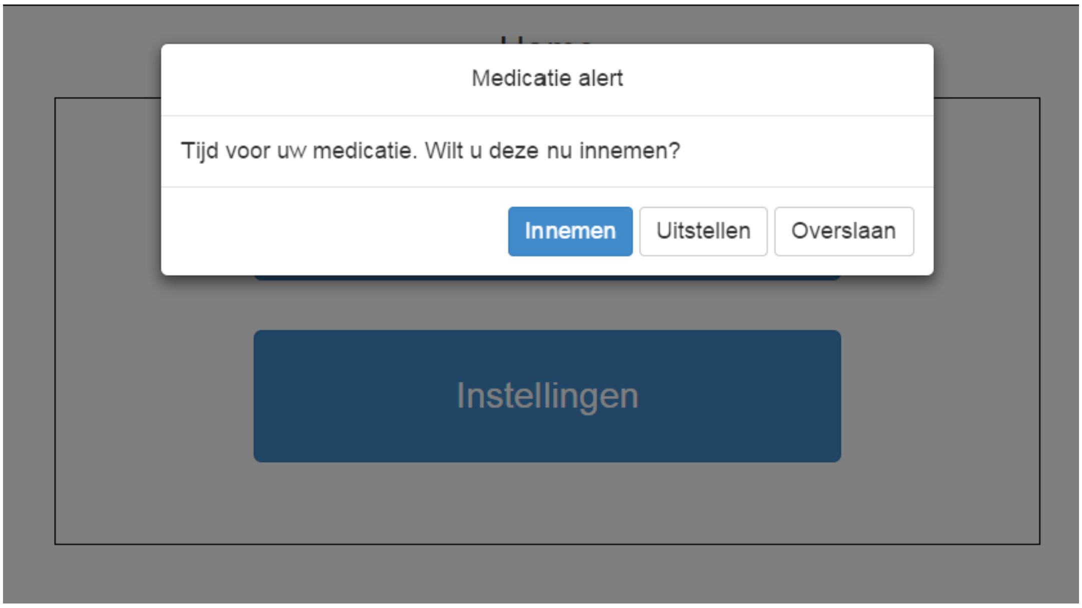

Instellingen
Notificaties
Medicatie
Controle
Herhaling van medicatie herinnering bij uistellen.
5 minuten
Maximale tijd van uitstellen medicatie voordat de verzorgende moet worden genotificeerd.
30 minuten
Alarmering verzorgende
Pieper
Alarmering bij
Overslaan
Maximaal uitstellen
Beschikbare medicatie onjuist
Medicatie inname niet afgerond
Opslaan

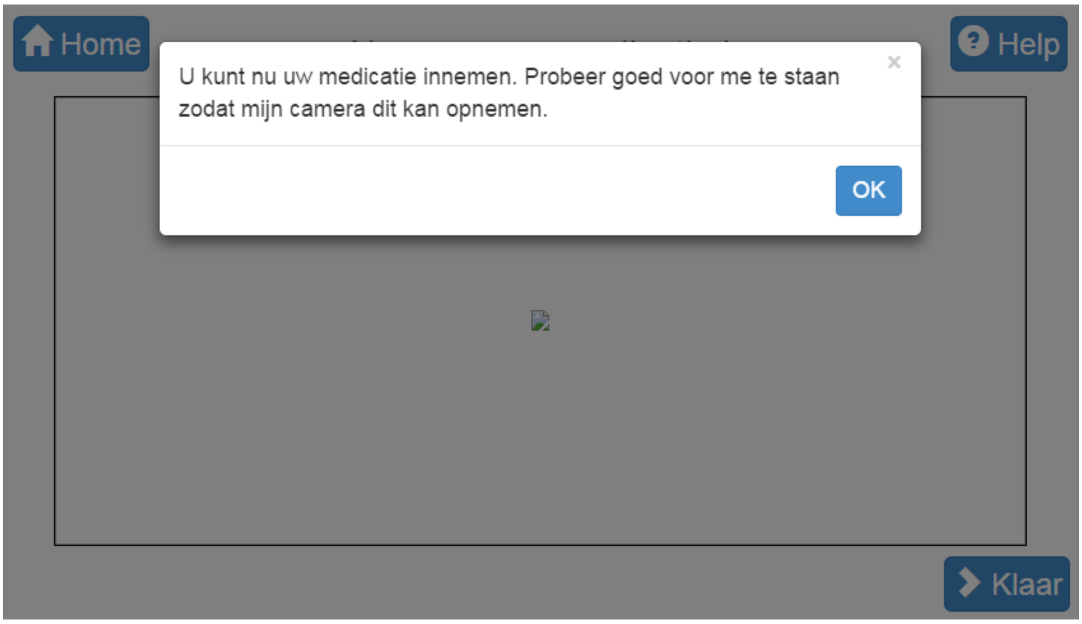

Instellingen
Notificaties
Medicatie
Controle
Opbergsysteem van de medicatie
Baxterrol
Medicatie inname momenten
9 uur
12 uur
18 uur
22 uur
Extra medicatie buiten opbergsysteem
Ja
Nee
Opslaan


