Design Case Study for End User Development in Care Robotics

Study for delegation of care professional to adjusting robots in the care home.

Master thesis

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Abstract

At the time of the third millennium, technology is already surrounding humankind in many fields. It is found in our daily life in form of computers and smartphones but also at work. Robots are such technology artefacts invented by human to make our life and work easier. However, some people have fears of being replaced by robots in modern work settings.

In this study, the focus is on how humanoid robots can be used in care facilities together with a framework for End User Development (EUD) empowering the care givers as end users in the care facilities to control robots by using a smartphone app.

Moreover, the focus is on how an Android based smartphone app can be adjusted to the needs of the care facility staff over a long period of time, based on their experiences and needs. This study indicates a possible framework that can help care professionals as end users to program and control robots, as well as further opportunities of this idea.

The result of this study indicates that care professionals could learn to use and configure the application, and following the robot, to provide the seniors meaningful interaction over a longer period of time. Also, the results identified which part of the EUD app were most tailorable to be modified in a way that caregivers can create and modify the segments of the app for a certain task of the robot.
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<td>AI</td>
<td>Artificial Intelligence</td>
</tr>
<tr>
<td>DAO</td>
<td>Data Access Object</td>
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<td>EUD</td>
<td>End User Development</td>
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<td>EUP</td>
<td>End User Programming</td>
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<td>HCI</td>
<td>Human Computer Interaction</td>
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<td>HRI</td>
<td>Human Robot Interaction</td>
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<tr>
<td>ICT</td>
<td>Information and Communications Technology</td>
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<tr>
<td>IFTTT</td>
<td>IF-This-Then-That</td>
</tr>
<tr>
<td>IOT</td>
<td>Internet of Things</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>LED</td>
<td>Light-Emitting Diode</td>
</tr>
<tr>
<td>MiFi</td>
<td>Mobile Wi-Fi hotspot (portable router)</td>
</tr>
<tr>
<td>PwD</td>
<td>People with Dementia</td>
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<tr>
<td>SDK</td>
<td>Software Development Kit</td>
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<tr>
<td>TTS</td>
<td>Text to Speech</td>
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<tr>
<td>VPL</td>
<td>Visual Programming Language</td>
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<td>WHO</td>
<td>World Health Organization</td>
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1 Introduction

This is not a race against the machines. If we race against them, we lose. This is the race with the machines. We will be paid in the future based on how well you work with robots. Ninety percent of your coworkers will be unseen machines. (Kelly, 2016)

At the moment, one of the challenges humans are facing is the increase in the elderly population while the population of the young generation is decreasing. The World Health Organization (WHO) estimated that the rise in population of people over 60 years old will double to two billion by 2050 (2018). In Japan, nearly one third of the population are over 65 years old (Muramatsu & Akiyama, 2011). In Germany 21 percent of the population which is more than seventeen million are over 65 years. Around 3.2 percent of them are living in care facilities, whereby 9 percent of these residents are over 85 years old (Hoffmann, et al., 2017). Beside medical needs, seniors in this institutes require mostly social care as well. In addition, loneliness is the main challenge to seniors in such care facilities (WHO, 2011). According to WHO, two out of five people aged over 65 years are reported to experience loneliness (2011, p. 22). The shortage of caregivers in social institutions shows a requirement of help for caregivers and for seniors in everyday life.

1.1 Problem and motivation

It is hard to imagine for the elderly who are not familiar with any kind of technology to accept and to interact with robots as part of their daily life. On the other side, the younger generation, growing up with technology, has already adapted to current technology and some have even prepared the newest technology such as assistants’ robots (see 2.2 Robotics). In preparation for understanding older adults regarding technology, this study needs to diagnose how much they know about technology itself, and how far they are willing to use it in everyday life. Besides this, most studies in literature are about adaption of robots in care homes. However, research rarely covers how to provide adaptive measures for caregivers themselves to use and change robotic behavior for the well-being of their residents, i.e. tailoring it to the individual needs. And this is what this work is all about.

The interest in this topic as well as my own motivation to carry out research in this field derives from the observations and experiences I collected during the three years of my Master study
and work as a student assistant in the research of “Robot in the care home”\(^1\) (Carros, 2019). Based on these experiences, the team received various feedback from participators such as care professionals, social care workers, caregivers and facility managers. Care professionals have a distinct responsibility for seniors and any obstacles to this matter should be avoided. Pepper robot as a social robot should prove that they are neither slowing down the activities of the caregivers nor disturbing the daily routine and schedule of the residents. Instead it should motivate them to interact with the robot at first step with the help of a user-friendly app for controlling it. Pepper has the capability of connecting to IOT (Paternô, 2019). That makes it possible to connect to a variety of gadgets which can track and monitor the health condition of seniors. Pepper can be presented as a companion robot to encourage the seniors to be more active and to inform the caretaker in case of emergency.

General speaking, the usage of robotic into the care home facility can be viewed from different angels. On the one hand, the current generation of residents at care facilities are around 80 to 90 years old. One hardly can imagine those people having knowledge of IT and technology. On the other hand, caregivers and social support staff also have a lack of understanding complex technology and have very different ways for the usage of technology in everyday life. This study takes a new look at scholars who are in the nursing school and compare their understating of technology with current care employees in the care facilities.

1.2 Structure of the thesis

The rest of the thesis is structured as follows. Chapter 2 gives an overview of the studies that looked at the technology used in the care home and the requirements that the application of such technology in the care facility should consider, as well as the definition of end user development and examples of common studies relating to with end user and social robot. Then the different types of robots and the robot that was used in the care home were listed. Chapter 3 describes the research question. Chapter 4 addresses the various method used during the study to learn about social practice and how this led to design practice. Chapter 5 provides some background on the Pepper Communicator concept and the structure of this concept. It also describes the communication between the server, the robot and Android app. Chapter 6 presents the results of the pre-study and assessments of how design practices have changed during these phases in and after mid-evaluation. Chapter 7 discusses the possibility of using the robot in a care home and the possibilities for the caregivers to use such a system and their attempt to

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\(^1\) Robotik in der Pflege.
program the robot. It also discusses the obstacles, limitations, and the future of work. Finally, this thesis ends with the conclusion.
2 State of the Art

The task of this work is based on the following three research areas: Use of “ethnography-based methods” in care homes, “End user development” (Liebermann et al.), and (social) robotics. As a starting point, the study focused on the daily life activities of seniors, workload of nursing and care staff. There is a narrow path between two concepts: 1) Can robots assist caregivers in the care home and do robots relief or increase care staff workloads? and 2) Can a robot run independently in a facility without any help from the staff?

2.1 Ethnography in the care home

2.1.1 Important motivational aspects of robot for care professional

One of the first questions people asked during interviews were “Can Pepper lift up seniors?” or “Can Pepper bring a glass of water or pills (medicine) to the patient?” This underlines the main focus of the study on the purpose of having a robot in the care home. Beforehand, the study should focus on the type of patient and target group and their activities inside the care facilities.

In the first step, the level of illness aged people should be investigated. According to WHO, the most common disease which aged people are facing contains: “hearing loss, cataracts and refractive errors, back and neck pain and osteoarthritis, chronic obstructive pulmonary disease, diabetes, depression, and dementia”. In some cases, they might experience several symptoms at the same time (2018). Also, the level of nursing care needed by each patient is different. In terms of care home, Impairments of patient categories as well as the abilities of the person in need of nursing care (German Federal Ministry of Health, 2017). According to Schwinger & Tsiasioti, the level of service is categorized in six classes. The six classes of Impairments are such as mobility, cognitive and communication, behaviors and psychological problems, self-sufficiency, dealing independently with illness and therapy related requirements and burdens and organization of everyday life. Traditionally, in Germany three levels of care were classified from basic care needs to hardship care needs in the care home. Since 2017, the level of care has increased to five levels (2018, pp. 173-4). The level of care is highly depending on the severity of the impairment.

