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Abstract:
Projections of the old-age dependency ratios of the western world tells us that within long our eldercare system will be overburdened. One solution is socially assistive robots, designed to help with concrete tasks in social ways. Until now researchers within this field have mainly focused on technological advancements, but in order for the robots to be accepted into the homes of the elderly, they need to focus just as much on factors for acceptance of the older users, as well as making them a integral part of the development process. This report is describing our one-year collaboration with a nursing home, and our use of the design approach Participatory Design (PD). PD was chosen as it adequately fulfills the requirements of taking into consideration the needs of the users, and making them an integral part of the development in all stages of the design process: From initial group meetings, to workshops, to prototype testing. Our intention was to develop our own socially assistive robot, based on knowledge gathered from PD and literature on acceptance. We agreed with the elderly and their caretakers on the task of assisting them with the morning routine, including waking up the elderly among other tasks. We found that by using PD and knowledge on acceptance to develop a socially assistive robot, we could meet the requirements of the users, and within a 12 day intervention, get the robot accepted.

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Supervisor:
Matthias Rehm
Kasper Rodil

Projectgroup no.:
151036

Members

Thi Truc Mai Nguyen

Bjørn Thorlacius

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Thi Truc Mai Nguyen & Bjørn Thorlacius
Group 151036

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1. Introduction

1.1 The Problem, Solution Domain, and Motivation for this Project

Living standards in the western world are getting better and better as time goes on. Improvements in medical science are appearing ever faster, leading us to live longer with every passing decade. Generally this is viewed by the population as a good thing, however, no good things ever come for free. Longer lifespans brings more age-related disabilities, and with these, more people that needs to be cared for, and as time goes on, this amount does not decrease. In 2050 projections tells us that the ratio between elderly needing care and the working population needing to care for them, will reach astonishing numbers: 76% in Japan, 49% in Europe and 34% in USA, as just some examples. Unfortunately, we do not need to wait that long to feel this effect, as the eldercare workforce already is under pressure, with the sheer number of older persons threatening to collapse the whole establishment. The dominant group of eldercare workers are women between 25 and 54 years of age, and this is not projected to change much between now and 2050. Additionally if this does not sound bad enough, the increasing equality between the genders means that less and less women are entering this profession, as their opportunities are expanding. We are left with the feeling of a disconcerting future, and something has to change to the better before the system is overburdened.

The scientific community is working hard to address this problem, and the topic of this report is the advancements of science within assisting robots. It might sound like science fiction, but for the last 30 years roboticists have made continuous progress in everything from artificial intelligence, machine vision, and efficiency of robotic movements, with the intent that these will all work together to form devices able to take over where the workforce is falling behind. Some of these already have solutions on the market, even though the bulk of the projects are still in early to mid development phases. This field is called Assistive Robotics (AR) and as it stands includes everything from big machines capable of lifting elderly persons out of bed and carry them around, to smaller solutions with functionalities making them act as companions, whether it be just for conversations or to help with medicine reminding. Research in robots in this last group is named

Socially Assistive Robotics (SAR), and devices of this nature are able to help in situations where the elderly might be mostly able to manage her health herself, with the help of something standing ready at her bedside table. Whatever the solution might be, if it helps through social means (conversation etc.) it operates under the field of SAR.

Even though SAR solutions have generally shown to be useful, whether it be in field testing of ones that are meant to tackle many different problems at once, or in experiments with smaller solutions in nursing homes, now that they are entering the phase of getting implemented into the homes of the elderly, some people in the field are arguing that there is a tendency that they do not adequately address some major problems. Their reasons are that researchers in the field are primarily focusing on aspects of functionality and not enough on aspects of acceptance. Meaning that they while they are developing some pretty impressive robots, they are not taking the actual needs, among other things, of the elderly population into consideration. They express that if these robots are to be properly accepted into the lives of the intended users, the roboticists will find themselves with problems that should have been addressed in the very beginning of their robots' developments.

To describe the actual problem in more detail, the keyword, as mentioned above, is *acceptance*. There seems to be a mismatch in what the developers of these SAR robots are explaining as important problems, as well as how they solve them, and what the elderly community describes as problems and how they want them solved. If the SAR robot developers want their robots fully accepted into their users homes, they have to start listening more carefully to their users needs, and work less from outsets of new technical achievements, it is argued. The factors of acceptance for new technologies for the elderly have been researched extensively throughout the years, and they can now be described from everything to the size of the robot to how it should behave. Developers just need to take these factors into account and shape their robots accordingly, because if they do not, we might end up in 2050 with robots capable of functionally solving every task conceivable in the lives of the elderly, but with unseen consequences that might mean, that they get to be nothing more than incredibly expensive coat hangers.

Unfortunately, the solution is not as simple as reading a few articles on acceptance, and then spending an afternoon with the drawing boards designing the perfect eldercare robot. Developers should spend a long time discussing in detail with their intended users exactly how they would like a certain task to be completed with the use of a robot, they should do workshops trying to figure out what lies beneath the skin of the problem, and then find the solution that deals with all the aspects of it.

This development approach is called Participatory Design. It usually starts with workshops and ends with repeated iterative testing of prototype after prototype. Adapting it to whatever problem might occur in the process. Even though in retrospect this seems like an obvious way to develop devices for a group as challenged as the elderly population, no one has actually done it before.

This is subject of this report. We decided to learn as much as possible from participatory design projects with older persons, combine it with knowledge gained in our own workshops with these people and their caretakers, to finally successfully develop a socially assistive eldercare robot.

1.2 The Research Question

Our problem statement can then be shortened down to this:

> Is it possible, and what are the implications and the lessons learned in the process, to develop a socially assistive eldercare robot, using strategies from participatory design, as well as implementing established factors of successful acceptance of the elderly community, and will it in the end be successfully accepted?

2. Background

This section will describe the roots of robots for the elderly, the research concerns of the past, their results, and how these shaped into the need and probably potential of including the end-users (elderly, family and stakeholders) in the development processes of social robots, using proper participatory design approaches. It will also analyze socially assistive robots currently in development and on the market with respect to these concerns.

2.1. The Beginnings of Robots for the Elderly

Robots, as a solution to the problem of the increasing amount of care-needing elderly persons, has been a somewhat popular research area for a couple of decades. The first projects dates back to the end of the '80s, start of the '90s, focusing on the most obvious of problems related to the most common disabilities of the elderly population, such as mobility [1]. However the robotic platforms that were being utilized in the research back then were not developed for the aged population, but multifunctional grasping manipulators intended to integrate generally disabled people into society. Some of the first solutions are displayed in figure 1 and basically tried their best to perform the actions of a third arm. They were intended for patients almost fully paralyzed, so that they could perform basic actions without any interaction from a caretaker. These were at the time either workstation-based, stand-alone systems, wheelchair-based, mobile robot systems, or a collaboration of multiple robots working together [1]. A few of these have been selected for further description.

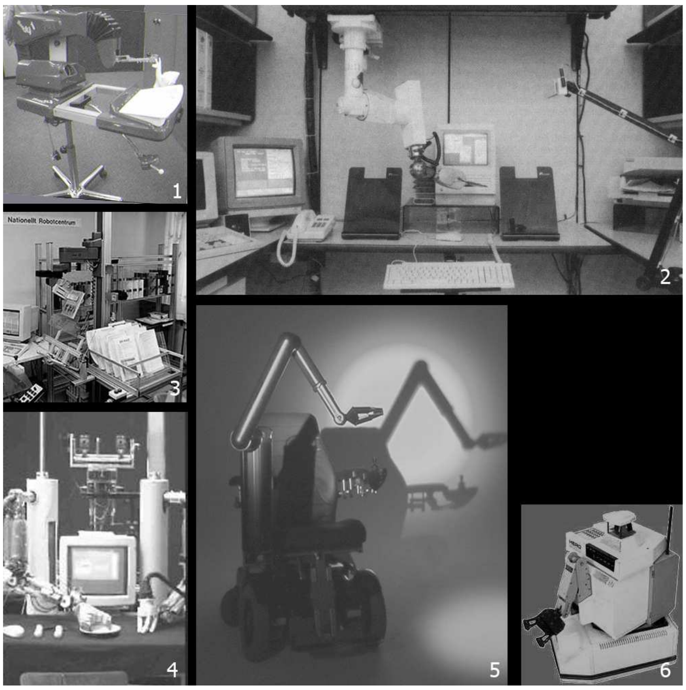

Figure 1: 1: Handy-1, 2: DeVAR, 3: RAID, 4: ISAC, 5: MANUS. 6: HERO-2000.

The Handy-1 – 1987

An example of a workstation-based system, the Handy-1 was originally developed at the University of Keele, UK, to aid an 11 year old boy with cerebral palsy and has since then evolved to being the most successful low-cost, commercially available robotic system [2]. It was at the time of development created to assist with basic needs, such as eating, drinking, shaving and teeth cleaning [1].

The DeVAR – 1989

Short for Desktop Vocational Assistant Robot is another example of a workstation-based system. Developed at Stanford University for paraplegic war veterans this system utilizes a PUMA-260 robot on an overhead transverse track. It is equipped with a prosthetic hand, was developed for office work (such as handling floppy disks, picking and hanging up phones, etc.) and was controlled using voice commands. The developers recognized safety as being important, and equipped it with no less than four different emergency stop functions [1, 4].

The RAID - 1991

Another workstation-based robotic system developed for office use. Its name is short for Robot for Assisting the Integration of the Disabled, and was developed for the purpose of integrating disabled people into clerical and accountancy work. The system comprised of a robot, a PC, a fax, a phone, and a printer [1, 3].

The ISAC - 1992

Short for Intelligent Soft Arm Control the ISAC is an example of a stand-alone manipulator system, developed at the Intelligent Robotics Laboratory at Vanderbilt University. It is another system developed to help with eating and drinking, with the goal of helping the user out in a natural environment. Some intelligent software tracks faces and recognizes objects, and controls the robot using a voice command system [1].

The MANUS - 1992

A wheelchair-based system. A robotic manipulator arm and a wheelchair made into one easily reconfigurable combo-unit designed to help in unknown environments. It can be programmed to suit individual needs, but most emphasis on its use is placed upon the manual control of its gripper. The arm was made to fold away under the armrest so as to not obstruct needlessly [1].

The Combination of ISAC & HERO-2000 - 1993

An example of a collaboration of multiple robots. The ISAC and HERO combo work together by the user specifying what he or she wants, then HERO fetches it and gives it to one of ISAC's hands. Back in the day this kind of system was argued to be the most promising solution within versatility of tasks. It is voice controlled and gives vocal feedback when errors are encountered etc. An intelligent part of the system is its ability to recognize fuzzy commands (such as “come closer”) which might even be task specific, and can even be used to 'teach' the system new functions [1].

As can be understood from the above summaries of robotic systems much of the past research was centered around motion - and the dexterity - of grabbers, planning of tasks (and understanding human signals during these), sensing the surroundings, and interacting with disabled people safely. The dexterity and motion of manipulator arms were in the past described as being mostly insufficient [1], because systems were very rarely equipped with hands as dexterous as those of humans. The systems were required, and expected with future developments, to perform well in unknown environments doing advanced tasks with everyday household appliances, such as stoves, microwaves and cupboards, which were considered severely limited with the gripping solutions at the time. For what can be said about planning, it was explained as the concept of making robots understand the various sequential steps needed to fulfill the requirements of everyday tasks, such as cooking for example. The work in the past was inspired by early A.I. work from the '60s and researchers felt fairly confident in their competence despite its difficulty. Successfully cooking a dish, for example, might not be a straight forward sequence of steps, since the user might want to add new steps along the way when observing the robot. Therefore 'planning' also incorporated additional user instructions on top of unexpected environment changes etc. Sensing surroundings, the third area of research, was at the time understandably a very difficult task. It involved touching objects and investigating their material compositions and machine vision as the dominating approaches. Machine vision of robots at the time was not at all close to their human counterparts, but impressively many of the above described systems successfully recognized objects and tracked faces, among other things. The robots also needed to avoid obstacles when moving from one place in the home to another, which as another aspect of concern of research at the time, was important for safe interaction. Safety as the last concept to be discussed here also had a very important place in past research, since unknown actions of the users (such as sneezing or coughing) could potentially place strong manipulator arms on collision courses. One of the systems above, the DeVAR, had safety as a main concern, and as an example incorporated four different ways of stopping the system by the user, if the user shouts, if the user tells it to stop, if the arm encounters a resistance higher than a set weight, or if the user presses a 'panic' button.

When we get closer to present day solutions to the growing need for eldercare devices the importance of describing these past concepts become clear, as they resemble some of the more popular of modern solutions and research areas for current robots in expensive projects even today, despite the fact that these systems were not being developed with elderly people in mind specifically, but just bundled them together with people with other disabilities. This approach makes sense when seen retrospectively (mobility disabilities are widely present among many of the handicapped), however it is clear that there is a need of specificity in the design approaches. It is arguably naïve to think that an 11 year old with cerebral palsy is as capable as any elderly person.