Instellingen
Notificaties
Medicatie
Controle
Verantwoordelijkheid medicatie:
Verzorgende
Verantwoordelijkheid medicatie controle:
Verzorgende
Laatste medicatie controle uitgevoerd door:
Jan de Boer
Uitgevoerd op:
02-08-2014
Status:
Correct
Opmerkingen:
Geen opmerkingen
Updaten
Opslaan

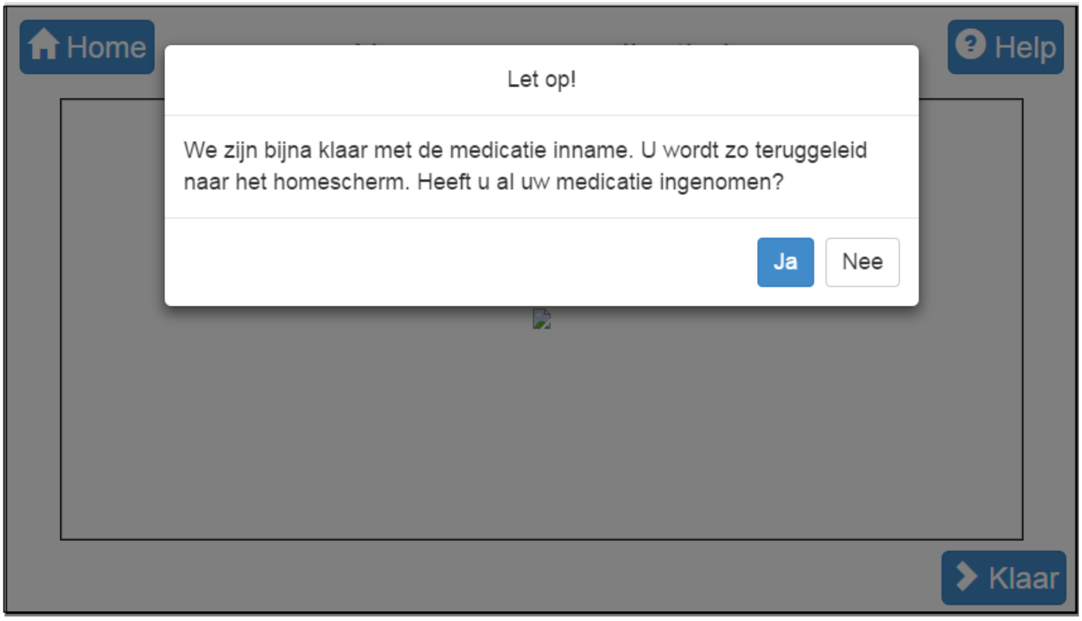
Appendix E - Interface

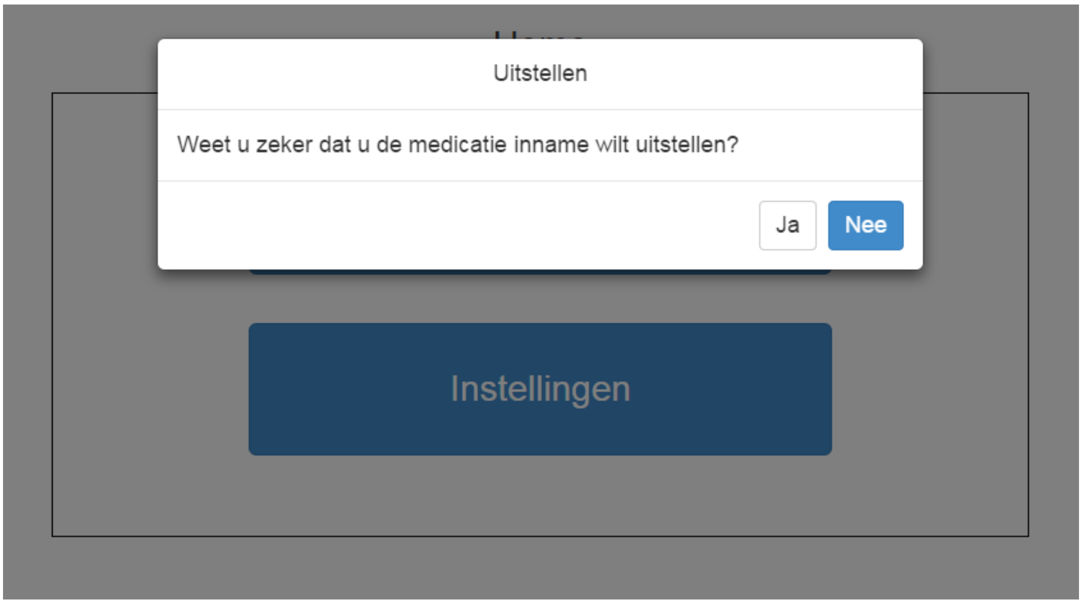


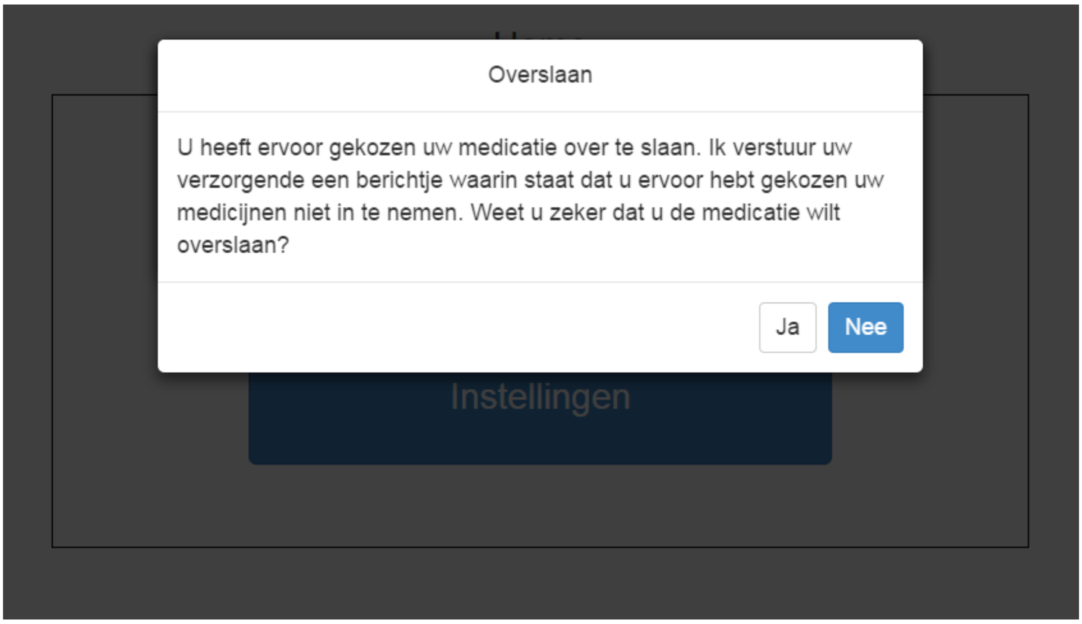



Home
Help
U kunt nu uw medicatie innemen. Probeer goed voor me te staan zodat mijn camera dit kan opnemen.
OK
Klaar


Home
Neem nu uw medicatie in
Help
Klaar


Home
Help
Let op!
We zijn bijna klaar met de medicatie inname. U wordt zo teruggeleid naar het homescherm. Heeft u al uw medicatie ingenomen?
Ja
Nee
Klaar


Uitstellen
Weet u zeker dat u de medicatie inname wilt uitstellen?
Ja
Nee
Instellingen


Overslaan
U heeft ervoor gekozen uw medicatie over te slaan. Ik verstuur uw verzorgende een berichtje waarin staat dat u ervoor hebt gekozen uw medicijnen niet in te nemen. Weet u zeker dat u de medicatie wilt overslaan?
Ja
Nee
Instellingen


Home
Instellingen
Notificaties
Medicatie
Persoonlijk
Herhaling van alert bij uitstellen
-
5
Minuten
+
Maximale tijd van uitstellen voordat een verzorgende moet worden genotificeerd.
-
30
Minuten
+
Alarmering verzorgende via:
Pieper
Alarmering bij:
Overslaan
Opslaan


Home
Instellingen
Notificaties
Medicatie
Persoonlijk
Medicatie opbergsysteem:
Baxterrol
Extra medicatie buiten opbergsysteem?
9 uur
12 uur
15 uur
Opslaan


Home
Instellingen
Notificaties
Medicatie
Persoonlijk
Verantwoordelijkheid medicatie bij verzorgende?
Hoofdverzorgende:
Anne de Jong
Huisarts:
Dr. A de Groot
Stationsweg 4
9771 AH Groningen
050 2254798
Opslaan

Appendix F - Results Acceptance questionnaire

The statements of the questionnaire could be divided into different subjects which together estimated the predicted use of the robot. The first subject was ‘Anxiety’ and questioned via the statements if using the robot for medication intake could evoke feelings of anxiety. The mean score on this topic for all of the participants was 3.76. This score is mirrored so a higher score means less feelings of anxiety.