The next step examines the possible settings for future use of robots in care homes. There is a considerable amount of literature on IT and ICT based solution with positive feedback by older
adults (Unbehaun, et al., 2019; Meurer, 2018). Those studies have been carried out on the use of “Human Robot Interaction” (HRI) in care facilities which mostly focused on people with cognitive and physical diseases. With rising age, one common issue for aged people is losing of the cognitive functions. Around half of the population of over 85 years old are dealing with dementia in the industrial countries. In addition, cognitive impairment is another common disease experienced by some aged people. This illness effects their ability of living independently and their self-care (National Research Council, 2001).

2.1.2 Technical ability of caregivers

Previous works have mainly focused on the well-being of older adults in the care home. But, few researchers have addressed the role of caregivers aimed to use technology to increase the well-being of the residents in the care home. One of the examples is the experiments on the role of caregivers which were performed on engaging people with dementia with a videogame-based training system by a group of researchers in Germany (Unbehaun, et al., 2020). In their study, they have implemented and improved an exergame training system for the people with Dementia (PwD) in over two years. On the final evaluation, they investigate on the role of caregivers in order to measure the integrate the system into daily routines. For this purpose, 25 caregivers together with 52 participated in the final evaluation for four months. The role of caregivers was to set up and run the exergame for PwD based on the daily training plan without get any constant support from researchers. The system introduces to caregivers in two training sessions and a manual guide provided to them so that they know how to use the system and its games.

The finding of Unbehaun highlights the success of the system which can control and operate by the caregivers is relying on “the physical, cognitive and social benefits for PwD, but especially on the added value perceived by their social care-network” (2020, p. 1). In addition, the results proved the system improved the well-bieng of PwT and with that made the daily care routines of caregivers smoother. Therefore, that was important to consider their setting in order to create a setup for the care professional in order to control the robot and investigate how it can affect on the caretakers.

2.2 Robotics

In literature, there seems to be no clear definition for robots. Nevertheless, the robot can be defined as an autonomous machine that has an awareness of its surroundings as well as the capability of decision making (IEEE, n.d.) that means ‘not alive in the biological sense’
(Richards & Smart, 2016). Robots can differ in shape, appearance, and certain functionality. Despite the fact that there is no uniform definition for robots, they can be categorized based on its features, capabilities and mobilities. In this section, different types of robots will be discussed.

2.2.1 Type of robots

As mentioned above, there is no clear definition for robots; however, some experts have categorized the robot based on the most common definitions. For instance, Leenes et al. defines five categories for robots (2017):

1. Nature: refers to the material in which the robot manifests
2. Autonomy: refers to the level of independence from external human control
3. Task: refers to the application or the service provided by the robot
4. Operative environment: refers to the contexts of use
5. Human-robot interaction: refers to the relationship established with human beings.

In addition, Leenes explains the variety of possibilities that can be considered in each category. In the care facility environment, it is essential that a robot has a mid-range autonomy to operate independently and that it can be controlled by human. It also needs to be designed in a way to have a strong relationship with the user. Moreover, the Institute of Electrical and Electronics Engineers (IEEE) classifies robots in 15 different categories such as disaster response, medical, entertainment, musical, humanoid, etc., which mostly represent the operative environment and nature rather than the other three dimensions explained above.

The first investigations into robots in the elderly care home have shown that there are only a few studies that categorize the type of robot that can be used in the care facilities for seniors. Rehabilitation robots and assistive social robots were the two classes of assistive robots for the elderly proposed by Broekens et al. (Broekens, et al., 2009)(Figure 1). For instance, smart wheelchairs, artificial limbs, exoskeletons and robot RIBA (Mukai, et al., 2010) which were not mentioned in the paper, but by their nature belong to the class of rehabilitation robots. Aibo, PARO, iCat and Pearl are assistive social robots used in their studies. Furthermore, the focus of his team was to measure the wellbeing of seniors after their interaction with those robots in the care home. Turja et al. became with a solution of breaking through robots as an excellent assistant of caregivers in a care facility (2018):
Remotely operated robots are more positively appraised than autonomous robots (Savela et al., 2017). Monitoring robots can keep track and register health- and safety-related factors and call for help when needed (Sharkey & Sharkey, 2010).

On the one hand, the study of Dickinson et al. considers the type of robot based on Leenes et al. categories and defines the suitable robot for their study that needs to have a degree of autonomy with the minimum low level of relatively (2018). In their study, NAO and Pepper, PARO -which have been used in the elderly care home for a long time - and Kaspar- who was used to care for children with autism- were examined.

2.2.2 Programmable robots in the care

There are different types of robots that are used in the care homes around the world. From a programming perspective, they can be divided into two classes. The programmable one that comes usually with a platform, software or API that allows end-users or programmers to control or program the robot at either a low or high programming level. In the second category, there are those robots that have been pre-programmed by the manufacturer and either can or cannot be controlled by the user in the care home. This section focuses on the robots that can be programmed by the end-user at any programming level. Some of those studies on programming the robot that used in the care home are presented here.

Figure 1: Categorization of assistive robots for elderly (Broekens et al., 2009)
**Pepper and NAO**

Both robots are identical in the way they can be programmed and the API that programmers can use to program the robot using libraries from the robot manufacturer. These robots are designed by SoftBank robotics in Japan and produce in Paris, France. Both use the NAOqi operating system based on the Linux operating system (Aldebaran, n.d.; Softbank Robotics, 2016a). The manufacturer’s standard program is a visualized program called *Choregraphe* (Leonardi, et al., 2019). There are SDK in C++, Java and python that enable programmers to program in different level. In NAO, for example, developers can program the NAO robot practically as a soccer robot at a low programming level, and it has been used in the *RoboCup* Standard Platform League since 2007 (Wege, 2017; Böckmann & Laue, 2017). On the other hand, the tablet on the chest of Pepper allows the development of the content in JavaScript. These robots are used in many studies related to robots in the care home and end user programming.

**Healthbot**

Healthbot is a service robot type that was developed by a multi-disciplinary team to increase and maintain the wellbeing of the elderly (C. Datta, C. Jayawardena, I. H. Kuo and B. A. MacDonald, 2012). The robot’s applications are capable of face recognition, to welcome the user, Skype communication, to connect the user with relatives and to measure the vital signs. Datta and their colleagues examined the appropriate design and languages that can be developed for the current applications of this robot. The purpose of their investigation was to develop an application that could be controlled by the seniors. Their development called RoboStudio which is a visual programming environment “*based on the idea of abstracting the textual domain specific language to the user and provide a familiar development environment using common design elements present in most Integrated Development Environments*” (2012, p. 2355). The list of elements displayed on the robot’s touch-screen and the interaction of older people with the robot will be transcribed and loaded on the robot framework.