In the new millennium we begin to see some of the first actual projects that concerned themselves with the problem of elderly people exclusively, and taking the ideas of these users and their stakeholders (care staff, family, friends etc.) into account. A project named ELDeR, short for Enhanced Living through Design Research [5], in 2000 highlighted the past concerns as explained above, that most technologies intended for eldercare up until that point were addressing general problems of declining mobility and cognitive skills, and regarded social and emotional needs as a less important factor. The project recognized, what will later in this report seem even more important, that "*failure to consider the social, emotional and environmental dimensions of the aging experience results in missed opportunities for new technologies and applications, and poses difficulties for the adoption of potentially useful products.*" [5, p. 2] The project mainly focused on finding out what is needed for the "universal usability" of eldercare products, though not specifically robotic in nature. They used ethnographic methods adapted from anthropology and the social sciences: actively learning from a literature review of past successful methods, lifestyle interviews about the elderly people's routines and households, elderly people's self-documented day-to-day lives (supplying them with cameras and log books for the task), and personal observations of the life inside a senior community in the area (accompanied by note taking and photographing). Their observations and conclusions of these confirm their initial statement, namely that eldercare, as it is experienced from the elders and their care staff, is not about only focusing on problems of mobility and cognition, but involves a complex mix of social and emotional factors. They identified a couple of important concepts to remember when designing eldercare products: social, psychological and aesthetic dimensions and their relation to usability. Their firsthand interviews with elderly produced a couple of examples. When a 92 year old lady was asked about her hearing aid, she told the researchers that she would only use it when she knew she would need it. Even though the researchers explain that her hearing was noticeably deteriorating. Her need for a feeling an independence from technology that helped her with her disability outweighed the obvious usefulness of it. Another example was a 90 year old lady that didn't wear her "emergency necklace", that let her call for immediate help should she need it, simply because she "didn't like it". The researchers inferred that a need for the perception of users in the development process would help the adoption of technologies intended to help them, because if neglected this trend, of the elderly not using devices simply because they are reminding them of their old age and disabilities, will continue. As for the aesthetic dimension, the ELDeR project provided some useful knowledge as well. They explained an example of an elderly woman that lost her mobility and as a result got a wheelchair. However, the result was not as figured, that she would move around as much as before, it was actually the opposite. The assistive tool embarrassed her, and because of this she stayed inside the confines of her own home much more than before and lost contact with friends, the experience was later followed by a depression. The project noticed a predominant use of mobilityscooters in the community however, and realized that the difference between a wheelchair and a scooter is obvious, the scooter has a more sporty and exciting look and feel. They also mentioned the economic barrier for many elders when purchasing new products, and explain that if developers started to design devices with a potential broader user base, the social stigma of eldercare products and their costs will be reduced. Smaller devices with a thought on aesthetics in their development process are concluded to be of biggest acceptance rates.

These conclusions were made fifteen years ago, however this report will show that even though a lot of technological advances has been made, products are still developed with mainly functional aspects in mind, with less thought on aesthetics, social, emotional and economic factors. But before we move on to those, let's investigate when the idea of socially assistive robots began to appear as a contrast to contact assistive robots.

At the same time as the ELDeR project the emerging field of robots for elders also start to appear. As we reviewed earlier, the problem of the increasing amount of elderly people versus the decreasing amount of staff and increasing price of healthcare in general was already recognized in the early 90's [1], and as we move into the 2000's more diverse and specific solution domains are

Figure 2: The first prototype of "Flo, the Robot" from 2000.

emerging. The earliest example is “Flo, the Robot”, from the Nurse-Bot project of Carnegie Mellon University (figure 2) [6].

The motivation for this robot's development was a recognized need for assistive technologies in areas of “medication remembering” and similar cognitive tasks, since almost no work had been done on this, even though the technological advancements required was up to par. They explain that the area of mechanical aid has been developing for a time, but that they forget the importance of reducing the cognitive load of a group of people that predominantly have various degrees of dementia or mild cognitive impairments, potentially (and often) causing severe problems in day-to-day lives. Specifically their work was centered around five primary functions: cognitive prosthesis, safeguarding, systematic data collection, remote tele-medicine and social interaction. This project displays a certain trend within eldercare roboticists however, that they do not supply much information to *why* these functions are important, and *how* they were chosen. A trend that was to follow in many projects later as well. At first look their explanations seem relevant, such as the one for the need of robot being able to facilitate social interaction: *“Finally, the vast majority of independently living elderly people is forced to live alone, and is deprived of social interaction. Social engagement can significantly delay the deterioration and health-related problems. While robots cannot replace humans, we seek to understand the degree at which robots can augment humans, either by directly interacting with the person, or by providing a communication interface between different people that is more usable than current alternatives.”* [6, p. 2], but as the ELDeR project concluded, and as later reviews of research using socially assistive robots also show, researchers need to take their time investigating the needs of their end-users in depth. There is also no thought on the aesthetics of the robot or its emotional and psychological effect on the elderly when entering their home. This early Nurse-Bot project work was centered around hardware and software functionality, face-tracking, navigation, speech etc., and mentioned that it is a “proof of existence”. Of course they explained that they need to do more work since it is all preliminary, which would indeed be needed considering they tested it during an experiment with robotics students as participants, the results of which is hardly relevant. The idea of using robots as social companions in the daily life of elderly people, reminding them of medicine, calling elder care staff if they fall, etc., was appearing with this idea though, and it was a relevant step for the field.

The Nurse-Bot project unveiled a new prototype in 2002 – Pearl (figure 3) [7], with which the researchers once again specifically focused on functionality. This time they decreased the number from five general areas of interest to two very specific tasks: reminding people about routine activities such as eating and taking medicine, and guiding them safely around their environments. They again do not explain why they chose these tasks specifically, however, they *do* in their conclusion use a couple of lines to explain that they field tested early prototypes in a residential retirement community, but do not describe their specific findings unfortunately. It would be interesting to see if some of the ELDeR project conclusions would fit. Needless to say, robots were getting more diverse now, and to separate robots doing physical assistance from those working primarily with social assistance, the field needed proper categories with proper names and definitions.

Figure 3: The "Pearl" prototype from 2002.

2.2. Defining Socially Assistive Robots and Their Use

The Definition

In 2005 Feil-Seifer and Mataric recognized this need and published a paper on the subject [8]. In the past all robotics that assisted people in any way was largely referred to as Assistive Robotics (AR). This is not useful anymore, since it does not include any robotic technology that does not assist through contact. The term AR was not even properly defined at this time, however an adequate definition is a robotic device that aids any user with any problem. The definition Socially Interactive Robotics (SIR) was already in use and described robots with the specific task being interaction itself. Feil-Seifer and Mataric defined Socially Assistive Robots as an intersection of AR and SIR. SAR robots would share the goal to assist human users with AR, but with the specific limit that the assistance be social in nature. The relation and difference to SIR is that the goal of SAR robots is to develop close social ties, using proper interaction, with their users in order to satisfy the need of successfully assisting with a certain task, where with SIR robots the interaction is the key goal.

The Use

Socially interactive robots need to be interactive through any of these means: Embodiment, emotion, dialog, personality, human-oriented perception, user-modeling, socially situated learning, or intentionality. For socially assistive robots we need to add groups of people that they could potentially assist using any of these interactive means. These would be: elderly, individuals with physical impairments, individuals in rehabilitative care, individuals with cognitive disorders, or students (for teaching purposes). The tasks of the robots can be anything related to the needs of the specific user, and evaluation of its performance should be determined by how well the robot engages the user socially and how well the assisted task is performed.

As we can see, the Flo and Pearl robots are both socially assistive robots under this definition. They have specific tasks they need to assist with (Pearl reminds elderly of dinner or medicine) and tries to do so by being as social as possible (Moving slowly when needed, understanding words and answering back etc.). As an apparent contrast robots explained in the very beginning all try to act as extra hands, and would then fall into the category of Contact Assistive Robotics (CAR).

Since this definition the popularity of the robots has increased, and much research has been done in their interaction with elderly people, and therefore a good amount of reviews are also present [10 - 15].

2.3. Reviewing Related Previous Work with Social Eldercare Robots

A total of six reviews of social robots for the elderly has been analyzed and summarized in this chapter. Not all of the reviews are specifically targeting SAR robots intentionally, but the research and robots they investigate usually fall into this category (the most popular examples of these are presented in more detail in the next chapter). The results of the reviews are often similar and can be categorized into five subsections:

1. The Motivations of the Research
2. The Envisioned Uses of Social Robots
3. The Actual Effects of Social Robots in Eldercare
4. The Lack of Reliable Research Methodologies
5. Factors for Successful Acceptance of Social Robots by the Elderly

The Motivations of the Research

Researchers all agree that social robots are a viable solution to what is often called the “graying of the western population”. This is the on-going effect on the lengthening of the life expectancy of humans in developing countries, the following increasing need of care, and the appearing shortage of healthcare personnel [10 - 13, 15]. The problem is global, with the first country expected to feel its effects being Japan, with a ratio of 76% of the older population (65 and older) to the working age population (15-64 years old) deemed dependent on society in 2050, according to World Bank Statistics. In layman terms this means that for every 100 potentially working adults, there will be 76 elderly to care for (at the moment it stands at 41% [9]). To battle this projection, the Japanese government is trying to integrate various kinds of assistive robotic technologies into elder care, including various CAR, SIR and SAR robots. Although not as severe in Europe the dependency ratio is still projected to reach 49% in 2050, and being confronted by initiatives funded in some cases by the Seventh Framework of EU. The old-age dependency ratio in USA is expected to hit 34% in 2050, which is also being confronted by governmental funds into assistive robotic technologies. These numbers might not be as serious as they sound though, since advancements in medicine and care strategies might mean that people go further into old age before needing care [12]. As mentioned above, the aging of the population is just one factor of the problem. With the ratios becoming larger, the working population becomes smaller, and the elder care staff within this smaller still. A study from 2002 explains the situation as dramatic, as the majority of the eldercare workforce is women between 25 and 54 years of age, the amount of which will pretty much stay unchanged as the elderly population rises. Equality between men and women has also risen significantly during the last four decades, which has brought more opportunities for women, which results in less entering the long-term care workforce [16]. This problem needs a proper reliable solution, and it is the thought of roboticists and health care researchers that robots can play an integral role in this, with many different uses [10 - 15].

The Envisioned Uses of the Robots

Bedaf et al. in 2013 studied what services, for assistive robots in eldercare, would be most crucial to successfully tackle in order to ensure the independence of elderly users [16]. They asked a total of 113 participants (41 elderly) the question: "Which problematic activities in the daily life of elderly people are threatening their independent living?", and to then asked them to rank their answers according to what is the most important. Their results were interesting but not really surprising: Walking came in first, climbing stairs second, doing the household third, and so on. The study was supposed to find some tasks that the Care-O-Bot 3 team could focus on (as well as other researchers in the field), however, they realized that it is not as simple as just solving one problem after another. Their main conclusion was thus that it might be a fruitless endeavor to look for an "*all-encompassing service robot capable of many tasks.*" [17, p. 5] and that robotic solutions with narrow functionalities may lead to faster success. Their methodology (the question) also does not specify the use of a robot for the task, and therefore it is debatable whether or not these would even work for such a device. Other researchers often base their intended use on assumptions, or future visions without relying much on studies [11]. However, there is a tendency in the field to split the robots into SIR and SAR robots and explain their potential uses [8, 10, 12], also labeled service-types (SAR) and companion-types (SIR). Service-types are equipped with functionalities that are related to the support of independent living by supporting basic activities, such as eating, bathing, going to the toilet, getting dressed etc., and might also provide household maintenance, and maintaining safety [10]. The companion-types are mainly focused on enhancing mood and psychological well-being, by providing companionship, examples being the Paro robotic seal, developed to simulate a real pet in animal-therapy sessions, to help demented elderly [12]. The definition of SAR robots supply us with some additional examples of potential future use, being tutoring, and physical and emotional therapy [8]. The main point of both of these types of social robots is that they should seek to do these tasks, while becoming an integral part of the everyday lives of older people [11].

The Actual Effects of Social Robots in Eldercare

In 2009 a study reviewing the effects of SAR robots in eldercare reported that there seemed to be a use of robotic systems in eldercare, but even though their methodology for finding publications were designed to be wide, their search only revealed a limited set of studies, using only four versions of SAR robots, the Paro, the NeCoRo, the Aibo and the Bandit. Two of which, Aibo and NeCoRo, are no long in production and the Bandit was still in the development phase [15]. Interaction with the Paro had improved mood, encouraged communication and decreased stress levels in older persons, as well as improving hormonal values (shown in urine tests), indicating improved functioning of vital organs [15]. The NeCoRo decreased agitation in therapeutic sessions, but this might have been a novelty effect, since it was concluded after only a two day study. There was also no difference in agitation when using a plush cat versus a robotic one. The Bandit was studied in a setting where it helped elderly people suffering from dementia solve cognitive games. It improved reaction times and incorrectness [15]. The Aibo robotic dog was tested both against real dogs and toy dogs. In the first study no difference was found, though both decreased loneliness and increased attachment, while in the second, and others like it, they also concluded that robot-assisted activity reduced loneliness, and improved emotional states of elderly suffering from dementia. Besides these four robots the effects of a fifth and six was reported in other literature. The fifth is the Hopis robot developed by Sanyo. It was commercially available and equipped with various healthcare related functions, such as taking blood pressure, measure temperatures, measure blood-glucose levels, diagnosing eye diseases, and interviewing users about their health and emailing the results to their doctors. Despite this sales were poor and production was canceled. The sixth robot was the Yorisoi Ifbot which was meant as a companion for elderly people. It was tested in a rest home, but users lost interest after just one month [13]. These failures might just be the effect of a field that is currently exploratory in nature, with pioneering work being an important step to investigate acceptance of and trends in users [15]. This effect is also shown in the apparent lack of relation between the wanted results of the research, and the intended application of the robots, where the outcomes were often only partly related the desired added value [15]. Additionally, many of the results reported here are not to be understood as significantly proven however, because of a variety of factors: Firstly, the majority of the studies are conducted using the Aibo and Paro robots, which presents a problem when applying it across all social robots [10]. Secondly, most of the studies are done in Japan, and results should not be carried over to other cultures if this is expected to have an impact [10]. Thirdly, almost all of the studies are done with elderly living in nursing homes, and as with cultures, conclusions should not be expected to be similar if done with elderly still living at home [10]. And fourthly, research methodologies are often not robust enough to derive reliable results [10], which is the focus of the next subsection.