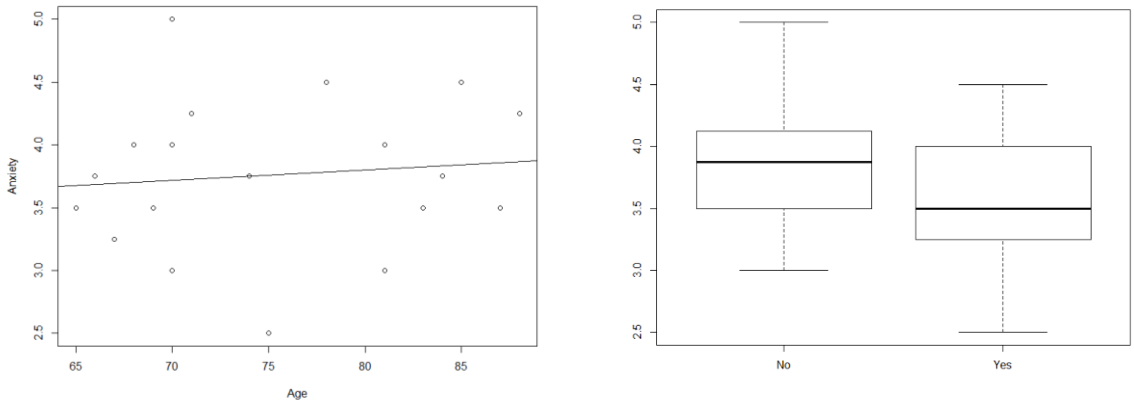


Figure 32 Left: Correlation Anxiety and Age. Right: Boxplot Anxiety score in care-groups.

The correlation coefficient for Anxiety score and age is 0.1 (Figure 30). On the right side of figure 32 the boxplots for the groups with care and without care are shown. The median for the group without care is higher than the group with care. The mean score for anxiety for the group without care is 3.88 and for the group with care 3.57.

The second topic of the questionnaire is ‘Attitude’. This investigated the feelings of the elderly towards the robot. Mean score of all the participants for this topic was 3.73.

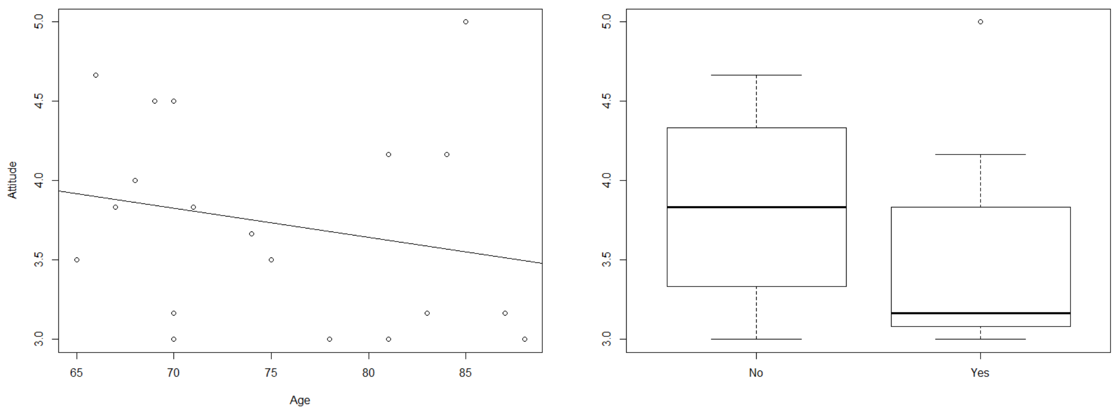


Figure 33 Left: Correlation Attitude and Age. Right: Boxplots Attitude score in care-groups.

The correlation coefficient for Attitude and age is -0.22. This is a small strength of association. As can be seen in the boxplots the median for the group without care lies higher than the median for the group who does receive care. The boxplot of the group with care is skewed towards the lower side (Figure 33). The mean score for that group on this topic is 3.57 while for the group without care the mean score is 3.82.

Facilitating conditions was a topic that focused on things in the environment that could influence using the system. The mean score for all participants on this topic was 3.5. In the figures below it is shown if age or receiving care was of influence on this score.

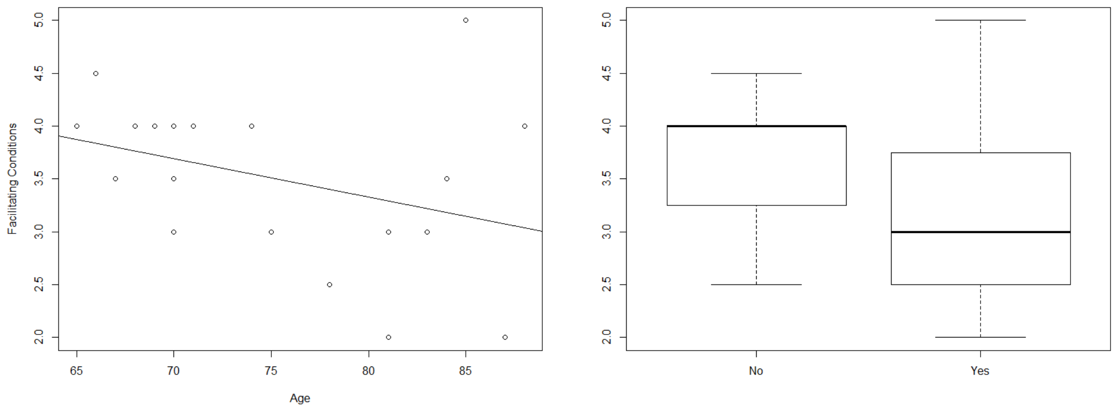


Figure 34 Left: Correlation Facilitating conditions and Age. Right: Boxplot Facilitating conditions score in care-groups.