**Chosen robot**

The robot chosen for this study is a humanoid robot called Pepper developed by Aldebaran Robotics in Paris, France. This company is now owned by SoftBank Robotics in Tokyo, Japan. (Softbank Robotics, 2016a). Pepper is a humanoid robot with a height of 120 cm and a weight of 29 kg. Thanks to standing on three wheels, it can work up to 12 hours without charging (SoftBank Robotics, 2016b). It has a medium to high level of autonomy, that can be selected by the user. The face and voice recognition capabilities beside 10-inch tablet on the chest to
allow the robot a good interaction from human to robot. It can detect humans, track them, and
guess their age, emotional state and gender.

There are several researches of the usage of social robotics in the care facilities; however, only
a few of them have dealt with the EUD in robotics since it is a new field. Additionally, a few
of them dealt either with the usage of the Pepper robot in the elderly care home, or the program-
ming of these robots by the care professionals.

2.3 End User Development

The research field EUD offers access to technology novices like caregivers, specifically for the
personalization and adaption of the software systems, without having any knowledge of pro-
gramming skills.

“EUD can be defined as a set of methods, techniques and tools that allow
users of software systems, who are acting as non-professional software
developers, at some point to create, modify, or extend a software artifact”

(Lieberman, et al., 2006)

This deals with the question of how users can be empowered to adapt and personalize applica-
tions in order to adapt them to the context of use and the personal needs of the user. In case of
care facilities, care professionals should be able to use and program the robot in a way that it
can became their assistant for routine tasks. Lieberman et al. (2006) argues that the systems to
be designed for EUD “must be easy to understand, to learn, to use and to teach” and be under-
stood by the user (2006, p. 2); otherwise, the chance of using both program and robot could be
limited due to their high workload. One fundamental challenge of this concept is to develop a
program that can be used frequently and programs in the care facilities during their activities.

There are two similar concepts which has overlapping with EUD such as end-user program-
ming and end-user software engineering (Ko, et al., 2011; Burnett , 2009). Since care profes-
sionals do not have knowledge of programming, having such device that programmed well and
by using such Bricks component that can be linked together to execute a function that expected
from a robot.

Categorization of existing application which might be on the robot or self-created on the appli-
cation and savable to have easy access for further use. Robotics in care setting can be discussed
from two perspectives. One is using robots to carry seniors and move them to another place or
bring some medicates and drinks to them which is mostly like a machinery task for robots in
this setting. Or think about social tasks for the robot to become a part of the community of care professionals. For social perspective, the behavior of seniors in regard to interact with robots are completely different. The robot by itself cannot recognize how it should react to individual persons and how it can provide a feeling of security and having matters under control to seniors. The end users as non-professional programmers are playing an important role as they should be able to use the application for programming the robot without needing to have any programming skills or understanding of the complexity of programming processes itself. Therefore, the user interface needs to be developed according to these special needs. One way to achieve this goal is to make the system “tailorable” with the help of “design metaphor” that means “to break down software into components which are understandable by end-users.” (Stevens, et al., 2006, p. 269). Based on Stevens et al. Study, the design of a tailorable software depends on the level of complexity. “Configuring a component”, “changing the component’s composition” and “designing new components” are the three dimensions of complexity in the run-time settings. There are two approaches which will show if the component of a system is tailorable: 1) Find a decomposition that provides the needed flexibility and 2) find a decomposition that is understandable to the end-user (2006, p. 272).

End user activities can be designed in two different ways either activities which enable the user to choose some predefined behavior which is called “Parameterization or Customization” or activities which are created by the user from the beginning of the creation process and enables the user to modify it. This is called “Program Creation and Modification” (Lieberman, et al., 2006). The program needs to be user friendly in a way to empower the end-user to follow the instruction smoothly with the capability of modification in the programming section when it is required. Especially in the case of health and care, it is essential to have a different setting for different seniors and it therefore requires knowledge to modify the system. Each employee can now create his or her own settings, and run it in an individual way.

2.3.1 Tailoring of functions

By definition, tailoring is “the activity to modify a computer application within its context of use” (BAECKER, et al., 1995; Won, et al., 2006) that is usually performed by individual users, groups of users, etc. (Won, et al., 2006). Based on the definition of Won definition, tailoring is done according to the original design and that begins “during or after the installation of the application” (2006, p. 116). Stevens et al. argued that tailorability was “a way to integrate the user into the system design at a very late phase of software lifecycle” (2006, p. 271). In their
study, they [offered] a *component-based tailorability* framework that allows users to modify the system by changing the component structure in the system at run-time. With this concept, users allow to “to tailor a system to the domain context without designing new components” by simulating a programming language using the system, which is made up of basic components (2006, p. 272). Stevens and his colleagues differentiate the component-based tailorability in three different levels of complexity. The first level is *Configuring a component* which has the least complexity and the easiest way to tailor a system by configuring of a single component. The middle level is *changing the component composition* which allows the user to insert, delete and rewrite components or create complex ones. This level requires the user to understand individual components and how they interact with other components. The higher level is *designing new components* that requires programming skills on the part of user in order to develop new components, as they do not depend on the existing components. From the point of view of the source code, the level of access and modifying the code source is defined as the *visibility of component’s implementations*. It is described by Won et al. as black boxing where users cannot see the source code, white boxing where users have the full access to the source code and gray boxing which users have access to parts of the code (Won, et al., 2006, p. 118).

![Graph showing tailoring levels and language layers](image)

**Figure 2:** The concept of tailoring levels and language layers applied to the tailorability mountain (Ludwig, et al., 2017)

Building a tailorable system is not an easy task. In the literature remark two main difficulties are identified in building a tailorable system such as supporting the re-design while in use and allowing the end user to play a role in re-designing their infrastructures (Wulf, et al., 2007). In addition, they argued that user skills such as system knowledge and programming skills are required to reach the level higher than that of parameterization. Ludwig and their colleagues offered a *gentle slope* towards increasing the complexity of tailoring the architecture and interface to encourage the user to learn and use the system. To achieve a *gentle slope*, they break
down the steps “and helping people from one step to the next (like a staircase; see Figure 2) – through software system appropriation as well as (hardware-related) infrastructuring. This mountain is not only concerned with tailorability, but also with the general concepts of use and appropriation” (2017, p. 33). As mentioned before, the two upper complexity levels beyond the Parameterization level in the software-related EUD are programming related (Wulf, et al., 2007; Ludwig, et al., 2017). Basically, Ludwig differentiated between programming and use in EUD. The four levels described by Ludwig are:

- **Use**: Use of a tool as presented to the user without changing any tool settings.

- **Parameterization/Customizations**: Customizations of a tool by choosing from alternatives represented by the developer.

- **Recomposition/Integration**: Adding new features to a tool by merging different tools or remerging existing components of a tool.

- **Extension/Altering**: Adding new features to a tool by extending it or developing new components and adding them to the tool or changing the existing components that it is made of.

The *Use level* is the stage when the system looks like a black box for the users, meaning that users have no idea how the system works and they cannot identify a problem when it occurs. *Parameterization* is the level at which the user has a basic awareness of the functionality of the system and can configure and modify some parts of the system.

In case of empowering the end-user in the care home to control and program the robot, that is essential to focus on the *Use level* at the beginning of the study in the first hand. After the end user has been made familiar with the functionality of the robot and his/her trust gained in the control of the robot, Parameterization can take place. In order to understand whether this upper level of complexity is achievable by the end-user, his/her background programming and technical knowledge had to be determined in advance.