The Lack of Reliable Research Methodologies

This lack might also be because of the exploratory nature of the field of SAR robots, a lot of the reviews are describing a lack of reliable research methods being present [10 – 12, 15]. Good control conditions are often not present, as it is arguably difficult to test a SAR robot against a fake version of same if needed [10]. Additionally the amount of participants, as well as lack of randomization of these, in the research has been criticized, and the resulting experimental effects drawn into question [10, 15], calling for a need of larger RCTs (randomized controlled trials) [15], to conclude that the intended effects are at all present. Long term studies are rare as well, and effects such as novelty and Hawthorne - temporary changes in environment brings temporary changes in behaviour - can not be excluded in several studies [10]. In general, longitudinal studies using many participants over long time can ensure that the heterogeneity of differences gets factored into the results [10, 11, 12]. This would also ensure that positive and negative long-term effects on the perception of social robots by elderly are properly investigated, as finished robots when implemented needs to occupy the residents of the users a long time to ensure successful care [8, 11]. Sociodemographic factors, such as age, previous experience with robots, cultural differences, gender, education, and family status are also underrepresented in research dealing with the acceptance of the robots, even though researchers are aware of the weakness of not doing so [11, 12]. They argue that it is difficult to do so with small sample sizes, and often rely on acceptance models where these sociodemographic factors are not present [12], therefore a proper model of acceptance for social robots is needed. Additionally, not just the differences in participants is not considered, but also differences in the robots they use [11, 12, 14]. This is not to say that researchers test different robots against another, but instead criticizes the lack of this notion in goals aiming for the general implementation of social robots in eldercare. It becomes clear when investigating the research, that methodologies are often adapted to fit specific robots, but as the robots are very different, a need for a uniform approach is apparent, in order for various results to be comparable [12]. The last point of criticism is that methodologies are often not described enough to make reproductions possible, and a need for conceptual clarity and thoroughness in the research is called for [10, 11]. This has some peculiar consequences, since in some cases different studies experience contradictory results, as in one example, where one study reported that the Paro increased stress (when the Paro moved a little, compared to no movement), and another reported that it decreased it [10].

Factors for Acceptance of Social Robots by the Elderly

This is perhaps the most comprehensive subsection in this chapter. The importance of properly getting the robots accepted into the residents of the elderly, in both nursing homes and independent living situations, will secure the successful implementation of the last fifteen years of research into robots specifically developed for the purpose, and consequently into the lives of the older persons.

Generally, research into SAR robots are divided in two: actual health effects (stress, communication, medicine reminding, etc.) and what is needed to secure accept and adoption. The second part is very comprehensive, and some serious work has been done in this area. It is mentioned that designers should be mindful of the acceptance of robots, since it does not relate fully to other smaller technological implementations. Smaller incremental innovations are more readily accepted than radical ones [12]. The need to understand the factors that contribute to the acceptance of these radical innovations for older people are important, to not repeat past mistakes and continue the trend of the rejection of robots for healthcare [13], as shown with the Ifbot and the Hopis.

The factors for acceptance can be divided into two parts, individual factors pertaining to the elderly, and robotic factors pertaining to the personality and such of the robot. The individual factors are also in some literature called 'sociomographic factors', as mentioned earlier, and they are: age, needs, gender, previous experience with robots / technology, cognitive abilities and education, and the social network of the user. The robotic factors are apparent hedonistic gains, adaptability, personality, gender, size, appearance, usefulness, and safety. In order to develop robotic solutions for the elderly, each and everyone of these should be carefully investigated for most optimal acceptance. This next part will go through each, and report what research has found most important.

The first of the individual factors is age. The older you get the more resilient you are to the use of assisting robots. As age-related disabilities begin to manifest themselves, and the specific functionalities of robots are about helping with these disabilities, however, the population above 75 years begin to soften up to the potential use. The age-group of people between 64 and 74 years old are interestingly more likely accept inconveniences of disabilities than adopt an assisting robot. Older people do not trust new technologies as readily as younger people, but to address this, they expressed preferences towards female voices, small sizes, slow movements, a serious aspect, and robots of a single colour [13].

The preference for seriousness relates directly to the fact that older people are more accepting of healthcare robots if there is a specific perceived need for it. Therefore, carefully assessing needs and matching these to the functionality of the robot can result in higher acceptance rates [13].

The gender of the user has shown to affect acceptance. Research has shown that males have stronger psychological connections between anxiety about robot behavior, negative attitudes about interactions with robots and social influence of the robot. Females might have stronger connections between anxiety towards behavioral aspects, emotional aspects and robot interaction.

Previous experience with robots has a significant effect on acceptance, and therefore it would be clever to include the users in the design process of the robot. Participatory design with older persons should be the approach to develop new robots to make full use of this [11]. This effect is also found in actual robot interventions in the lives of older people. A five-week trial showed that the older persons became more accepting of the robot moving closer to them as time progressed [13].

About cognitive ability and education it was found that higher education related to greater acceptance of general technological solutions [13], and the more cognitively functioning the user is, the more interacting they are with a robot against a fake version of same [13].

The social network of the user is predicted to have a big effect on the adoption of robots [11, 12, 14, 15]. Not surprising, the opinions and perspectives of friends and family will have a large influence on how people perceive and subsequently accept robots [14]. When robots become more common in the surroundings of the user, we can expect their adoption rates to increase, in order to seem "modern" [14]. But the social network also has a potential negative effect on the acceptance of robots. As described earlier, the ELDeR project saw a connection between a technology reminding the elderly and his/her surroundings of a disability. In that case the wheelchair indirectly effected the movements of the user negatively, and was followed by a depression [5]. In this case, it might benefit acceptance rates by reducing the size of the robot to something that can be stored away, or hidden [14]. Although, when the disabilities of the users gets unbearable, the potential use of the technology once again outweigh this effect [14]. Children are predicted to pressure their older relatives to adopt technologies as well [14], however this does not negate the previous preference to want to store it away.

The robotic factors are more extensive than the individual ones, but equally important to make use of.

Hedonistic gains, pleasurable effects, are reported to have one of the highest effects on acceptance [14]. Robots need to appear exciting, with an obvious enjoyment factor to it. However, even though the specific functionality of the robot might not be hedonistic in nature, it might indirectly have gains viewed as such [14]. For example, a robot reminding a user to take medicine, can make the user feel healthier overall, and supply more energy for pleasurable tasks. Companionship is also considered a hedonistic gain, as it will induce trust and a feeling of a connection towards the robot [14]. Direct fun and secondary pleasurable gains are very important to ensure acceptance [11, 14].

Adaptability is about recognizing that the disabilities of older persons are not homogenous at all. They span everything from difficulties in movement to seeing and hearing impairments, to mild and severe cognitive impairments. Developing adaptable robots is thus important [13].

The importance of the personality of the robot for acceptance is about making sure it behaves most optimally [11, 13, 14]. The two main points from research here is concepts of seriousness and social intelligence. Robots that match the personality of the user are most readily accepted [11], but some adaptations to this are necessary. Fun robots are preferred for task-completion, even though serious robots perform the task most optimally [11]. The social intelligence of the robot is an interesting area. People anthropomorphize robots more than other technologies, and this result in expectations of more than usual social intelligence, which is a problem if it does not live up to these and disappoints the user at first impression. Developers might even want to make their robots seem dumber than they are, to lower this risk [14]. It has been suggested that this act of lowering the intelligence, or just making it seem like it, can make people be more forgiving of mistakes, as they are with pets [14].

The gender of the robot is not that big of an area yet, though as mentioned above in the individual age factor, older people prefer female voices. The general idea at the moment is that stereotypes of users will apply to robots as well, and therefore it might be a good idea to investigate cultural trends in the area where the robot is supposed to be implemented [13].

The size of the robot is not discussed as widely, but again, older people prefer smaller robots that can be stored away [13]. Size is also related to safety, where smaller robots are viewed as not being able to do as much damage to the home as bigger ones [14]. Basically, the smaller the robot, the more likely it is to be accepted [14].

About the appearance of the robots, whether or not they should look human is debated. Some state that the appliance of humanoid robots will be beneficial to acceptance rates because of their ability to utilize “human tools”, such as body language [11]. 47% of 2000 people, unfortunately not specifically elderly, questioned, said they did not want the robot to look human, against 19% that said they would prefer such an appearance [13]. In another study older people expressed a preference for robots without faces [13]. The amount of “humanness” in robots is also related to how socially intelligent they appear. If a robot looks human, people might expect it to be able to hold human conversations [13], and as such might disappoint the users. About animal appearances the same notion of stereotypical views as with gender applied, people that were not fond of animals would be less likely to interact with animal-like robots [13]. The most important point to be made about appearance is that robots should always avoid portraying their users as dependent and weak [5, 14]. Users are also afraid to appear lazy to their peers, when confronted with automation technology [14]. The last point about whether or not robots should look serious is also important. The failure of the Hopis robot, described in the subsection about actual effects of robots in eldercare, can be attributed to the robot not looking as serious as the task it was performing (monitoring health) [13], and as such, developers should be mindful about the fine line between *fun* and *serious*, and investigate the different approaches with their end-user. The acceptance of the robot will always be affected by the appearance, as it is directly related to what previous experiences people use to form an initial understanding of it [14]. Here the Hopis robot is a perfect example as well, since it basically looks like a furry toy, and peoples past experiences with such toys are nowhere near healthcare.

Factors of usefulness affects acceptance in various ways. The robot must seem easy to operate and the need for its use must be obvious. If the robot seems to lose its functionality after a short amount of time, for example, if the disability of the elder gets so bad that at a point the robot is not able to help anymore, and thus becomes obsolete, it will affect acceptance. Adaptability is key here.

The last robotic factor for acceptance is safety, which is deemed the most important of all, and should overshadow all other concerns [14]. Until robots prove their safety to the general population, there will always be a degree of mistrust, since a robot is looked upon as “having a mind of its own”. The smaller the robot, the less dangerous it seems, and users should always be in control of when and where it operates [14].

The intention of this section was to summarize in detail all research with socially assistive robots (or just social robots in some cases) present at the moment, as reported in various reviews, in order to learn the most efficient way to develop a socially assistive robot for elderly users and their caretakers. Due to the work in the field being quite extensive, many recommendations can be drawn, both from actual experiments with clear goals and from work trying to determine the factors most important for successful acceptance.

The robot, in conclusion, must meet the user’s needs, which should be very apparent, understood and acknowledged. It is important that it is slow, safe and reliable. It should be small, both in order to seem less dangerous, but also so it is easier to store it away out of view of peers, as not to remind friends of the user's disability. It should not be too human-like, and preferably faceless. Its personality should fit its task, being serious for serious tasks, but if possible with a certain “fun” attitude about it, because hedonistic gains always are important to the adoption of new technologies. Female voices are preferred in general, but applying a gender to a robot will also be viewed with established stereotypes of the users. It should not look animal-like, to avoid some users attributing characteristics of previous experiences with such, since some of these might negatively affect its acceptance.

In order to choose a task to assist with, part of the development process must draw in experiences from everyone involved in its use when implemented, in short all stakeholders (family, carestaff, financiers, etc.), but most importantly, the elderly. Relying on information on the characteristics of the users from other research, might be detrimental to the acceptance, since users are not homogenous in their disabilities, and needs within similar disabilities vary widely. Also, since previous experiences with robots affect acceptance rates, developers can benefit from effectively incorporating the intended users into the design process. Since elderly has expressed a concern for the potential obsolescence of the robot (if it ceases to be useful), adapting its functionality throughout the process, to always be useful, will also be beneficial. A concluding remark here is that focusing on solving single tasks with the incorporation of end-users is expected to result in faster acceptance and successful implementations.

The question is then, what is the best approach to successfully develop a socially assistive robot? One review has an answer:

> *"There is a need for participatory design that includes users at the early stages of social robot development and continues to include them iteratively throughout the design process. In this way, it will become more apparent at an early stage for engineers, designers and users to identify the influencing technological changes and their social consequences. All stakeholders should be involved—not just older people or users—which means both the eager beneficiaries and the critical challengers. Through participatory design, traditional stereotypical views of robots can be undermined and a clearer understanding of what social robots of today really can and cannot do can be achieved."* [11, p. 10].

Participatory design, if done correctly, is thus argued to be a way of taking all needs and concerns of older people and their caretakers into consideration, and address them adequately, through an iterative process of "experiment, adapt, and repeat" in robot developments. The problem is, no proper work has been done in this field, and lessons on how to proceed must be drawn from research as closely related as possible. Before we approach this subject, however, lets look at a few examples of the previously mentioned socially assistive robots, to see if they in some way or another develop their functionalities and appearances together with their end-users, as well as how well they fit the presented factors for acceptance.

2.4. The Incorporation of Stakeholders in the Development of Popular Socially Assistive Robots

This section will serve to quickly describe some of the most popular socially assistive robots in eldercare at the moment, and compare them to the previous concerns. The robots were chosen based on the frequency of their appearance in the reviews. Specifically we went through development reports of the robots where available, and looked at how much the developers incorporated stakeholders in the design process.