The correlation coefficient for Facilitating conditions and age is -0.34 (Figure 34). This correlation coefficient falls under medium strength of association. In the right figure it can be seen that the participants without care have a higher median than the participants with care. The boxplot of the group with care is skewed towards the lower part. The means for the group with and without care are consecutive: 3.21 and 3.66.

Another topic of the questionnaire was ‘Intention to use’. This is the prediction that someone is going to use the robot for a longer period of time. Mean score of the participants of this study on this topic was: 3.77.

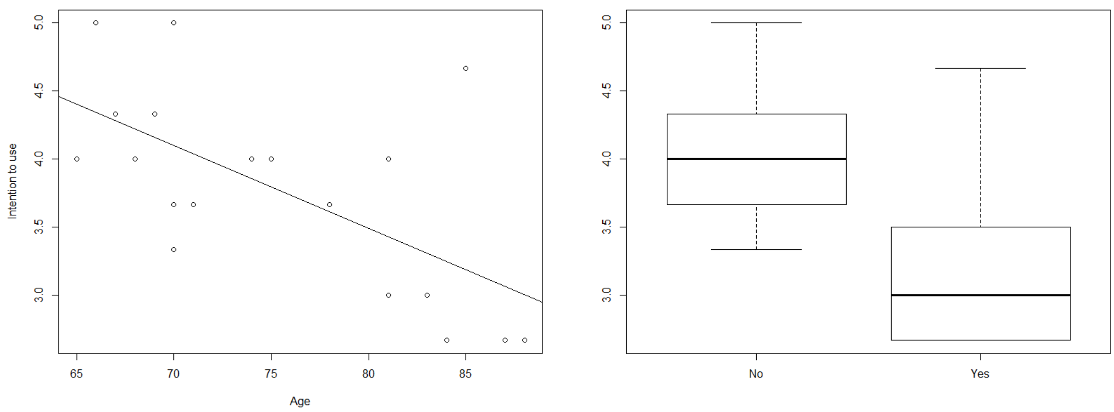


Figure 35 Left: Correlation Intention to use and Age. Right: Boxplot Intention to use score in care-groups.

The correlation coefficient of the ‘intention to use’ topic is –significant with r(17) -0.63 $p<0.01$. This is a large association strength. The boxplots of the two groups with and without care show that the interquartile ranges of both boxplots not overlap (Figure 35). A two sample t-test has a significant result,with t (9.06) = 2.54 p=0.03. There is a significant difference in means between the two groups. As can be seen in the figure the mean for the group without care is higher than the group with care and for the second group the boxplot is skewed to the lower side.

The topic ‘Perceived adaptiveness’ investigated the extent to which participants expected that the robot could adapt to their needs. The mean score of the participants for ‘perceived adaptiveness’ was 3.72.

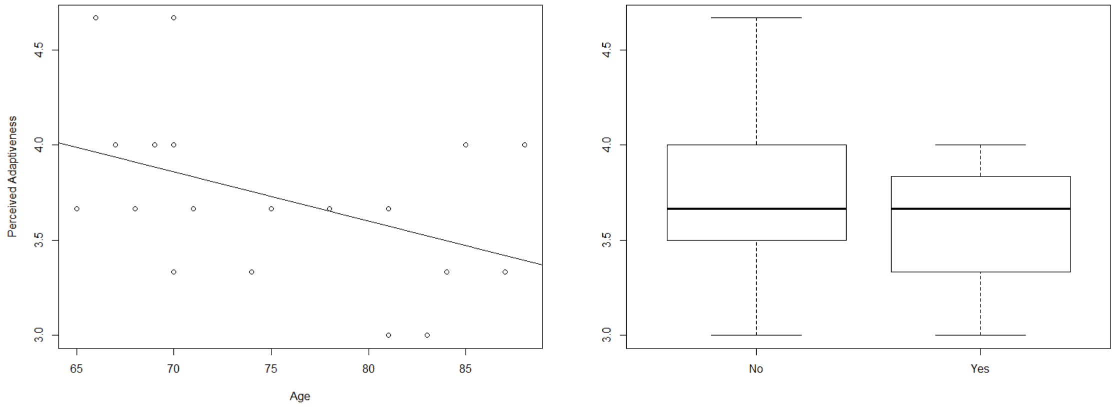


Figure 36 Left: Correlation Perceived Adaptiveness and Age. Right: Boxplot Perceived Adaptiveness score in care-groups.

The correlation coefficient for perceived adaptiveness and age is -0.43. This is a medium strength of association. As can be seen in the boxplots of figure 36 the medians of the groups with and without care are about the same. The boxplot of the group with care is skewed towards the higher answers. Mean scores for the groups with and without care are: 3.57 and 3.8.