### 2.3.2 End User Programming

The literature review examines the different tools that end users can use to program the system using End user Programming (EUP). It could be helpful to understand which programming method is best suited to meet the end user needs. According to Alexandrova, EUP “*is an active research area that aims to enable everyday people who are not professional software developers to create custom programs that meet their particular needs*” (2014, p. 2).
Programming approach

Buchiana and her colleagues suggest three programming perspective approaches to end user programming, such as *programming by processing of natural languages, programming by demonstration*, and *visual programming languages* (Buchina, et al., 2019).

According to Chopra et al., *Natural Language Processing* is a field of *Artificial intelligence* that translates the spoken language of humans in a way that can be understood by computers (Chopra, et al., 2013). *Natural Language* facilitates the interaction between robots and humans through the use of natural language (Liu & Zhang, 2019). An example of natural language processing comes from Lauria, et al. In their study, they tried to teach a robot to follow the route by using natural language that can briefly express the logic and the list of commands (Lauria, et al., 2002). This approach is mainly used to translate text transcription in a way that the computer (robot) understands and that it enables the execution of the commands and thus tasks specified in the transcription.

In the *Programming by Demonstration* in robotic, the user moves the robot to a specific position and records the path that the robot has been taken to the point, when the robot can learn and autonomously follow the path to reach that point. In addition, the robot operator can simulate different pattern paths in different conditions so that the robot can perform the movement based on the learned condition (Beschi, et al., 2019; Villani, et al., 2018). Programming by demonstration, known as Learning from Demonstration in the 1980s, is an extension of *walk-through programming* (Villani, et al., 2018) that sparked the interest of manufacturing robotics and was mainly used to program industrial robots (Billard, et al., 2016). According to Villani, the two main categories for the robot programming approach are *off-line and on-line programming*, with on-line programming including *traditional lead-through programming* and *walk-through programming* (2018, p. 9). In offline programming, the 3D model of a robot is programmed on the computer using a simulator. Walk-tough programming is a programming method with which the user without programming knowledge can move the end-effector of the robot to the specific position with controller meanwhile the robot “records the desired trajectory and the corresponding joints coordinates” (2018, pp. 9-11).

The most common approach to end user programming is the *Visual Programming Language* (Buchina, et al., 2019). *Visual programming* according to Ko et al. consists of “*a set of interaction techniques and visual notations for expressing programs. The phrase often implies use by end-user programmers, but visual notations are not always targeted at a particular type of programming practice*” (2011, p. 7). The VPL uses graphical elements including icons and
symbols usually “characterized by shape and color to help users understand their functionality and facilitate the construction of the robot program” (Bravo, et al., 2017, p. 2). In addition, they point out that this is the most common approach of interacting with robots as well. The examples of VPL that Buchina listed are: Mindstorms language, Mindstorms EV3, EV3 Programmer App, Choregraphe, creator ATR and flow-based language each of which includes sets of blocks that have defined inputs and outputs. The most advanced visual programming environment is TiViPE which is capable of scheduling events that take place in parallel. One of the disadvantages mentioned by Buchina et al. is that these programming environments take up a lot of screen space by connecting the blocks together via wiring connection (Buchina, et al., 2019) or by adding the puzzle pieces side to side like jigsaw puzzle (Bravo, et al., 2017). It is therefore challenging for programmers to develop such an environment on small screens such as tablets and regular smartphones.

Metaphor and programming style
Metaphor and programming styles are the two levels of various techniques purposed by Paternò and Santoro and are mainly used in the area related to EUD (Paternò & Santoro, 2017). In their study, they explored the different usage styles and programming environments related to EUD (see Figure 3).

Compared to the programming style, the metaphor concept has no connection to the programming world; in fact, it has an accurate meaning in the real world. Based on Paternò and Santoro defention “metaphors provide users with easily understandable cognitive hints expected to facilitate the creation or customization of an application by decreasing the learning effort needed by a non-professional user to manipulate programming concepts and artefacts” (2017, p. 46). The metaphors discussed so far are as follows: pipeline metaphor, jigsaw puzzle metaphor, timeline and rules, and logo which can be located in this level, but where not mentioned in their study presented here (Paternò & Santoro, 2017, pp. 46-49):

The jigsaw puzzle metaphor is a puzzle-shaped program in which each piece contains software components and the design allows the user to understand the possible structure. The mechanism of this metaphor is that each puzzle piece indicates a requirement. Two puzzle pieces can only be matched if they support each other’s requirements (Pinto-Albuquerque & Rashid, 2014). Scratch, AppInventor, Puzzle, MicroApp and Zipato are those jigsaw puzzles mentioned by Paternò & Santoro.
Timeline is presented as a temporal line on which graphic elements and events are aligned. The advantage of this metaphor is that relevant information can easily be arranged in chronological order. An example of this metaphor is TagTrianer (Daniel Tetteroo, 2015) which was designed for physiotherapists to create training programs for patients with harm and mobility problems. Timeline can be a solution for care professionals to program a social robot to set sequences of tasks and events and have the robot execute those tasks.

Rules are defined by sequences of if-then statements that express system behavior. The concept of this metaphor is based on “how the system should behave when specific situations occur” (2017, p. 49). One of the drawbacks of this metaphor is that it requires a basic knowledge of programming, such as understanding operator priorities, Boolean operators, etc. The rule-based approaches can be combined with other programming techniques. For instance, in TARE (Ghiani, et al., 2017), rules are represented in trigger-action events. To illustrate this, this metaphor can be used in a social care robot to greet people when the robot recognizes them or to take appropriate action to the touch sensors.

On the other hand, programming style is more related to the interaction pattern and programming techniques to simplify the EUD. Some of the programming styles they investigated are:

Figure 3: Metaphors and programming techniques considered in EUD approaches (Paternò & Santoro, 2017)
“programming by example, trigger-action –based approaches, natural language techniques, spreadsheets, mashups, mock-up –based and tangible programming techniques”. (Paternò & Santoro, 2017, pp. 49-53). In the study of Zubrycki and his colleagues, they reviewed the studies that covered programming of robots by non-programmers (Zubrycki, et al., 2017). The relevant programming environment that can be used to program the social robot mentioned in these two studies is discussed below:

**Spreadsheets** provide a clear representation of data that allows users to identify and solve simple issues in a short period of time.

**Mock-ups** is more of a design tool than programming language. It provides various tools for rapid prototyping in the early stages of design.

**Tangible interface** is a programming tool to program the robot without using the computer by connecting the physical blocks together (Paternò & Santoro, 2017). The advantage of this technique is the environment in which the robot can be programmed in a collaborative way. **Tangible interface** mainly considers young children between the ages of three and eight (Bravo, et al., 2017). The examples of this tangible programs are Social Robotic Toolkit, Cubetto, Kibo Project Blok, CHERP Tern, Playte, PROTEAS, Algoblocks, and Robo-Blocks.

**Trigger-action programming** is another visual programming method that enables users to create a rule and assign it to an action. The system performs the action automatically when the trigger event has occurred (Huang & Cakmak, 2015). This method mainly proposed by some authors for controlling IoT devices and *Smart Homes* (Huang & Cakmak, 2015; Leonardi, et al., 2019). The most popular trigger-action programming is *if-this-then-that* known as IFTTT². It is an online service that allows users to create a program to control smart homes (Huang & Cakmak, 2015). This service is similar to the *if-then* action described in the previous section where users can create a condition and the system will trigger the action when the condition occurred. In the work of Leonardi et al., they presented a trigger-action programming for controlling a social robot (Pepper) in connection with the control of IoT devices. Compared to IFTTT, where each rule includes one trigger - one action, they used a tailoring environment that allows more complex scenarios to be developed using AND/ OR logical operations (Leonardi, et al., 2019).