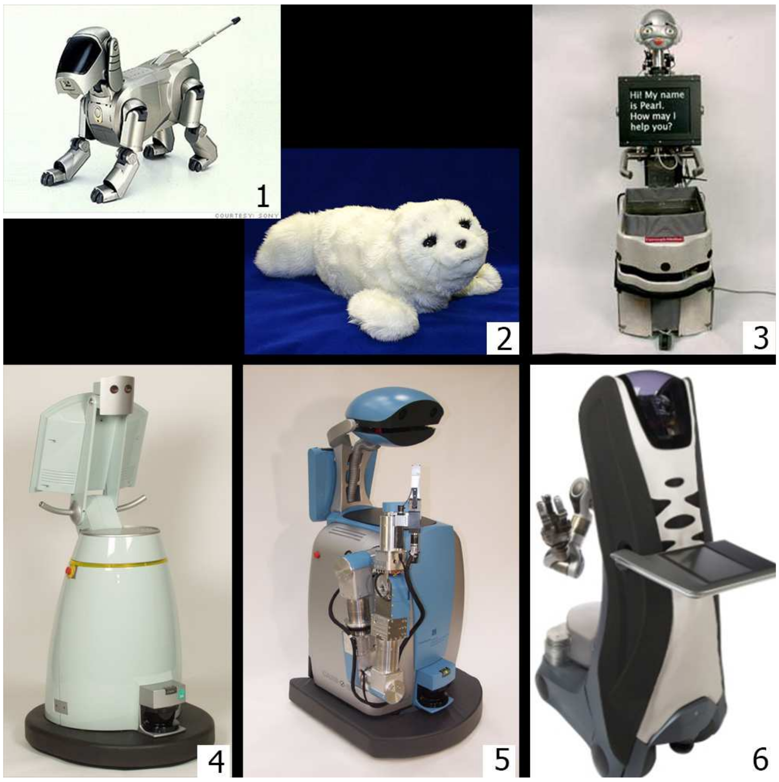

Figure 3: Popular SAR robots. 1: Aibo, 2: Paro, 3. Pearl, 4: Care-O-Bot 1, 5: Care-O-Bot 2, 6: Care-O-Bot 3

Aibo

The Aibo was created as an entertainment robot by the Sony Corporation. A small device resembling a dog. It wasn't developed for eldercare use specifically, and therefore these users were not part of its development, obviously [18].

If this was to be used in eldercare, we see some of the concerns being addressed involuntarily already. It is small, so it can be stored away and does not seem very dangerous. It has an obvious hedonistic appeal to it, since its main design reasoning was to be entertaining. Its personality and appearance is that of a dog, and therefore trying to make it perform serious healthcare related tasks is not optimal. A last remark is that, people that dislike animals, will tend to interact less with it as a result.

Pearl

Developed specifically for eldercare, Pearl is one of the most studied SAR robots. In a report explaining its development, tasks seem to be based on assumptions, without much emphasis on why these tasks were chosen [7]. They do not mention the reason for its visual design, but they do, however, test every finished prototype on elderly people.

The main problem with this SAR robot is its size. At about 1.5 meters tall it takes up a lot of space, and is thus difficult to hide away, and might seem dangerous, if it goes “off on its own”. Other notable problems is that it has a very human face, it is intended to perform many different tasks, and it seems very socially intelligent, which might disappoint users if it does not live up to expectations. Besides testing prototypes on elderly people, the developers did not perform any sort of participatory design with them. It might have a certain hedonistic appeal to it though, since it seems very high-tech, and if not too reminding of disabilities, elderly might want to “show off” with it.

Care-O-Bot 1, 2 and 3

Developed as a home assistant for elderly the Care-O-Bots are probably the most advanced and expensive of robots in research at the moment. The third version is equipped with the latest industrial components needed to most satisfyingly complete its tasks [19], with production costs reaching a total of €250.000 [20].

They have about the same amount of input from potential end-users as the Pearl. That is, the only time they interact with them is when their prototypes are already completed. Some of the same concerns also apply, as its big size (being a problem with storing away and safety issues), and hedonistic high-tech appeal. It is however faceless, not at all human-like, which is beneficial. The idea of the Care-O-Bots was, like the Pearl, that it should be able to perform many different tasks, which might not be optimal for success and acceptance.

Paro

Developed especially for research in robots in animal therapy, this robot is probably the most studied SAR robot in relation to eldercare. Its design is that of a Seal, and its purpose from the beginning is that it should be applied in the field [10]. A lot of studies show some promising effects of Paro, as mentioned in the previous section, but some issues with its development still apply.

It does not have any incorporation of stake-holders in its design process, since its development was focused around animal-therapy from the very beginning [10]. About the concerns from the previous section, this is probably the one that fits the best. It is not human-like in appearance, even though some previous experiences with animals might effect its acceptance. It is small and thus easily stored away, and arguing whether or not it might be safe for interaction with elderly, it is safe to say that that it will not seem dangerous.

In conclusion we see that views of stakeholders are not taken into consideration when popular SAR robots are developed. This means that we might benefit much more from research in SAR robots in eldercare, if we start utilizing robots that are developed with end-users in mind through the entire design process, in which developers openly discuss everything from what task the robot should perform to how it should look and feel while doing it, with the elderly and their caretakers.

As mentioned before, and presented in short via concrete examples in this subsection, no work has been done in developing socially assistive robots with participatory design approaches and thus, in order to continue, we need draw on experiences from research that matches it the most. Reviewing work done with elderly people, and in some cases healthcare in general, helps us in order to supply the development of our SAR robot with some proper guidelines to follow, in order to increase acceptance rates as much as possible.

2.5. Participatory Design in Eldercare

We have previously heavily reviewed participatory design (PD) work in eldercare, in an article reporting our work and results with workshops in a nursing home. This review and a short history of PD can be found in appendice 1.

This section will heavily summarize our found guidelines, in an attempt to adequately describe what literature teaches us about how to perform successful participatory design workshops. These lessons can be categorized into six general areas:

1. Participants (who and how to incorporate them)
2. Environmental Factors
3. Establishing and Following Models
4. The Role of the Researcher
5. Anticipating End-Results
6. Guidelines for Product Functionality

Participants

Researchers should incorporate participants from all groups of intended users. In our case, this was both staff and residents at a nursing home. Researchers should be careful when working with participants that might have disabilities that can make their statements to the workshops intelligible, to rely too much on the interpretations of their care-givers. These might very well be useful in some instances, but there are reports on times when the interpretations did not express fully what the participant actually meant. The last remark is that when gathering participants from the older population, it might be useful to look into established groups, such as support groups. Because, if the participants already know each other, they will be more interacting in discussions.

Environmental Factors

Workshops should be held in undisturbed and relaxed environments. If the participants are arriving to the researchers, and no the other way around, places should be close to public transportation.

Places should be well lit (some participants might have problems with seeing, etc.), and with as little ambient noise as possible.

Establishing and Following Models

Some projects had it as a goal to present and try out models of how to perform a participatory design study. During our work we took this to heart and set a secondary goal to create a model for developing a SAR robot for other researchers to potentially follow. Some examples are the KITE model, the OASIS model and the BIME development approach.

The Role of the Researcher

The main role of the researcher is to facilitate the workshops in the most efficient manner, valuing comfort and safety. To build trust is one of the most important factors, and is through various projects done in various ways. Obviously another aspect of facilitation is to make sure all voices are heard in the workshops, and to not put more emphasis on some ideas than others, without discussing this with all participants first.

Anticipating End-Results

Developing any kind of product with any group of participants is always an open-ended procedure. Researchers should never anticipate that end-results are by any means finished, since whenever the newest prototype is tested out, new adaptations are probably asked for. In line with, is the fact that researchers should always expect first prototypes to be failure prone and not live fully up to expectations.

Guidelines for Product Functionality

At some point, the end result needs to be agreed upon however, and when that happens, the literature teaches us some basic guidelines for its functionality, for a successful implementation with elderly users, these are:

1. No learning should be required.
2. Support equipment should look familiar to existing solutions.

3. The device should not take control away from the user.
4. The user should need to interact as little as possible with the device. An ideal device automatically detects support is needed and then acts correspondingly.
5. The device needs to reassure the user. A device should not alarmingly remind a demented user, instead it should do so in a nice relaxing tone.
6. The device should if possible have an additional use than the one specified, since it should not remind the users of their disabilities.

These are interesting to look at with a mind taught with the previous information of what can be learned from reviews in SAR robot research. The most prominent of which is number 6, which we keep seeing in anecdotes and acceptance studies as well.

2.6. How to use Participatory Design in the Development of Socially Assistive Robots for Eldercare

How to properly design SAR robots for the elderly using participatory design is dependent on the extensive incorporation of the elderly and their caretakers in the design process. Workshops should be held with the goals of specifying what problems they are having, and where they would appreciate the assistance of a robot.

Prototypes should be built based on the knowledge gained in these workshops and on the factors of acceptance found in literature, in order to most successfully get the end-product, the SAR robot, adopted into the homes as fast as possible.

The problem of the "graying of the western world" is approaching ever faster, and we need solutions that work optimally in all aspects of their interaction, rather than technically determined devices that only look at functionality. These latter devices when implemented will undoubtedly have to be modified to fit the findings of acceptance, when they inevitably fail.

Current projects such as the Care-O-Bot and Pearl will have to deal with these factors of interaction, when they at some point in the future get commercialized, unless, as might be the case [17], they realize in time and get some adaptations on their drawing boards.

The Right Methodology to Follow

In conclusion of this entire background chapter, we propose a new way for roboticists to develop their socially assistive robots intended for eldercare. It is based on principles from participatory design, important factors of acceptance, and lessons reported by other eldercare robot projects. We argue that even though some projects experiment with robots not intended for eldercare show promising results, the need for longitudinal studies and comparable methodologies outweigh their conclusions of potential use of the robots.

3. Method of Developing Our Own Socially Assistive Robot

This part with describe our work in trying to use the factors for acceptance from the previous chapter, as well as participatory design workshops, in order to build our own socially assistive robot. Additionally we attempted to, like the ELDeR project researchers, to perform some ethnography, by shadowing staff in the nursing home during their work day. We will in detail explain how we built our robot, from drawn sketches, to 3D models, to lasercutting and putting it together, as well as the electronics and programming. In the end of the chapter we will describe the procedure of our twelve day robotic intervention.

3.1 Participatory Design

To find out what a potential robot could assists both the residents and staff with, the first step was to arrange separate workshops with the separate users. What we essentially were looking for were the robots requirements by both staff and residents and at the same time find a compromise between them. The reason for why the compromise between the users is highly essential is that there most likely will arise conflict if only the need of one group of users is satisfied which will be explained further. If we were able to find a task which would benefit both users, there is no question that the acceptance of the robot would be higher, and we therefore investigated the differences and similarities between the world of the staff and that of the residents.

Participants used in workshops

Staff

All workshops with staff were arranged by the management. Because the nursing home was quite busy we were only able to get 4 staff member to participate in 1 workshop (figure 6) and the second 2 was able to participate.

Residents

As we had spent some time at the nursing home before the participatory design workshop began we had already gotten to know some of the residents. We had spent many days at their coffee table and in this way gotten familiar with them. The management had therefore given us permission to arrange the workshops with the residents ourselves and we could therefore go out there whenever we wanted. Three residents were used during these workshops and two of the residents had a very good relationship already which was beneficial as they would together discuss experiences of living at the nursing home and the difficulties and challenges of getting old.

Workshops

Staff

Two workshops were able to be arranged with staff. Our intention with these workshops was to get introduced to as many tasks which the staff would have to solve every day and how the staff felt about them. The idea was to discus if a potential robot would be able to solve or aid them with the tasks they felt lowered their ability to give the older persons quality of life or created distress. Look in appendence 2 for more information about tools and procedure.

Figure 6: Workshop with staff.

Residents

Three workshops with the residents were arranged (figure 7), as well as two individual ones with only one resident in each. It was difficult arranging the workshops the same way as the staff as the resident did not think of their routines taskwise and therefore we had to take another approach. What we essentially were looking for was descriptions of how they experienced their daily routine. Many different tools and props were used for this such as pictures of different event which usually occur during a day, for more information about tools and procedure of workshop look in appendices 2.

Figure 7: Second workshop with residents.

Tasks Found through Participatory Design Workshops

The intention of our workshops was to get further information about the specific tasks. What we also hoped was that staff and residents could somewhat agree upon a task which the robot could assist them both with and would both benefit from. To our surprise this was possible as Staff and resident both mention in the separate workshops that there were many challenges in the morning routine.

Staff

From 17 tasks identified in the workshops with staff, they dominantly took place during the morning routine (for more information about these task look in appendice 2). This made sense since it essentially was the busiest time during the day as the staff members had to get 37 residents up all having different challenges because varying conditions.

The morning routine consisted of two assignments which was guiding the residents and personal care (figure 8).

Guiding the resident	Personal care
- Guiding the resident in cloths - Brushing teeth - Wake up - Stand up	- Giving eye drops - Giving medicin - Giving shower - Taking resident blood pressure - Changing urine bag

Figure 8: The various tasks from the morning routine.

This subject was dominantly discussed during the workshops and one staff expressed the problems which often occur:

"It can easily take 40 minutes. You can have a resident just staring at the towel you gave her, and you have to say wash your face. If you know that there is one in the other room which keeps ringing and ringing, and has to go to the toilet, and I keep having to say, now you have to take you tooth brush, you have to put it in your mouth, turn the tooth brush, you have to brush your teeth, and if it is like that through the whole routine, then I end up taking the prosthetic teeth out of her hands, brushing them myself, and putting them into her mouth. That's often what happens, we go in and completely take over because we just don't have time."

The staff expressed that personal care was best left to staff member:

"Personal care is giving a bath, washing them, putting food on their table. I can't really see anything here, we would need help with. Also a part personal care is to show comfort, some residents need to be touched."

Resident

During the workshops we found storytelling to be a beneficial way for the resident to express themselves as they generally liked telling stories. We found this to be the most informative way of getting a picture of the challenges the resident experienced. The residents had mostly discussed how the morning routine could be challenging. Getting old often result in many mobile and cognitive disabilities and this disables them to do many things themselves. Therefore the resident expressed that they cherished the things they were capable of doing themselves. When the resident loses the ability to take care of themselves it means some loss of control of one's own life as they become dependant on the staff or just have to follow the time schedule of how things are done at the nursing home. Sometimes there is not space for the individual resident's need. This was something which residents expressed could occur in the morning routine as many enjoy having a calm morning but sometimes they had to be rushed as one resident expressed:

"It is like that, you can't wake an old women up with ice cold hand when she is lying under a warm duvet. I love relaxing in my bed, instead of "Eyes open and then out of the bed!" No, I don't like that. But I like having a good talk in the morning and make jokes, this way it's nicer."