Perceived enjoyment focused on the enjoyment that people thought they would experience while using the robot. The mean score of the elderly who participated in this study was 3.49.

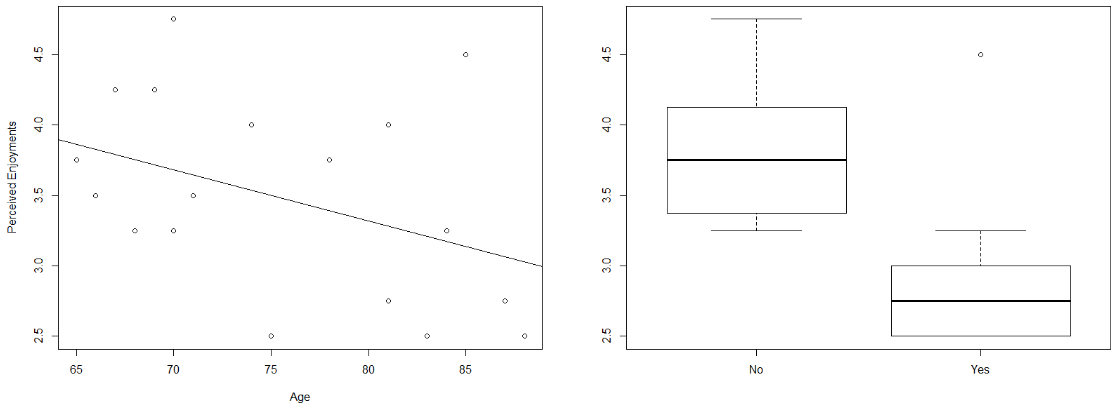


Figure 37 Left: Correlation Perceived Enjoyment and Age. Right: Boxplot Perceived Enjoyment score in care-groups.

The linear association between ‘Perceived enjoyment and ‘age’ has a correlation coefficient of -0.4, which is a medium strength. The boxplots of the two groups with and without care show that the interquartile ranges of both boxplots not overlap (Figure 37). A t-test reveals that the mean for the two groups do significantly differ with t(9)=2.69 p<0.05. Mean for the group that does not receive care is: 3.79. The mean for the other group is 2.96. Both boxplots are skewed. The answers of the participant concentrates at the lower part.

Perceived ease of use can be explained by how effortless people expect the robot to be. The overall mean score on this topic is: 3.39.

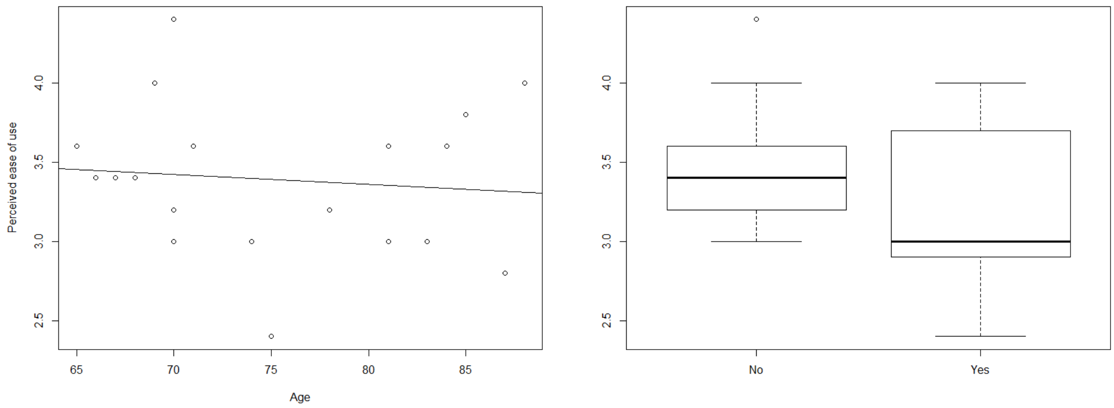


Figure 38 Left: Correlation Perceived ease of use and Age. Right: Boxplot Perceived ease of use score in care-groups.

The correlation coefficient of 'Perceived ease of use' and age is really small: -0.01. The boxplot of the groups with and without care show that the interquartile ranges overlap and the median of the group without care is higher than the one of the group with care. The group without care has a mean score of 3.48 and the group with care had a mean score of 3.23.

The next subject is 'perceived sociability'. The definition of 'perceived sociability' is in this case if people expect the robot to perform social behavior. The mean score of all participants on this topic was 3.47 which lies between the Likert-scale items 'neutral' and 'agree'.