**Programming by example** known as *programming by demonstration* (see 2.3.2 - Programming approach) is a programming approach where the system records the action taken by the user in

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² [https://ifttt.com/](https://ifttt.com/)

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an interface that can later be used by the system (Amant, et al., 2000). Choregraphe software uses Programming by Example to create animation for Pepper and NAO robots. User can create a timeline, and there user can start to record the movement of part or all body of the robot and software automatically translate the timeline to the programming language.

**Platform**

In the previous section, types and different styles of programming environment were discussed. Some of these programming techniques are developed for use on specific platforms that are beneficial to the user. For many years, the main EUD approaches have focused on desktop-based applications; however, more recently, some studies have looked at EUD approaches to mobile technologies (Paternò & Santoro, 2017).

Martin-Ortiz et al. investigated on a possible framework for therapists to program a NAO robot for the therapy for children. In their results, controlling the robot via mobile devices turned out to be a proven choice compared to controlling the robot via a laptop, which has less than half of the estimated options (Martin-Ortiz, et al., 2017). The aim of their study was to work with therapists that can help them to design an interface through which they can interact with the robot without the need for a robot expert. In this study, they took advantage of the client-server architecture in a way that a server was running on the robot, sending and receiving the commands between the server and the devices. Moreover, they used an Android platform (tablet) as a client part.

**Abstraction level of social robot**

In the literature review, one of studies examined the different types and methods of programming that enables the end user, as a non-technical professional-, to program the robots with IoT devices (Zubrycki, et al., 2017). Section 2.3.1 discussed the level of complexity and gentle slope involved in tailoring a system. Furthermore, it is important to know the possible level of abstraction when programming a social robot in order to be able to recognize what level of abstraction is required in the robot so that end-users know it and can program it. Diprose and his colleagues divided the robot’s social abilities into five levels of abstraction as follow (Diprose, et al., 2017):

- **Hardware primitives** are the lowest level of abstraction that programmers can use to control and retrieve data from the hardware. At this level, the user is able to control LEDs, joints and retrieve data from cameras, microphone, etc.
• **Algorithm primitives** are on the second level of abstraction, which gives the robot the ability of social interaction, such as face tracking, speech recognition, sound source localization, etc. The examples of that on Pepper robot are ALknowledge, AlTracker, NAOqi People Perception and etc.

• **Social primitives** are the third level of abstraction, which is atomic units of social interaction implemented by *algorithm primitives* and in some cases by *hardware primitives*. For example, the focus on human abilities requires a combination of face tracking using *algorithm primitives* and servo motor control using *hardware primitives*.

• **Emergent primitives** are the fourth level of abstraction, which merges more than one *social primitives*. The example of this level is when different *Social primitives*, like gaze, gesture or dialog, are merged to enable the robot to express emotions. On the NAOqi, the AlGazeAnalysis module provides the ability of analyzing the direction of the steady look of a person.

• **Methods for controlling primitives** are the highest level of abstraction, which is used to control and create the level of upper behavior. The example of this level is a finite-state machine, with which a dialog between humans and robots was created using the combination of listening and speaking primitives.

As Diprosa et al. suggested, tool developers require to diagnose which abstraction level is suitable for the user to program a social robot. In their result, they indicate the higher level of abstraction is more convenient for programming social robot application; nonetheless, they mentioned with increasing the level of abstraction, the less power programmers have to control the robot.
3 Research Question

In the following, this study attempts to bridge problems and solutions identified in chapter 2. Part of the research of this study is based on Investigation on how End User Development can help and what is needed for it.

End-User Development is not limited to programming. It includes the creation and management of resources such as icons, images, and models. The program defining the behavior of an application needs to be connected with resources defining the look of an application. End-User Development tools should support the creation as well as the maintenance of these connections (Repenning & Ioannidou, 2006)

As already mentioned, care professionals were selected as a target group with no programming knowledge. The EUD has found the most efficient means to enable them to control the robot and program it themselves. The Pepper robot as an assistive social robot can be programmed using a device such as a computer or a smartphone. There is a lot of information that can be gathered from the robot and send to it. End users use this ability to adjust the setting to their needs to control the robot. They decide which components should be controlled and which components should work independently. Current research seems to validate the setting in which care professionals are encouraged to use robots in their daily work in a care home. Developing one or several tasks is essential but the modification and sharing of activities is a challenge. Users need to be able to create, modify and share their programs with others by following the concept of tailoring. As a matter of fact, the structure of the program section must be designed in such a way that the target group can develop a series of activities as an end user.

Regarding to the above remarks, the research question was formulated as follows:

How can the use of the EUD framework support the care professional with taking the lead of the social care robot? How can the care professional program and modify the components as an end user and in what level of complexity can they do it?
4 Methodology

The following chapter will describe the methodology used to answer the research question. This master study is based on the Design Case Study as a qualitative research approach which will be discussed in detail in a subsequent section. End User Development in care robotics is a combination of empirical work besides programming an android application with adjusting NAO Communicator (which was designed for remote controlling of the NAO robot; see 5 Concept of Pepper Communicator) to the needs of care professionals.

4.1 Design Case Study

Design Case Study is ideally structured in three phases (empirical pre-study, design and evaluation and appropriation (Figure 4)) (Betz & Wulf, 2018). This method developed by the chair of business informatics and new media at the university of Siegen to understand the connection between “social practices and the design space for IT artefacts in their support” (Wulf, et al., 2018, p. 30).

![Figure 4: Structure of a Design Case Study (Wulf, et al., 2015)](image)

In the empirical pre-study phase, the focus is on gathering a comprehensive understanding of the user group and their social practice. One approach to reach out target group and identify problems and needs is to conduct interviews with end-user as a target group. The aim of this
phase is to document their social practice and the analysis of existing tools, media and their usage. In the second phase, IT artifact design, such as software or hardware prototype, develops based on the finding of empirical work. Therefore, the final design is developed and refined by the feedback of the end-user. Evaluation as the last phase deals with the sustainability of the technology in the everyday life of its users. The activities in this phase provide the quality of the design remarking user experience and usability (Wulf, et al., 2015).

4.2 Methodology of pre – study

In the following, the aim of pre-study phase is described. Based on this, the qualitative method is used to understand the social practice of target group with conducting interviews, focus group and analyzing them. All qualitative data was analyzed with MAXQDA software. MAXQDA is a qualitative data analysis software which supports different qualitative source formats such as TXT and RTF for basic text formats and transcription, PDF and DOC for text format, MP3 and AVI for audio and video common format, etc. (Knuckartz & Rädiker, 2019).

4.2.1 Interview

In the first phase, the project started by carrying out semi-structured interviews with three care professionals from different working fields in different care homes to learn about their work practice.

Thinking about a possible approach, to ease the usage of robots in care facilities like hospitals or in this case an elderly care home, motivated the research to interview different types of caregivers with diversity of gender and ages (see Table 1). Two of them were working in an institutional care facility that had experience in working with a social robot (One of the interviewees was a social care who had the experience in dealing with the robot and knew about the robot’s activities and the senior’s feedback.). Another one was a scholar student working in the care facility as an intern and was about to finish his training education in a care school.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age</th>
<th>Gender</th>
<th>Profession</th>
<th>Knew Pepper</th>
<th>Technology knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>53</td>
<td>F</td>
<td>Caregivers</td>
<td>No</td>
<td>Low</td>
</tr>
<tr>
<td>P2</td>
<td>61</td>
<td>M</td>
<td>Social care</td>
<td>Yes</td>
<td>Medium</td>
</tr>
<tr>
<td>P7</td>
<td>23</td>
<td>M</td>
<td>Scholar student</td>
<td>No</td>
<td>Very Low</td>
</tr>
</tbody>
</table>

Table 1: List of participators in Pre-study phase
The interviews took between 30 and 60 minutes each with an average of about 45 minutes. The interviews were conducted in different locations like interviewees workstation in the activity room of the facility and once at university. The questions were designed in English and translated to German by a German native speaker as the interviewer. All interviews were carried out in German language and one German native HCI student and one PhD candidate did the interviews and transcribed them.