Another person remarked:

"If you had something which could wake you up, then we would avoid those cold hands under the blouse, and then we have the time it takes to wake up by ourselves. Then you can get up when you think you are ready. It would be nice if we had something which tells us quietly: "Now you should lift your duvet." instead of those cold hands, then you can be relaxed and gradually wake up."

Combined Task Which Was Chosen Benefiting Both Groups

When we gather all this knowledge we begin seeing that residents and staff have common problems about the morning routine and how it could be improved. The staff members often end up having to rush the morning routine because of the many tasks and having many residents to get ready. Staff members saw the robot as a smart potential alarm clock which could wake the residents up and guide them to be ready for when they arrived, this would result into staff having more time to be social when having to give personal care. The residents' need was to be mentally prepared for when the staff arrived and in this way achieve a calm morning.

If a potential robot could wake up the resident and guide him/her up from the bed it would release time for staff to do other tasks and therefore it would have a big impact on the care which the staff would be able to give.

These workshops also made one thing clear which was that the morning routine could not be easily defined. Even though staff explained the morning routine as detailed as they could, how exactly the routine was completed was unclear as the ways the staff members handle it often were not planned. Staff members would handle every resident differently and therefore flexibility was needed. Therefore explaining how the routine was done was difficult as it not always was the same.

What was clear was that the staff and residents both agreed that the robot's potential were in waking up the residents and getting them ready for break first, and this task was therefore chosen to be investigated.

3.2 Shadowing the Staff

Our participatory design workshops suggested that the main challenges lay in the morning routine and what the robot specifically could do was to wake up the residents giving them a calm morning and getting them ready for when the staff would arrive. Staff would in this way also have more time as they would not use any on getting the residents up. The participatory design workshops gave us a very good picture of the staff members' daily work, but as these workshops were very abstract it did not give an exact picture on how the morning routine was actually done and therefore the next step was to investigate this. The most obvious way to get an exact picture of the morning routine was to go out to the nursing home a follow the staff around while they were doing their routine. Our aim with this was to identify how and where specifically our robot would fit in without it being to obtrusive. When following the staff we would pay special attention to some of the variables and topics which was discussed at the workshops such as how long time was used on the different tasks. Shadowing the staff also gave us the possibility to identify potential residents who would be able to participate in our later twelve days case study, with the prototype of our SAR robot.

Procedure

We would show up at the nursing home in good time and follow two staff member around from 07:20 until 12:30. The staff members were supposed to do whatever they would usually do. As she went into the residents home we would note everything down using note book and special printed paper (figure 9) giving us the possibility to write down time, observed task, any comment which needed to be noted down and space to note down if we could possibly help. Noting everything down gave us a detailed schedule of the staff members' morning routine and this made it possible for us to analyze later (Figure 10).

Time	Observed Task	Comment	Can we help?

Figure 9: Specially printed paper

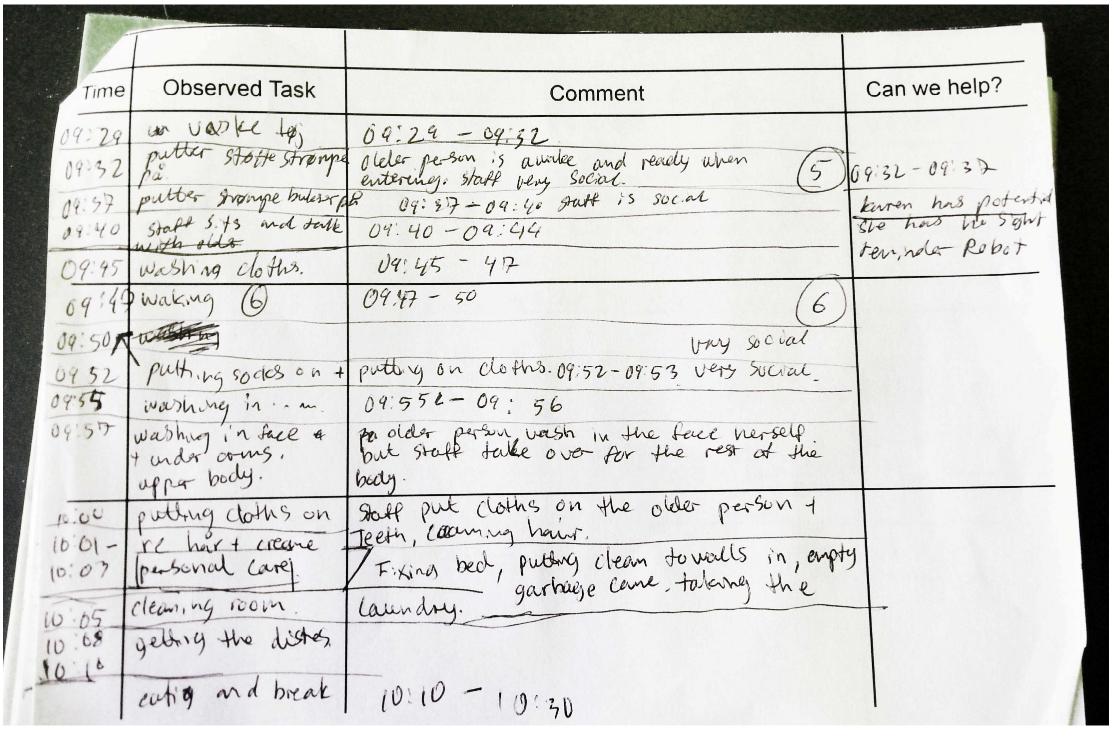

Figure 10: Specially printed paper with notes

Analysis of the Staff Members' Schedule

For getting a clear view of the morning routine we gathered all the data in Microsoft Excel and added other observations, which was not noted down on the actual day. These documents can be found in appendice 3.

When analyzing the data the nature of living at a nursing home became very clear. Many residents were very dependant on staff due to challenges with mobility or other challenges such as blindness or bad hearing. Many residents was also depending on medical assistance such as the staff having to give medicine, or resident have their urine bag change or getting eye drops, which often took place during the morning routine. Every individual had many different challenges and it was therefore also clear that finding a way for the robot to be implemented were challenging as the morning routine was very fixed. We also question the need of our robot as staff and resident both seemed to have accepted that things worked in a certain way. What became clear was that if our robot would have to assist the residents in the morning routine it would have to be adapted according to the resident's need.

The data from shadowing the staff presented a complicated system with a very flexible routine as the staff would have to deal with the varying challenges the resident experienced everyday. On the same time the routines was very fixed as task was done on specific timing such as breakfast was served at 08:00. The challenge lay in having to implement the robot, without having to complexly restructure in a negative way.

After going through the schedule many times we found an opportunity to possibly assist both the residents and the staff members. Going through this data we also identified two residents who we discussed with staff members could potentially be participants in a later intervention with a socially assistive robot.

The Residents Identified as Participants for the Robotic Intervention

Going through our data we were able to identify two residents who were able to participate in our twelve days case study.

Resident A was 97 years old and suffered from dementia which resulted in her having bad memory. She was very physically limited but was able to walk to some extent.

Resident B was 90 years old with a case of mild cognitive impairments which also resulted into her having bad memory, but otherwise she was clear minded. She, opposite of resident A, was very capable of walking as well as able to do many things herself.

They had in common that staff members would serve their breakfast on the table and therefore our robot was able to assist them both in a similar matter. By looking at the data we found that if the robot would wake up and guide these residents, it would also benefit the staff as she would not need to use time on waking the residents as they would be ready for when the staff member arrived with the food.

The Interaction Specified for the Robotic Intervention

The time schedule of the staff suggested a twenty minute window for the interaction between robot and resident. This would give the robot twenty minutes to wake up the resident and guide her up before the staff member arrived. This would also give the resident time to calmly wake up and mentally prepare herself, which was the need we found through the participatory design workshops. Therefore, these specific twenty minutes of time was the interaction that we needed to analyze.

As we had only followed staff members routine we had only gotten a picture of how the staff members experienced it, and therefore our twenty minute interaction was only based on the staff members' point of view so far. We therefore expected many unknown variables to appear when implementing the robot in the homes of the residents and this also suggested that we would have to adapt the robot to the residents' individual needs throughout the twelve days case study.

Since we knew that the robot interaction would have to be adapted to the residents' individual needs the next goal was to create a system which made it possible for us to change and manipulate the robots' behaviours throughout the twelve day intervention.

3.3 Building the Robot

Sketching the Design of the Robot

The first thing to do when starting the process of building the robot was to write up what the robot needed to be able to do. This would give us a list of requirement which the robot needed to have built-in. As the robot had to be able to play sound a speaker was required. This would be placed in the head so the robot was able to direct the sound to where the resident was (figure 11-12).

As we also wanted movement actuators were needed and since we only needed two degrees of freedom to direct the sound we only needed two. One to rotate the head horizontally, and one to rotate it vertically.

Working with Factors of Acceptance

The design was, besides what was found in the participatory design workshops, also guided by what we found in the literature on factors of acceptance. What this means, is that we could confidently describe what we needed as:

1. It should be small, both for safety reasons, and so it could be hidden if needed.
2. It should not look human in any way, also including it being faceless.
3. It should not look animal-like either.
4. For interaction it should have a female voice.
5. It should have one single colour.
6. It should be serious in nature and appearance. But should have some "fun" attitude in appearance as well, if possible.
7. Lastly, its appearance should not remind the user of her disability.

The End Design

Our end result was a small robot with round shapes and with a head that could be directed precisely. The next step was creating the shape in 3d, for later implementation into a program that would outline what we needed to lasercut, to complete the assembly.

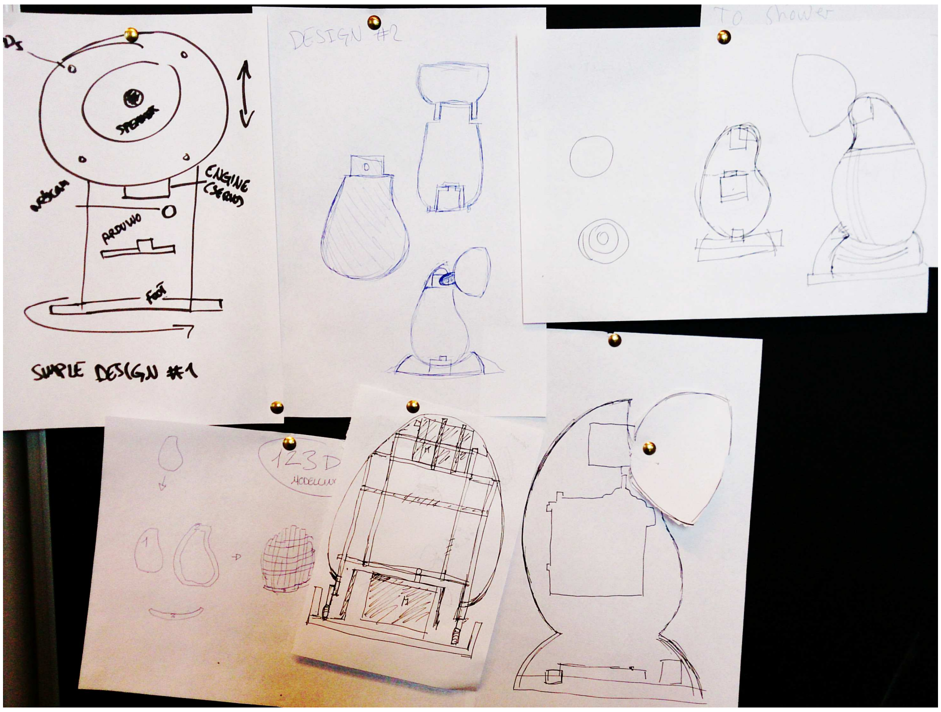

Figure 11: Sketching process.

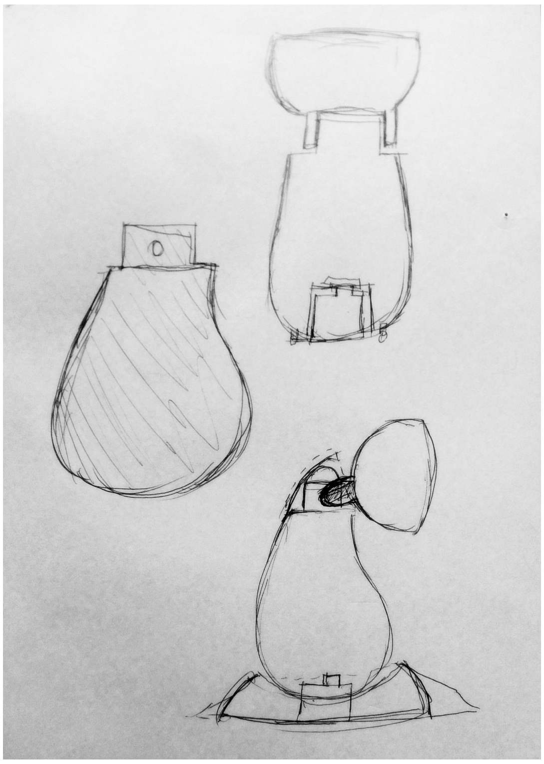

Figure 12: Later sketching process.

Figure 13: Robot 3D model, with some slicing from 123D Make apparent.

3D Model

3D Studio Max was used for creating the sketch in 3D (figure 13). The way the robot would be constructed, was so the actuators would be able to be placed inside one half of the robot and than the other half could be clicked on top of it, which would then serve to keep the robot together. The actuators and speaker was measured to know exactly how much space was needed inside the model. Space for wires running from the head of the robot and down towards the back was also made.