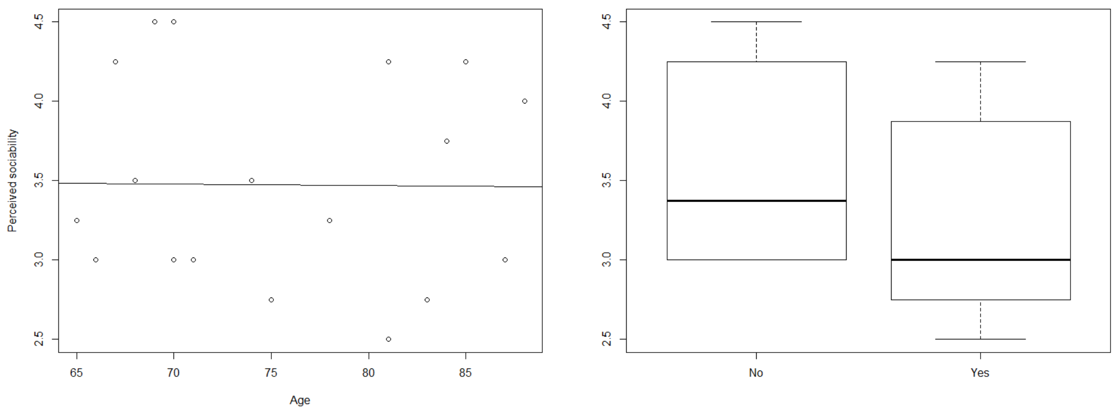


Figure 39 Left: Correlation Perceived sociability and Age. Right: Boxplots Perceived sociability score in care-groups.

As can be seen in figure 39 the regression line of the correlation between 'perceived sociability' and 'age' is almost flat. This means that there is a very weak association. The means of the groups with and without care are: 3.29 and 3.58, respectively. The boxplot of the group without care is skewed towards the lower side and the median of that group is higher than that of the other group.

Perceived usefulness investigates if the robot is expected to be assistive. Mean score over all the participants for ‘perceived usefulness’ is 3.82.

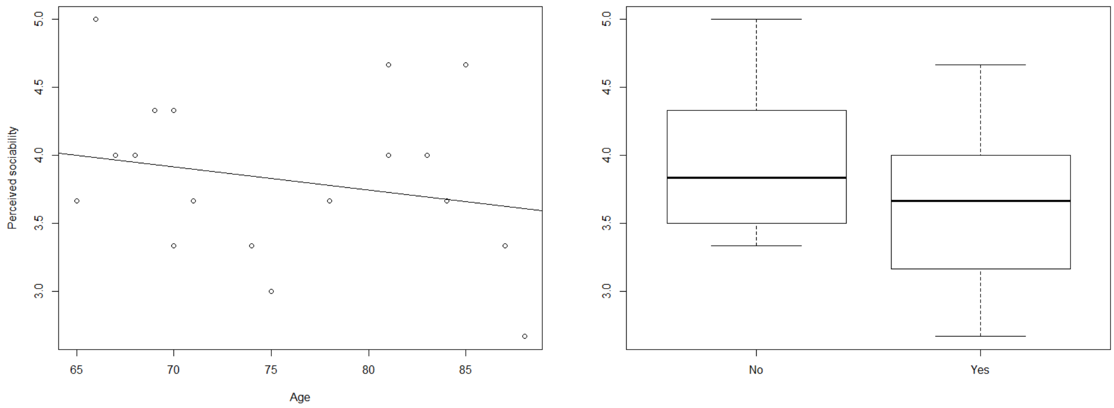


Figure 40 Left: Correlation Perceived usefulness and Age. Right: Boxplot Perceived usefulness score in care-groups.

Correlation coefficient of the correlation between ‘perceived usefulness’ and ‘age’ is -0.21. This coefficient is considered a small negative strength of association. On the right side of figure 40 it can be seen that the boxplots for the groups with and without care do overlap. The median of the group without care lies a little bit higher and the boxplot of that group is skewed. Mean score for this group was 3.94. For the group with care this was: 3.62

The topic ‘Social influence’ focuses on whether the elderly think that people in their near environment want them to use the robot. Mean score for all the participants for this topic was 3.44.

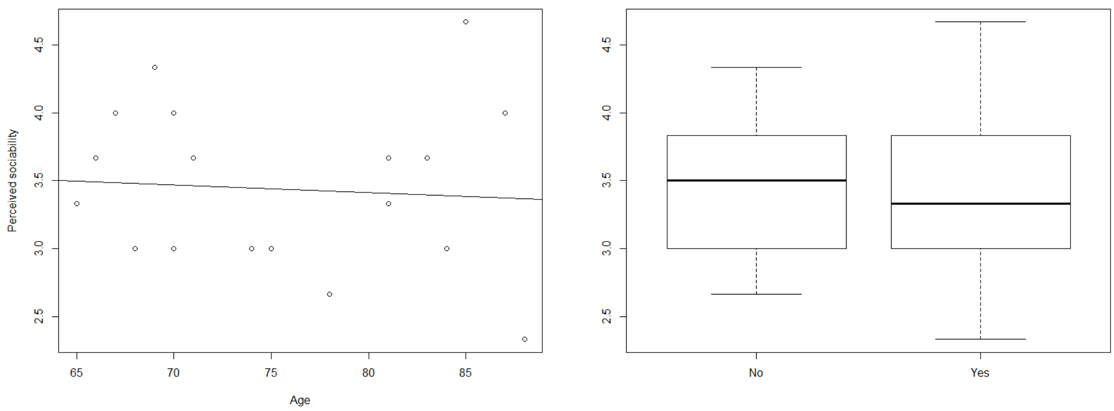


Figure 41 Left: Correlation Social influence and Age. Right: Boxplots Social influence score in care-groups.