Introductory questions started with their professions and then led to open questions about their profession and the type of patients they deal with in the care home. The aim was to find out is the daily routine and interaction with the residents. Then the questions lead to activities in the care home and how they were implemented. It resulted in a semi-structured interview asking about their knowledge of technology and the type of technology they use in everyday life. In the last section of the interview, they were asked about how they could imagine the robot in the care home and how they would like to control it themselves. The interview ended with their expectations of how the robot should support their work.

4.2.2 Focus groups

In the final stage of the social practice, a *focus group* took place. Four care professionals from different care homes were invited to a care facility to discuss the future of robots in the care home and to find out their expectations, the current use of technology in their facilities and their knowledge of robots in general (see Table 2). None of them had any experiences in robotics nor did they use any kind of technology in their facilities.

According to Ritchie, the *focus group* or group discussion involves interviewing a group of four to ten participants who discuss research topics as a group. (2003, p. 37) In this way data is collected through the interaction of participants who present their own ideas, comment on or promote the ideas of others (Finch & Lewis, 2003). People differ from each other in their thinking, experience, knowledge, age, etc. The diversity of the group allows participants to influence each other based on what they say (Mack, et al., 2011). Based on Finch & Lewis, the *focus group* consists of six to eight people for a single meeting lasting from ninety minutes to two hours. They suggested the following five levels for moderating the discussion within the group: scene setting and ground rules, individual introduction, the opening topic, discussion, ending the discussion (2003, pp. 171-172).
The session started with the introduction of the project and the robot to the care professionals. Then, the app was introduced and they were shown some samples. Some pre-programmed applications on the robot such as dance, music, quiz game, etc. were launched. After half an hour, the moderator began asking introductory questions, which were general questions about their duties in the care home, the patients being cared for and their daily routine in their respective care facilities. In section of the opening topic, the technology used in the care home was discussed. Then the interviewer lead to an open discussion in which the participants asked questions and discussed their opinions. In the final discussion, they discussed how they envisioned the future of robots in the care homes.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age</th>
<th>Gender</th>
<th>Profession</th>
<th>Knew Pepper</th>
<th>Technology knowledge</th>
</tr>
</thead>
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<tr>
<td>P9</td>
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<td>M</td>
<td>Care professionals</td>
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<td>Low</td>
</tr>
<tr>
<td>P10</td>
<td>43</td>
<td>F</td>
<td>Care professionals</td>
<td>No</td>
<td>Low</td>
</tr>
<tr>
<td>P11</td>
<td>52</td>
<td>F</td>
<td>Care professionals</td>
<td>No</td>
<td>Low</td>
</tr>
</tbody>
</table>

Table 2: List of participators in the Focus group

4.3 Design and prototyping

The design phase was based on the empirical analysis of the pre-study. The first design was based on a new version of an existing Android app into the new framework. Then, during several user tests and evaluations the design improved in a way to become meaningful for the end-user (Wulf, et al., 1999). The aim of this phase was to create an inside view of the end-user’s perspective.

Two usability tests were conducted to make the end user familiar with the design of the app in the first place and gathering feedback from them regarding the design, and their perception of the robot’s reaction to their commands. One of those usability tests was conducted in form of a café test (Speh, 2016) to get the participator’s feedback on basic functionality in a short time. In this phase, the focus was mainly on items of the Android app with which they could control the robot. In this stage, the Android app did not have any functionality and served to the participators as an actual prototype. Therefore, a JavaScript platform was used by the system observer to control the robot when meanwhile a user was using the app.
<table>
<thead>
<tr>
<th>Participant</th>
<th>Age</th>
<th>Gender</th>
<th>Profession</th>
<th>Knew Pepper</th>
</tr>
</thead>
<tbody>
<tr>
<td>P3</td>
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<tr>
<td>P4</td>
<td>57</td>
<td>F</td>
<td>Caregivers</td>
<td>No</td>
</tr>
<tr>
<td>P5</td>
<td>46</td>
<td>F</td>
<td>Caregivers</td>
<td>No</td>
</tr>
<tr>
<td>P6</td>
<td>40</td>
<td>F</td>
<td>Caregivers</td>
<td>No</td>
</tr>
<tr>
<td>P7</td>
<td>23</td>
<td>M</td>
<td>Scholar student</td>
<td>No</td>
</tr>
</tbody>
</table>

Table 3: List of participants in Design test process

The task of the system observer was to monitor app and user and send those commands which the participants had chosen. At the end, the interviewees asked about the design and functionality of the items on the app. One of the usability tests was with four caregivers at the same time during their 15 minutes break in the activity room inside of the facility (Participants P3-P6, see Table 3). Therefore, there was no time to ask specific questions about their profession, technology interest, etc.

4.4 Mid appropriation

The aim of the evaluation was to determine whether the functional app can increase the motivation of the caregivers to control the robot as an end user (Dix, et al., 2004) and determine which part of the app is tailor able (Stevens, et al., 2006). Since the target group did not have technical knowledge to control and program a robot, there was no measurable value such as time aspects of finishing the tasks to reduce the pressure on the user. In addition, non-measurable values like feeling and impression of the user were matter. In total, two usability tests conducted with a social care worker (P2) as a primary end user and more planned with more him and other staff for final evaluation with.

4.4.1 Thinking Aloud Method

Generally, two evaluations were conducted by a single care professional (Participator P2 (see Table 1)) and the Thinking Aloud method (Nielsen, 1993) was used for data collection. Thinking aloud is a usability method that allows the designer to find out the user’s perspective on the design of the system. In this method, the designer asks the users to talk about their feelings in regard of usability and design of the software and whether they like it or not. Lazar described two tracks of data collection, such as quantitative metrics and qualitative data in the Thinking Aloud method. With quantitative metrics the focus is on measuring time performance per task. On the other hand, the participants could give a verbal overview of what they are doing and
describe it. The moderator could play an active role in encouraging non-talkative participants to share their thoughts on certain tasks (2017, p. 291).

There are several methods that can be used in thinking aloud and for this project the Coaching method was used (Mack, 1992). In this technique, one expert coach the participators who are learning the software and the user can ask questions when there is a need to. This method is slightly different from other usability tests in a way that the observer (coach) has an active role in guiding the participator into the right direction while using the system (Nielsen, 1993). There were two reasons to choose this method: 1) controlling the robot is a sensitive topic due to the complexity of its system and protecting the robot and the working environment from damage is an important matter and 2) the lack of technical knowledge might be an obstacle for the participator to explore the whole system.

In both mid-evaluations, the user was encouraged to describe what he liked and what made him confused during the test right after the test in an interview (Lewis, 1982). For each evaluation, different recording methods were used. In the first evaluation the focus was on the functionality of the app and impressions of the user for the app, but on the second evaluation the whole app was tested and a scenario was given to the user for one specific part of the app.