To be able to be laser cut, the model would need to be sliced into 2D lines (figure 14). We did this with the help of the software called 123D Make, which is specially designed for this task. The program would essentially slice the 3d model into pieces, making it possible to export directly to Autocad (figure 15), which could then be recognized by the lasercutter.

Figure 14: 3D Model in 123D Make

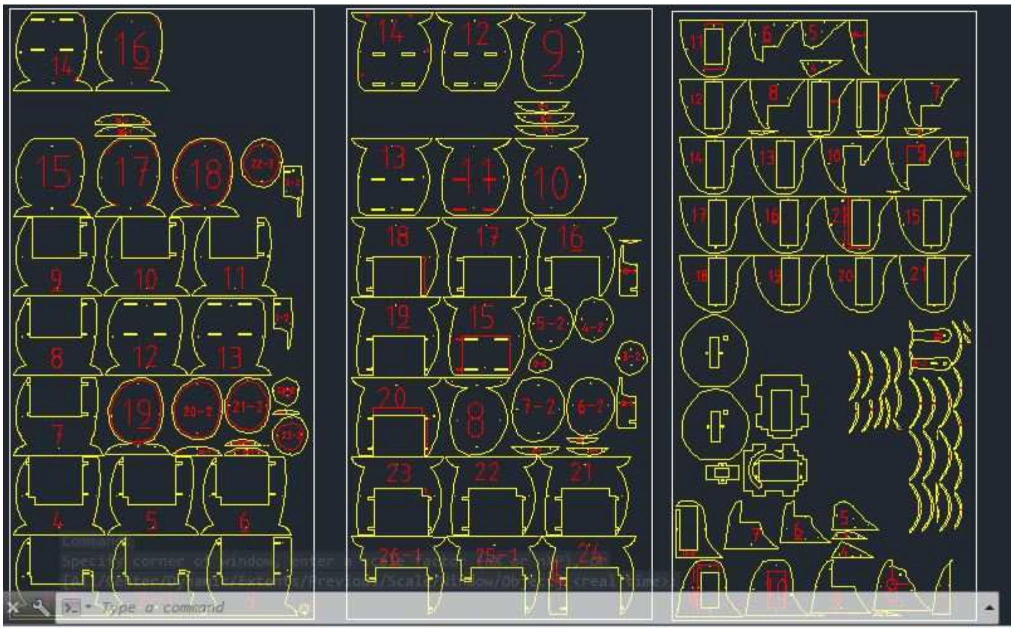

Figure 15: The Slices in Autocad.

Lasercutting

When the robot had been sliced in 123D Make, it was ready to be laser cut (figure 16). Using the lasercutter to cut the robot was clever as it was very fast and when it was done we would only have to glue the different pieces together (figure 17). We decided that since we needed to experiment with two residents, we would create two robots. After gluing the slices together, we smoothed the result using sandpaper (18).

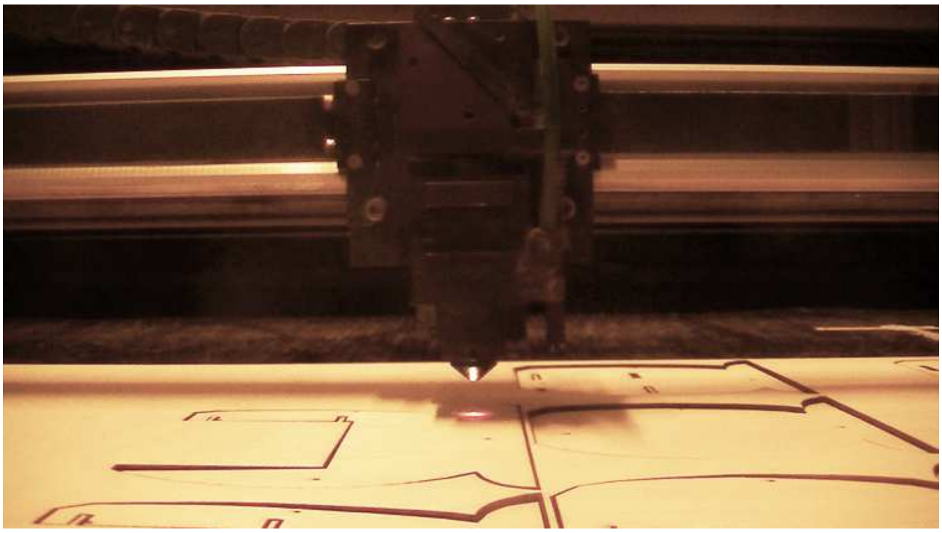

Figure 16: Lasercutting.

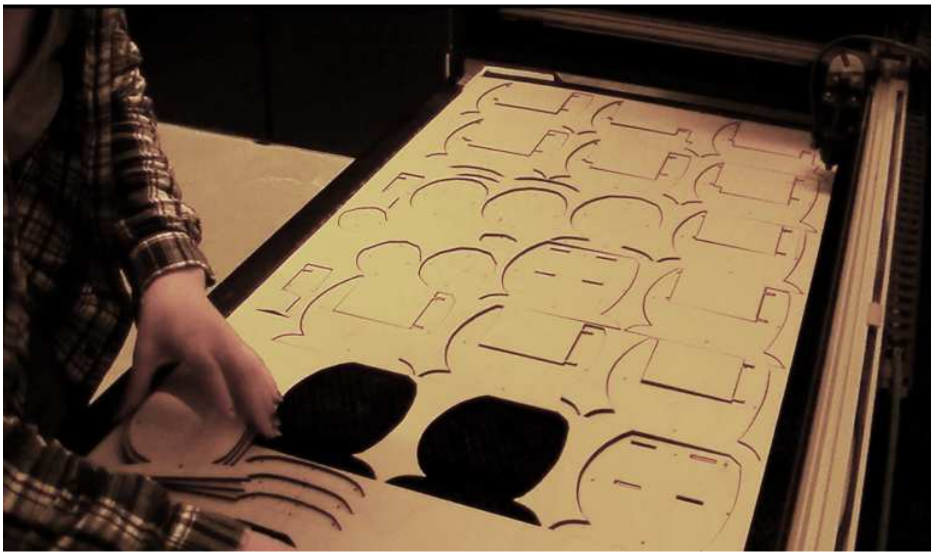

Figure 17: Withdrawing the pieces.

Figure 18: Finished robot.

Electronics

For controlling the robot we used an Arduino Uno which was powered by five volts from the computer and was connected by a USB cable (figure 19). In total four wires was connected from the robot to the Arduino. One red power cable split inside the robot which powered the engines and a black ground wire. The two last wires were used to connect the actuators to two pulse modulated pins on the board in order to specifically determine the angles of the actuators (figure 19). As the speakers were not loud enough on their own, we needed to boost the sound with an amplifier (figure 20).

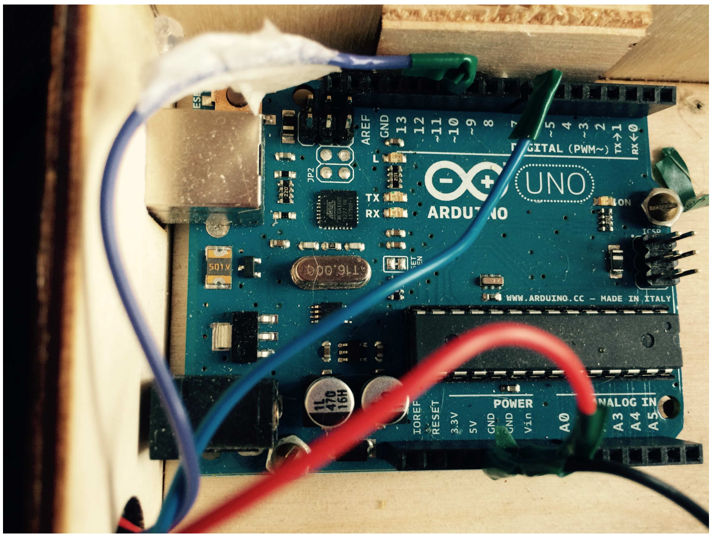

Figure 19: The Ardunio UNO board.

Figure 20: The amplifier.

To organize everything and not have the wires and the electronics exposed at the intervention, we constructed a box specially designed for the Arduino UNO and the amplifier (figure 21).

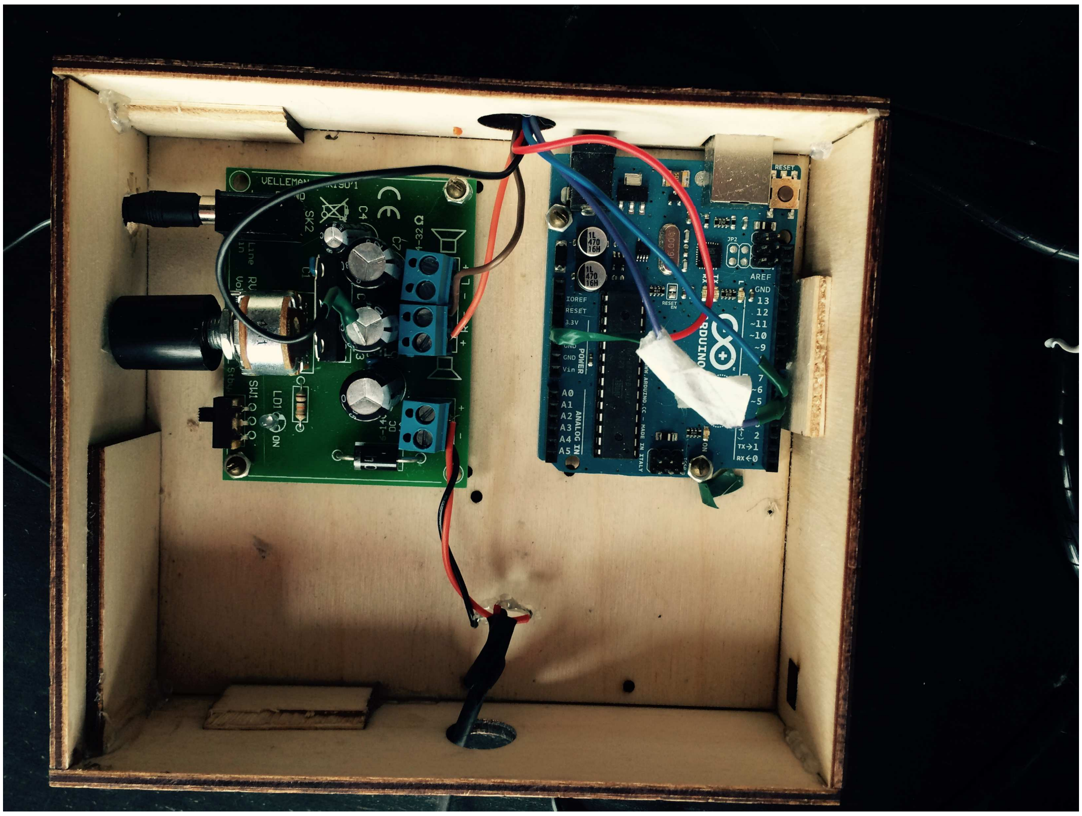

Figure 21: Box containing electronics

Programming

To control the robot during the intervention at the nursing home, we needed a reliable system that needed x functionalities:

1. To control the head horizontally and vertically.
2. To choose and sound file (a sentence) and play it.
3. To initiate music and fade it out when we needed it.
4. To say the name of the resident, to get their attention if needed.

The first part was controlled via the position of the mouse in a graphical user interface (GUI) showing an x/y coordinate system (figure 22). The x position determined the horizontal angle, and the y the vertical. For the sound files we placed them in a downward row on the left side of the

GUI, and with the arrow keys, the operator could go through each of them, and press the enter-key when he/she wanted to play the selected one. For the music we simply just controlled it when pressing the m-key, once to initiate it and once again to fade it out. For the name we simply bound the n-key to say it once.

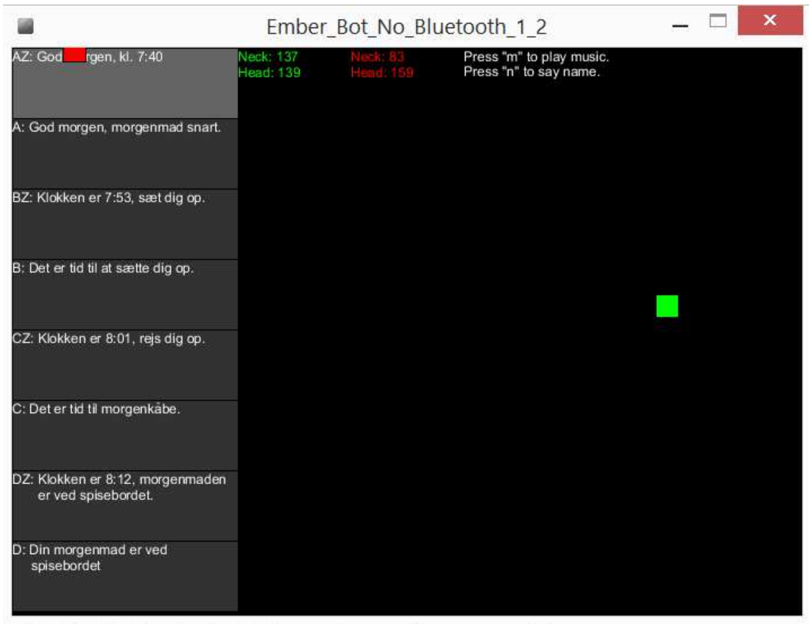

Figure 22: Graphical interface. The various sound files to be played are displayed on the left. The green square is the current position of the head of the robot, the red (upper left) is the cursor location.