The correlation coefficient for Social influence and age is -0.07. This is a small strength of association. As can be seen in the boxplots (Figure 41) the median for the group without care lies higher than the median for the group who does receive care. The mean score for that group on this topic is 3.43 while for the group without care the mean score is 3.45.

Social presence is the topic of the questionnaire with the lowest mean score over all participants. The mean score is: 2.53. This topic investigates if people could see the robot as a social entity.

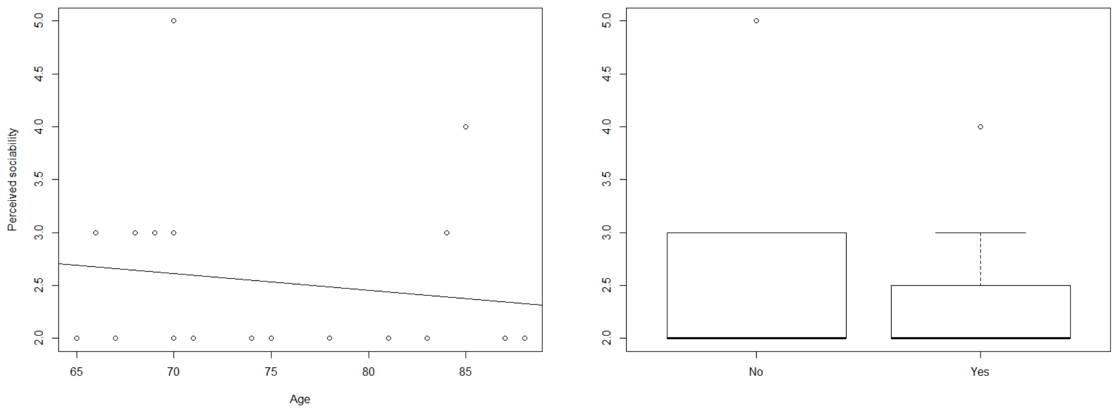


Figure 42 Left: Correlation Social presence and Age. Right: Boxplot Social presence score in care-groups.

This topic consisted of one statement: I could see the robot as a living creature. As can be seen in the left part of figure 42 most of the participants answered this statement with disagree. The correlation coefficient of the correlation of 'social presence' and 'age' is -0.14. This can be seen as low strength of association. The boxplots of the groups with and without care show that both groups have the same median and are skewed towards the lower side. The group without care had a mean score of 2.58 and the group with care had a mean of 2.43.

The last topic is 'Trust'. This investigates if the elderly trust decisions of the robot. If they can rely on the robot. Mean score of the participants of this study on 'trust' was 3.79.

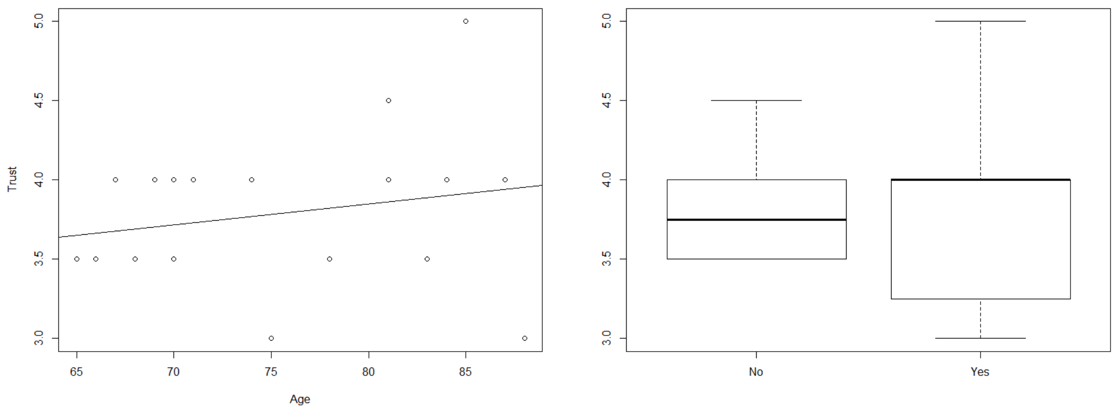


Figure 43 Left: Correlation trust and Age. Right: Boxplot trust score in care-groups.

The correlation coefficient for the topic 'trust' was 0.21. Which can be seen as a small strength of association. The boxplots (Figure 43) shows that the median in the group with care lies higher than that of the group without care. Both boxplots are skewed towards the lower side. The mean of the group without care is 3.79 and the group with care has also a mean of 3.79.