4.4.2 Wizard of Oz

During the mid-appropriation, the app or the server crashed several times due to unknown errors or because some items had not yet been implemented or were not functional. This method was used to examine user interaction with the app and control the robot or demonstrate the meaning of some functions and their usage in the app.

The Wizard of OZ is a technique that requires two systems to be linked together enabling the user to interact with the system that does not exist (Lazar, et al., 2017) or is not yet functional and the observer of the system (experimenter) executing the user’s commands and acting as a machine (Green, 1985). Lazar and his colleague describe one of the approaches for prototype testing in which a human behind the scenes responds to the user’s interaction during the test.

This approach is ideal to use in human computer interaction research and helps designers to study and evaluate the design before developing the complete prototype. This avoids finishing a fully developed prototype based on false user assumptions (S. Dow, 2005). In addition, as mentioned by Dow, the use of Wizard of OZ has some limitations. It can be used by an operator
whose role is to simulate some functions of the system or get involved when the system is working but cannot be trusted (2005, pp. 18-20).

In the beginning of the usability (prototype) test, The Wizard of Oz was used when the main app was under development and only the basic design was implemented. Implementation this method was much faster than implementing the same functions in the Android app and the Python server. This technique was boosted up through the design process at the beginning. The more Android app has been developed, the less this method has been used. Just before the end of the final design, it was used to correct the robot’s function or to completely stop the robot from misbehaving.

The Java Dashboard was the tool for Wizard of Oz (see 5.2 JavaScript prototype). This method was mainly used to correct the mistakes made by the participants or to execute their commands when the system did not respond.

4.4.3 First evaluation settings

The first evaluation was conducted in the public room of the care home. It took one hour to set up and to run the evaluation. In this test, note taking, audio recording and system and app log were used. The system log and app log collected valuable information about errors that occurred in the server and app during the test. This information later was used to reduce the error and bugs on the app.

The test was launched in the public space of the care home, where the residents have their coffee. For this test, some main functions of the app were functional and these have been tested. The aim of the test was to identify the hidden existing errors that can be discovered by the user. After the test, a short interview was conducted in English. Participant was asked to express his feeling on the test and his opinion about functionality of the app as well as the feeling of controlling the robot himself. In addition to the functionality of the app and its design, the German terminology used in the app was discussed.

4.4.4 Second evaluation settings

The second evaluation was conducted after the redesign phase (app and server) in regard of the participators feedback from previous evaluation. In this test, all parts of the app were functional and the design of the app had been improved. The duration of this evaluation was about one hour. The aim of this test was to determine if all items were understandable for the social care
worker (P2). The Thinking Aloud method was used to determine non-measurable values like impression and feeling of the user.

For data collection, note taking, video and voice recording, smartphone screen recording and system log have been used. The angle of the video camera was set up in a way that the participant, smartphone and robot could be seen in the frame. The developer option on the smartphone was activated and with connection to the laptop of the system observer all the log files from the smartphone were stored. One application was installed on the smartphone to capture the screen and to activate *show tabs* feature to show each spot taped by the user. The time on the smartphone screen was used to synchronize the time with the video recorder and system log. Moreover, the video editing technique was used to add all resources in one frame to get a total view of user activities. This technique provided a clear view what the user had done, what had happened in the system and how the robot had reacted to the commands analyzed.

After the test, there was also a short interview to discuss functionality, importance, etc. of the app. This short interview can help to get better feedback from the participant who did not feel confident enough to express his thoughts during the test. Some user may feel uncomfortable expressing their views when cameras are pointed at them or they feel the focus of attention like in such a test.

### 4.5 Final appropriation phase

After the solution and application of the feedback of the mid-evaluation, the app and server were ready for final evaluation. The aim of this phase was to determine how the remote app can enable the caregivers in their care home to use, control and program the robot. The focus of the test shifted from the design perspective to the usability perspective; in order to examine the level of tailorablebility up to which level the end-user can tailor the app. However, there were several challenges to overcome. The study was postponed due to the lockdown in Germany and most Europe countries be caused by Covid-19.

### 4.5.1 Workshop & usability test

After a long pause, one of care school allowed us to carry out the usability test and the workshop at their facility. There was a 90 minutes time limit to complete the test; although, a total of 3 hours is requested (30 minutes per participators). Because of mis-communication, workshop and user test were carried out in parallel and due to the lack of time, only two out of five volunteered for the user test. The workshop started with the presentation of ‘Robots in the care
home’, a project of the Siegen university. This was followed by a demonstration of the Android app and a brief introduction to how the test is performed and what to expect.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age</th>
<th>Gender</th>
<th>Profession</th>
<th>Knew Pepper</th>
<th>Technology knowledge</th>
<th>Voice Assistant</th>
</tr>
</thead>
<tbody>
<tr>
<td>P12</td>
<td>22</td>
<td>M</td>
<td>Scholar</td>
<td>No</td>
<td>High</td>
<td>Yes</td>
</tr>
<tr>
<td>P13</td>
<td>21</td>
<td>F</td>
<td>Scholar</td>
<td>No</td>
<td>Medium</td>
<td>No</td>
</tr>
<tr>
<td>P14</td>
<td>20</td>
<td>F</td>
<td>Scholar</td>
<td>No</td>
<td>Medium</td>
<td>Yes</td>
</tr>
<tr>
<td>P15</td>
<td>22</td>
<td>F</td>
<td>Scholar</td>
<td>No</td>
<td>Medium</td>
<td>Yes</td>
</tr>
<tr>
<td>P16</td>
<td>23</td>
<td>M</td>
<td>Scholar</td>
<td>No</td>
<td>Medium</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 4: List of participants in the workshop (care scholars)

A group of six attended for the workshop (Table 4). One of them left at the end of the introduction due to her time limit. Another was not involved in the discussion nor did she volunteer for the test. In fact, only four participants actively participated in the workshop. In the meantime, two of the participants (P12-13) who had volunteered for the usability test were asked into the test room. The Thinking Aloud method was used for the usability test. (see 4.4.1).

In the test room, there was a narrator whose responsibility it was to follow the scenario and read out the participant’s tasks. A screen recorder was used to capture the user’s interaction via smartphone. It recorded the time, voice, screen, and the location tapped by the user. One professional audio recorder was used to record high resolution audio and two cameras recorded a video showing the user, the Pepper robot, and the narrator in a single frame (Figure 5). In addition, two laptops separately recorded the system log files of the server and smartphone. In one
of them the Java Dashboard was ready for use in the event of a possible failure in the app or when an immediate command execution would be necessary. It had never had to be used during the test as everything worked without any problems.

At the end of each test, the participants gathered again in the group to discuss what they had done during the test and how they could control and use the robot. When the usability test was over, one of the participants presented the participants’ ideas on how the robot can be used efficiently in the care home and what role they envision for themselves in this process.