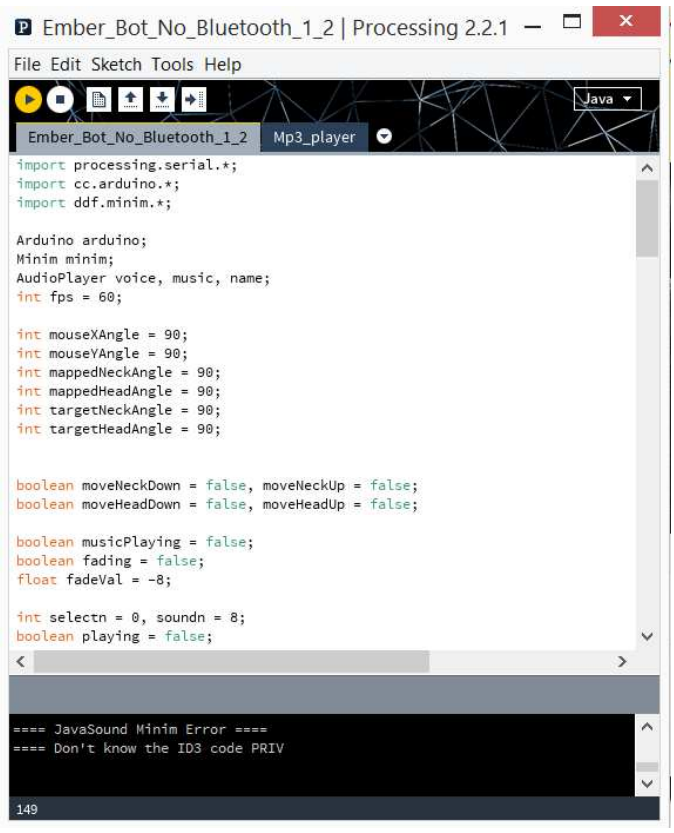

Figure 23: The Arduino development environment.

3.4 Twelve Day Robotic Intervention

Before starting the twelve day intervention we went out one day in advance to setup the robot while the residents were in their room. This also gave us the opportunity to introduce the residents to the robot and explain to them what was going to happen through the days. Doing the talk we received feedback from the residents about what their initial opinions were of the robot and if they thought any changes should be made.

While talking with the residents the robot was placed on their living room table and a wire were pulled from the robot and out through the residents main door which was smart as it made it possible for us to pluck in our computer outside her door every morning without having to go inside and disturb her while she was sleeping (figure 24).

In the time we were present at the nursing home we had gotten permission to film everything. A webcam was placed beside the robot giving a view on the residents lying in her bed which made it possible to record everything that was going on during the intervention, which we could then analyze later. We also used the video from this camera to control the interaction throughout the entire intervention. This was also smart as it gave us the possibility to intervene and potentially stop the experiment if resident showed any sign of distress.

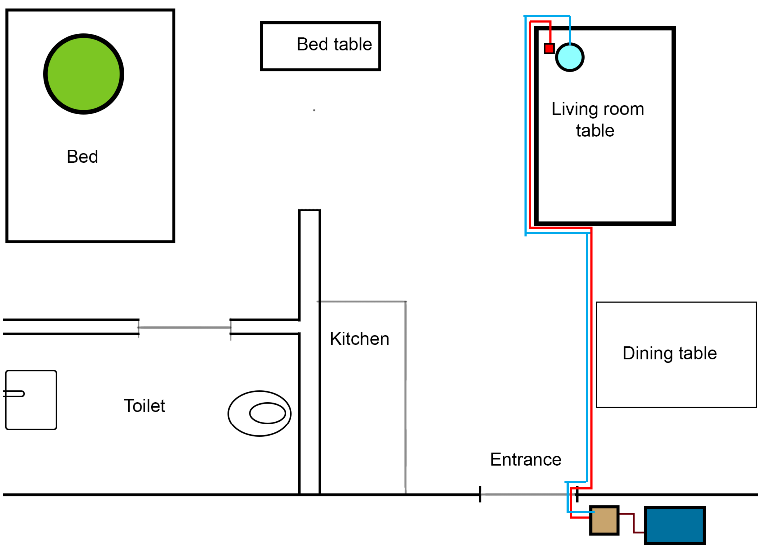

Figure 24: The intervention setup. The green circle is the resident, the red square the webcam, the turquoise circle the robot, the brown square the electronics box, and the blue square the computer.

The Procedure

Every morning during the intervention, we activated the robot with the first sentence at 7:40 AM. When the staff member arrived with breakfast we would switch off the robot and let the staff member go into the room of the resident. We would then wait for the staff member to come out and get feedback on how her interaction with the resident had been. We also got feedback from the residents during the period of the intervention.

Robot Behaviour and Activations

Since the robot had 2 degrees of freedom we were able to control the movement of the robot during the intervention. The body movement served to get the attention of the resident such as moving the robots head and gaze at the resident when she observed it. This would also be a way for the resident to understand that it was the robot which was communicating. The robot being able to gaze and follow the resident if needed also served to amplify the feeling of the robot being alive.

The robot communicated through natural language using a human female voice and it would specifically greet the residents good morning, tell her the time and inform that breakfast was on its way.

The robot communicated 3 different sentences during the twelve days. Activation 1 would greet the residents good morning and tell her the time and inform the residents that the breakfast was on its way. Activation 2 was completely similar to activation 1 but did not include the time of day. This made it possible for us to control the amount of times activation 2 was needed without the time of day being expressed wrong. These activations served as a way to wake the resident up and keep her updated on time and how the schedule looked so she was mentally prepared for when staff would arrive. The amount of time Activation 2 would vary depending on the day but was generally activated 3 to 4 time during the twelve day period. Activation 3 served to guide the resident to sit up in the bed and be ready for when her food was served in front of her.

Robotic Intervention Day 1 to 3

The first days the behaviour was the same for both residents and then eventually as we got feedback from staff and residents, we would adapt it to the resident such as how high the volume should be or if there should be add more elements to the robot behaviour (figure 25).

Activation	Time	Comment
1	07:40	"Good morning, the time is 07:40, breakfast will be here soon"
1	07:40	"Good morning, the time is 07:40, breakfast will be here soon"
2	07:44	"Good morning, breakfast will be here soon"
2	07:44	"Good morning, breakfast will be here soon"
2	07:48	"Good morning, breakfast will be here soon"
2	07:52	"Good morning, breakfast will be here soon"
2	07:56	"Good morning, breakfast will be here soon"
Staff arrives	08:00	

Figure 25: Table showing the activations of the first three days of the intervention.

These three days served as time for the residents to get use to the robots. We expected the residents to react confused and maybe distressed when the robots were activated, since the residents were not used to having the robot there or having changes in their morning routine. These days we therefore asked the staff member to re-assure the residents that everything was all right and it was the robot who playing the sound.

One resident expressed that the volume of the robot was too loud and it was therefore turned down. Through the three days the residents seemed to get more use to the robot and we therefore took the next steep of implementing Activation 3 (figure 26).

Robotic Intervention Day 4 to 5

Activation	Time	Comment
1	07:40	"Good morning, the time is 07:40, breakfast will be here soon"
1	07:41	"Good morning, the time is 07:40, breakfast will be here soon"
2	07:44	"Good morning, breakfast will be here soon"
2	07:46	"Good morning, breakfast will be here soon"
2	07:48	"Good morning, breakfast will be here soon"
3	07:51	"The time is 07:50 you rise up and sit on the bed."
3	07:55	"The time is 07:50 you rise up and sit on the bed."
Staff arrives	08:00	

Figure 26: Table showing the activations of day four and five of the intervention.

Activation 3 turned out not to have any effect during these days, since both residents only woke up but did not get up and sit when the robot asked them to. It became clear that getting the residents to sit up in bed was more challenging than we expected. We expected that the resident might need more time since they had not had the robot in their rooms for such a long time and we therefore continued Activation 3 even though it did not have any success.

Through these days we asked the residents if there was anything they thought could become better or should be changed. We also asked if there was any particular thing they like in the morning which the robot could assist them with other than waking them up. Residents B expressed that she wouldn't mind the robot playing music as this was what she enjoyed the most in the morning and we therefore implemented music in the robot behaviour (figure 27). Since we through the days had also observed how residents B several time would fall asleep while she was eating food and the staff member expressing that this was a problem as she constantly would have to go in a wake her up, playing music for the resident would possibly be a way for keeping resident B awake while she was eating. This was also a potential benefit for resident A, since she through the period had been confused about where the sound was coming from, the music possibly would help her understand that it was the robot.

Robotic Intervention Day 6 to 11

Activation	Time	Comment
Music start	07:40	
1	07:40	"Good morning, the time is 07:40, breakfast will be here soon"
Music fade	07:41	
Music start	07:43	
2	07:43	"Good morning, breakfast will be here soon"
Music fade	07:44	
Music start	07:46	
2	07:46	"Good morning, breakfast will be here soon"
Music fade	07:47	
Music start	07:49	
2	07:49	"Good morning, breakfast will be here soon"
Music fade	07:50	
Music start	07:52	
3	07:52	"The time is 07:50 you rise up and sit on the bed."
Music fade	07:53	
Music start	07:55	
3	07:55	"The time is 07:50 you rise up and sit on the bed."
Music fade	07:56	
Staff arrive	08:00	

Figure 27: Table showing the activations of day 6 to 12 of the intervention.

Since music was always present we cut down on the amount of time Activation 2 was played. Since resident B had expressed she enjoyed music in the morning, we hoped that the resident would wake up when Activation 2 began and continue to lie and listen to the music.

Because the robot was placed on the living room table at first, we expected that the residents potentially was not able to see it and therefore became confused by where the sound was coming form, since the robot was placed far away. We therefore asked the residents on the sixth day if they liked the robot being on the living room table or if they wanted it closer. Resident B expressed she wouldn't mind if the robot were closer to her and were therefore placed it beside her bed (figure 28).

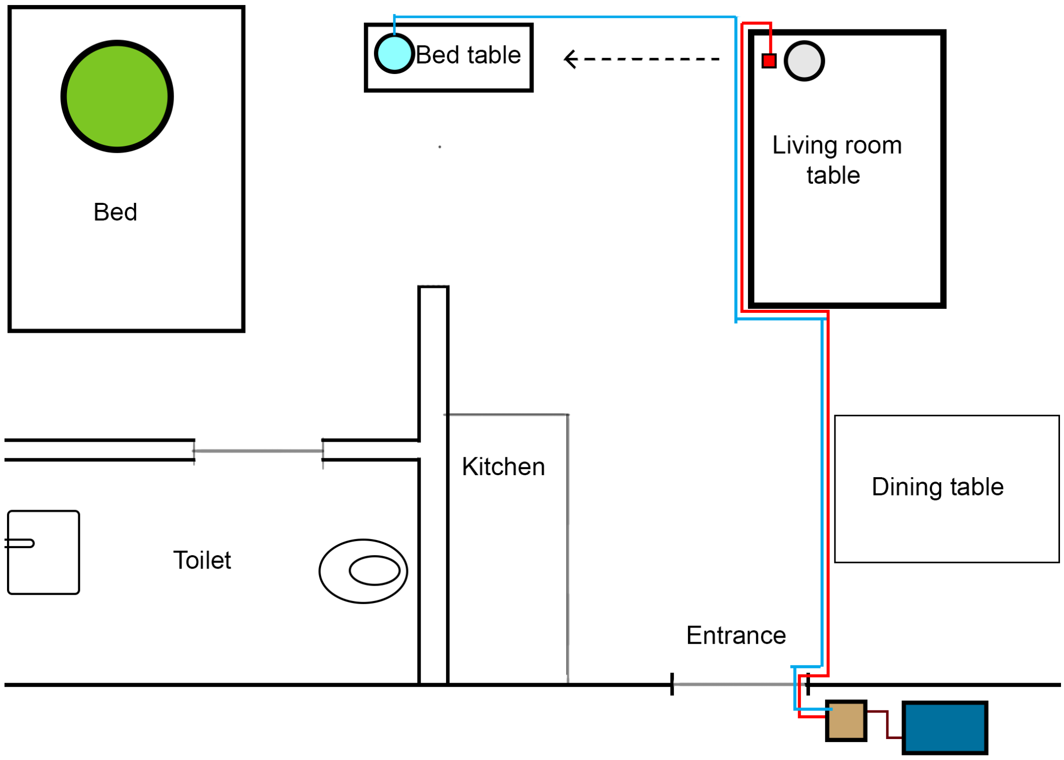

Figure 28: Robot moved from living from table to beside the bed.

4. Results

Many changes were made through the case study as we were adapting the robot to the need of the resident. The robot had specifically assisted in the task of waking up the residents and many interesting results appeared. In this chapter results from how the residents responded to being woken up by the robot, results related to the embodiment of the voice and results related to the body movements of the robot.

4.1 Waking the Residents Up

In terms of the robot waking the residents up it was to some extent successful in both cases. During the first days of the intervention both residents were not very fond of the robot, which was not a surprise as they were not familiar with the robot or to such as change in general.

Resident A

The resident would usually wake and sit up in the bed immediately when the robot was first activated and therefore Activation 2 was usually only played from two to three times.

During the first days the resident reacted very negatively to the robot and expressed her dissatisfaction to the staff member when she arrived. As this example shows:

> *Staff member: "It is that little thing there which can say stuff."*
> *Resident A: "It's stupid."*
> *Staff member: "You will get use to it."*
> *Resident A: "No I don't have to."*

Since the resident had severe dementia she always forgot from day to day that it was the robot, that was playing sound even though the staff member reassured her everyday. Even though she forgot it was the robot speaking, she seemed to become more accustomed to it the further into the intervention we got, and when asked what she thought about it towards the end of the intervention, she sincerely expressed that she was very fond of it:

> *Residents A: "It makes me very happy, but I'm so very tired."*

It was quite a challenge getting feedback from the resident also because she would express that she didn't mind the robot, but we were always in doubt about if she really knew what we were talking about.

Resident B

This Resident would not always wake up when the robot was activated and therefore Activation 2 had to be played more times compared to resident A. Sometimes the resident would wake up when the robot was first activated but fall asleep quickly thereafter, and sometimes she would not wake up at all until the staff arrived with her breakfast.

Another result is that she would sometimes react very negatively towards the robot, as we experienced at the third time the robot activated on the very first day. She actually shouted at the robot to make it quiet:

Robot: "Goodmorning, the time is 07:40, breakfast will be here soon."

Resident B: "SHUT UP!"

When staff arrived she complained her dissatisfaction and expressed that she was not pleased with the robot being there:

Residents B: "I had just fallen asleep and it just kept talking."

Staff member: "But it is´ morning now (name)"

Resident B: "Does it really have to be in here."

Staff member: "Are you upset about it being here."

Resident B: "No, but its just, it a matter of sleeping, I just feel asleep."

The reason to why the resident reacted negatively towards the robot was however not only due to the robot, but was also due to the residents having had big trouble sleeping the night before, and when the robot was activated that morning the resident had just fallen asleep.

During the twelve day intervention the resident would also only rise if the staff came in or if she had to go to the bathroom and therefore activation 3 had no success. This was not only due to the resident sleeping or not being able to hear it, this was also due to the residents not wanting to rise up when the robot asked her to. This she also expressed when the robot played activation 3:

Robot: "The time is 07:50, You rise up and sit on the bed."

Resident B: **"***Yes you said that earlier, I heard you already***"**

Further into the intervention the resident became more accustomed and familiar with the robot and she began getting more comfortable towards the robot being there. We also gradually adapted the robot to some needs of the resident, such as lowering the volume and adding music. Sometimes when the staff would arrive to wake her up and give her breakfast she would pull her duvet aside and confirm that she had already woken up. The staff member also became quite optimistic about the robot as she began experiencing the residents more fresh when she would arrive, but it was clear that the resident's mood and reaction very much depended on how she had slept during the night and therefore the resident would not always react positively and occasionally she would yell at the robot or tell staff that she was happy to see them, as in one example where she said: *"Oh its so nice to see a human".*

It was specially when the robot were moved closer to the resident and accompanied her when she was eating her breakfast that she began appreciating its presence and when asked what she thought about the robot joining her at breakfast she expressed that the found it very nice. During one of our conversations with the resident, towards the end of the intervention, she expressed to us that: "*I think it's nice. No, we are friends now, it was just because it was very loud, but now I like it."*

After the robot had joined the resident during her breakfast, it seemed like she began accepting the robot as part of her routine, and on the last day when we were about to leave and asked her about how she had experienced having the robot in her room, she answered: *"Yes first I didn't like it, it was very loud and I really got a shock. I think I told it to be quite the first day. But now I cant live without it."*

4.2 Results Related to Voice and Embodiment

Some interesting results were found that related to the voice and embodiment of the robot. Some times the voice would confuse the residents, for example. The embodiment of the robot would serve to enhance the interaction sometimes.

Resident A

Resident A was very confused about where the sound was coming from during the twelve day intervention and would several times wake up and go look for a person. We had hoped that if the staff explained to the resident that the sound was coming from the robot that she would eventually realize this but even after the sixth day the resident kept looking for a person, when the robot was activated.

When the robot was communicating that breakfast was here soon, she would often stand up from her bed and walk towards the living room table, and then look at her entrance to se if anyone was standing there. When this happened we would once again activate the robot telling the resident that breakfast was here soon, and move the robots head so it gazed at her. This had no effect even when she was close to the robot. When staff arrived and explained to her that it was the robot talking, she always responded surprised: *"oh it is that who is saying that."*

Resident B

The first days of the intervention the resident responded confused about where the voice was coming from. One day when the staff member arrived the resident had thought it was the staff member's watch which was able to play what time it was:

Resident B: "It's a smart watch you are wearing."

Staff member: "What?"

Resident B: "It's a smart watch you are wearing, it tells you the time."

Staff member: "Uh..Yeah?"

Through the days the resident became more aware that it was the robot that was communicating, and she also expressed that the robot had been too loud and wanted the volume turned down. It also helped when the robot was moved closer to the resident making it able for her to see the robot clearly and see it move.

4.3 Results Related to Body Movement of the Robot

We hoped that the body movement robot would amplify the perception of the robot being alive and that it was communicating the sound and this was successful with resident B.

Resident A

Through the twelve day intervention the robot had several times gotten the attention of the residents when it was either moving its head or body and she had also been observing it either from bed or walking over to it, and therefore she was aware of it presence. But even when the robot moved its head and gazed at the resident while it was playing the sound, the residents did not create any connection between the voice and the robot.

Resident B

Resident B reacted very well to the body movement of the robot during the period, mostly when the robot was moved closer to the resident while she was eating. During the residents breakfast the robot would occasionally rotate its head and gaze at the resident. When we had asked the resident what she thought about the robot moving she replied: *"I like that it's moving, then I know it's alive. If I wake up before him and it's not moving than I would ask "Are you not awake yet?!""*

4.4 Results Related to the Music of the Robot

Resident A

We had hoped adding music to the robot behaviour would make the resident more aware that the sound was coming from the robot when she was waking up, instead of a person. When staff arrived and as usual would explain to the resident that it was the robot playing the sound, the resident seemed in less of a negative mood after the music was implemented compared to before. Instead of reacting negatively, she seemed to be more curious.

When music was played for her while she was eating she expressed that the music made her very happy and that it was very relaxing for her.

Resident B

Adding music to the robot behaviour seemed to be effective when waking up resident B. When the music would start it would get the attention of the resident and she would be less shocked when the robot was first activated.

The resident was most fond of the music while she was eating, and this was a huge factor of her enjoying the robot in the end. It also turned out to be a good way of waking the resident up when she would fall asleep during her breakfast, as this was actually what she had most challenges with. Before waking the resident up by music we had tried waking the resident up without, by only using a sentence which stated that her food was getting cold. She reacted very shocked by this. Therefore only using music was sometimes experimented with later, which sometimes was useful, but sometimes was not enough to wake her, in which case we implemented both music and the sentence to wake her.

5. Discussion

This chapter is divided into sections about how well we matched the needs of a socially assistive robot for older persons to the ones found in the literature, and in our workshops. We will extensively discuss if the reactions of our elderly participants matches those predicted.

The factors are divided into individual and robotic. The first part is the most comprehensive, since it will attempt to analyze whether or not we were successful in getting the robot accepted by the individual participants, by looking at single instances of our intervention, and how they relate to the literature. The second part is more generally describing how the appearance and such of the robot affected the entire interaction.

In the end we will talk about our idea for a model of participatory design.

5.1 Individual Factors

The literature predicted that our participants would be resilient towards the technology, because of their old age. Due to this we could expect them to be negative about the placement of the robot in their homes at first, but maybe soften up to its use and potential hedonistic gains after it perhaps proved itself. We saw that in the beginning our participants behaved just as expected, they both at some point during the first days of the intervention expressed a negative attitude towards the robot. After the very first activation of the robot, resident B expressed sincere displeasure with it at first, the "Shut up!"-incident, and then afterwards quietly asked the staff member that entered her resident with her breakfast, a question that was quite telling: *"Does it really have to be in here?"*. Resident A also expressed a reaction of dissatisfaction to the staff member during the first days of the intervention: *"I do not have to get used to it"* with the reason being that *"It's stupid."*.

At another point time during one of the conversations between resident B and the staff member at the time, she expressed that she at that point did not want the robot to be there, because it was a *"matter of her sleeping"* which can be interpreted as an expression of the usefulness of the robot related to the perceived need of the resident, another one of the factors of acceptance. The literature tells us that the need for the robot should be clearly acknowledged by the user, and otherwise predicts a less successful accept of the robot. Since the need was expressed during our participatory design workshops, it was well established, but as the resident suffers from mild cognitive impairments with results in her having a suboptimal memory, she might not remember this. There is also a clear difference in saying something at one point, and then experiencing it some odd number of months later. This is actually an important realisation, that also underlines the importance of doing participatory design in all stages of the development of the robot, and not just to gather knowledge through workshops, which is probably true with any participant and not just elderly: What you say you need, might show to be less important when you eventually experience it.

The cognitive impairments of the participants affected interactions in more ways that one. With resident A's dementia being so advanced, as described in the results part, she would from day to day forget about the robots' placement in her home, and often this would react in her acting surprised whenever we would wake her up, and even in one case look for a person in the room, because she did not realize it was the robot that talked to her. The literature predicted that cognitive ability would impact our observations, by the more cognitively impaired the user, the less interaction would occur. This is exactly what we found to be the case. Resident A was much less interactive with the robot, and the entire process of adapting it for that matter, than resident B. It can then be argued that, at some points when working with elderly users, dementia will have a definite impact on a participatory design project, since in some cases it is almost impossible to iteratively design new prototypes with them, as the fact that holding conversations with them about such a new and abstract concept is actually inconceivable. How we decided to deal with this problem was to as precisely as possible from the videos try to find ways to increase the pleasure and success of the interaction, as well as the success of the task completion, by adapting the interaction to what we *saw* instead of what we could *talk* to the resident about. This was found to be effective, as after we began playing music as background to the activation sentences, she really seemed to be in a better mood, and as she also expressed her gratitude for the music later, it confirmed our expectations. The music also had a benefit related to resident B's cognitive impairment, since one of her disabilities was that she would fall asleep while eating her breakfast, and the music served to sometimes wake her when this happened.

The literature mentioned that previous experiences with technology effects acceptance, and that in a five week trial participants would be more open towards the robot moving closer to them. This prediction also proved to hold true, as resident B noticeably became more comfortable with the robot as the intervention progressed. Surprisingly, even though resident A had severe dementia, it also seemed to be the case with her, though it is hard to say since so many factors had an effect on this. While she did seem more accustomed with the robot as time went on, our own changes to the robot undoubtedly had an effect on this, as was also obviously the intention. Can we say that she would have become more accustomed if we had not made any changes to the robot during the intervention? No, unfortunately not. Despite this we feel an important statement can be made: Previous experiences with robots positively effect acceptance rates, but this does not mean that each and everyone of the potential users should have some participation in the participatory design, since this is obviously impossible, it *means* that if designers develop their interactions to not necessarily be perfect at the very first activation, but instead expect their users to get more accustomed to it over time, they will with some certainty experience higher acceptance rates.

The last thing to note in this area is that we can say for sure that letting resident B have time to get accustomed and comfortable with the interaction with the robot, had a very positive effect on her acceptance of it. This was expressed via one of the last things she told us: *"First I didn't like it ... now I can't live without it."*

5.2 Robotic Factors

How well the robotic factors for acceptance matched the predictions in the literature can also be said to pretty spot on.

The effect of apparent hedonistic gains on the acceptance was clear. The moment we added music to the interaction we saw a very clear positive change. In both cases when we asked about it, the residents were happy about it. As predicted, adding a small change with a pleasurable aspect to it, to an otherwise very dull task, increased the acceptance.

Adaptability of the robot showed to be of great importance to the success of the interaction as well. As described all through the method part, we went to the experiment with a set idea of what we thought was going to happen as an effect to what we wanted to do. We saw almost immediately that this was not the case, and that we had to adapt the behaviour of our robot, in order to get it accepted as much as possible. From in the beginning expecting it to be a simple case of waking them up, and getting them to sit up in their bed, to doing it a number of times with music applied.

The personality of the robot was also seen to have a relation to the predicted effects. The literature mentioned that the apparent social intelligence of the robot would have an effect on the interaction with its users. What we saw was exactly this, but with a twist. We gave our robot a human female voice, as according to the factors, but this had an effect that we did not expect: resident A all through the intervention kept thinking that the voice did not originate from the robot, but actually from a person inside her home. Multiple times she got out of bed and walked to her door in order to check if someone was there, which we argue was a direct consequence of the voice being so human-like. We tried to mitigate this by applying music to the interaction (for it to seem less like a staff member), and by reiterating for her that it was the robot by moving it and activating the sentence when she was close to it, after she she inspected for persons in her room, but to no avail.

To conclude this chapter, we need to quickly mention some of the last robotic factors for acceptance by the elderly, these are size, appearance and safety. About the size of the robot, we questioned resident B about it, and she stated that it was nice that it did not take up more space than it did. When we asked if we could move it closer to her bed, she had no objections, as long as it did not get in the way, which was a low possibility. When we questioned her about the appearance of it, she said nothing other than she thought it looked clever and useful.

The last thing to mention is the topic of safety, which was recommended as being the concern of developers to overshadow any other. While we always kept this in mind, there was not really anything we could do that would endanger the participants or any of their properties. Resident B at some point made a remark about this, however, when we asked if the robot was ever a problem for her: *"No, but I guess I can just turn it off at any point if I want to."* which even though she actually could not, we kept in mind, so to meet her request if we needed to.

5.3 Future Visions

The last step of most participatory design models is the "iterative prototype testing"-step, which requires all prototypes to be tested, adapted and tested again. We obviously have not gotten to adapt our robot and to subsequently test it a second time, but we do have some ideas for potential adaptations to the robot that would have to be done before that step can be realized.

The robot shall first of all be wireless, which can be realized through bluetooth, or some other similar technology, in order for it to be able to be stored away if the user wanted to. For safety reasons, and to reinforce that the elderly is in control and not the robot, it should have an on/off switch. The last change is that the humanness of the voice should be reconsidered in order to not confuse users suffering from dementia.

6. Conclusion

Our attempt to learn from past literature on the acceptance of robots for the elderly, as well as from our own participatory design workshops, with the intent to build a socially assistive robot and testing it out with participants at a nursing home was generally successful. However, we have a lot of potential work ahead of us, in order to successfully perform the last step of participatory design.

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