4.5.2 Observation

After the end of the lockdown in Germany in summer 2020, one of the care homes in a small town in Germany showed interest in the study. They requested the robot for a day in order to be able to assess the reactions of the care home residents to the robot. After positive feedback from the residents, they agreed to have the robot for a period of 6 weeks in the facility along with requesting an app to control the robot. That was an opportunity to test the concept of this study in parallel. The duration of the study was later extended to 10 weeks. A MiFi (portable router) was attached to the robot to establish the connection between the server, the robot, and the smartphones. Five smartphones with the Pepper Communicator installed and were given to them for study and use by each care giver involved in the study. An additional app was installed on the smartphones that allowed the server to start on the robot before the Pepper Communicator could connect to the robot. Care staff were asked to charge the smartphones, the router and the robot after each use.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age</th>
<th>Gender</th>
<th>Profession</th>
<th>Knew Pepper</th>
<th>Technology knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>P17</td>
<td>19</td>
<td>F</td>
<td>Social Care Internship</td>
<td>No</td>
<td>Medium</td>
</tr>
<tr>
<td>P18</td>
<td>54</td>
<td>F</td>
<td>Social Care</td>
<td>No</td>
<td>Low</td>
</tr>
<tr>
<td>P19</td>
<td>57</td>
<td>F</td>
<td>Social Care</td>
<td>No</td>
<td>Low</td>
</tr>
<tr>
<td>P20</td>
<td>52</td>
<td>F</td>
<td>Care professionals</td>
<td>No</td>
<td>Low</td>
</tr>
<tr>
<td>P21</td>
<td>74</td>
<td>F</td>
<td>Care professionals</td>
<td>No</td>
<td>Low</td>
</tr>
<tr>
<td>P22</td>
<td>38</td>
<td>F</td>
<td>Caregivers</td>
<td>No</td>
<td>Low</td>
</tr>
</tbody>
</table>

Table 5: List of participants in the observation and final interviews (care staff)

Due to specific regulations in the care home to reduce the risk of infection, only one person from the university was allowed to visit and access the robot. A protocol was written after each
visit. After a week, the social care staff who was responsible for the robot in the facility, requested an introduction session conducted to teach six staff members, such as caregivers, care professionals, an intern, and a social care staff (Table 5). They wanted to know how to use the app and how to control the robot with the app. Therefore, they learned how to start the server with the SSH app and then connect the app to the server and the robot respectively (see Appendix: Figure 1: Using Termius to start the server).

The next meeting was done over Skype as some difficulties arose due to light lockdown measures in Germany in winter 2020. Unfortunately, the Android app could not connect to the server after few weeks. As soon as it possible to visit the facility again, the problem was resolved and a usability test could be carried out with a social care staff.

After this usability test, the observation was continued in the facility. However, the usage of robot had to be reduced for a while because the care staff was busy with their preparations for Christmas. As well as the protocol which was written by a group of students from the university, a log file was used inside the app to record any interaction. The log files helped to track the frequency of usage of the app, the most chosen items, feedback, and errors if they occurred in the system.

4.5.3 Interviews

At the end of study in the care home, eight semi-structured interviews were conducted with the care staff. The interviews were conducted in German by three native speakers two of whom were HCI students and one of whom was a PHD student. These interviews were also aimed at “empowering the care professional to use the robot” in an ongoing study at university of Siegen. So far three out of eight interviewees (P17-19; Table 5) have tried to use the app and have attended all briefing sessions to learn the app. Therefore, the interviews with these three employees were transcribed and translated into English. In one of the interviews, the audio recorder did not work and the interview with this person had to be repeated. As a result, all interviews were recorded with a smartphone in order to record the voice parallel to the audio recorder. Due to the pandemic, the robot returned to university within a month of the Christmas holiday. On the last day, the head of social care was interviewed again to get a final overview of what had happened during that period. The interviews lasted 20 to 35 minutes and the final interview lasted 68 minutes.

In general, the interviews started by questioning their general impression of the robot, how they used the robot over the two months, how residents have responded to such technology, and how
the robot could help them with their work. These questions could indicate the acceptance of the care staff as well as the residents of the care home for the robot. The goal of the interviews then related to the use of the app and how it could help them to interact with robot and in what scenario they did or did not use the app to control the robot.
5 Concept of Pepper Communicator

Pepper Communicator is a new version of an existing android app (no longer on play store) which was compatible with android version 5.1 called NAO Communicator. This app could install and update a python server on the NAO robot. The NAO Communicator was a bridge between the NAO robot and android app (Eilers, 2015). It was designed on android version 5.1 and some of the components were deprecated and not usable. The fundamental of upgrading the Nao Communicator to the Pepper Communicator was not “old wine into the new bottle” as Hassenzahl (2008, p. 11) described it as User Experiences, but focusing on the quality of interactive technology to make those users feel confident who are not a big fan of technology interacting with the robot. Therefore, the Pepper Communicator is built from scratch to be compatible with Android 8.0 devices and with the ability of running on Android 7.0 devices. For some reason, some of the modules and methods on the Pepper software development kit (SDK) was deprecated and replaced by a new method on the server. Because of that, some of the methods on the server needed to be changed for better performance.

This chapter begins by discussing the chosen robot platform for this study and continues by following the reason to have a Java dashboard platform as a prototype and ending by the adoption of the old platform into the new one and the main reason to install the python server on the Linux device due to some technical issue (see Figure 6).

![Figure 6: System Architecture](image-url)
5.1 Robot

For this project, the robot platform Pepper is used. Pepper is a humanoid robot which is developed by Softbank Robotics (Figure 7). This humanoid robot is 120 cm in height and has the upper shape of a human body, making it more human looking (Pandey & Gelin, 2018). This robot stands straight on three wheels which can carry its weight and move it in any direction. This feature helps the robot to consume less energy. So, it can work for twelve hours in total with single charging. Pepper has 17 joints with total 25 degrees freedom in itself which makes the robot able to move its head, hands, arms, shoulders, hip and knee.

There are two platforms for robots to be programmed by the user. 1) Android Studio is a professional programming platform for programmers via Robot SDK platform which was developed by Softbank robotics. 2) Choregraphe specially designed by Aldebaran to program NAO and Pepper robots. Furthermore, Pepper has a middleware framework which is called NAOqi (Aldebaran, n.d.). NAOqi not only allows users to have access to sensors and resources, but also enables them to send commands and functions to control the robot via SDK (Pandey & Gelin, 2018) in parallel sequentially (Pot, 2009). The NAOqi executes by an object on the robot which is called broker. This broker has a list of...
modules which has a list of methods of itself. This broker has two main tasks to enable users to have access to methods of a module and allows users to find and call them outside of the process (see Figure 8) (Aldebaran, n.d.).

Pepper in general has four different settings for autonomous life:

- **Interactive**: activates voice- and face recognition of the robot to be in interactive mode. This enables the robot to listen to the surrounding and track the face of people around it. When the robot is in this mode, the movement function cannot work probably. To guarantee smooth riding, the setting autonomous life in this mode should be avoided.
- **Solidity**: deactivates both voice – and face recognition but the robot will move the joints to prevent overheating of engines.
- **Safeguard**: completely freezes the robot and its engines will lock in their position. In this state, the robot does not have access to move the joints.
- **Disable**: turns off sensors, engines and other interactive components and puts Pepper into sleep mode. In this state, the robot goes to its sleep gesture.

### 5.2 JavaScript prototype

After the pre-study phase, the Pepper Communicator was not functional. One solution to break through was to use a different approach to simulate the functionality of the app and present it to the care professionals. Therefore, JavaScript was chosen as a platform to simulate the functionality of the Pepper communicator (Figure 9). JavaScript uses the *qi messaging* library by Aldebaran to communicate through NAOqi (robot operation system) to the robot.

There is one Japanese forum which has a topic regard to Pepper NAOqi³. One topic focuses on one sample of the Aldebaran GitHub project. The project is simple and not that much into the beyond programming of Pepper but only template how to connect Pepper via NAOqi port. The idea of a dashboard which can host most of the useful functions required to control Pepper comes to mind. Some of these basic functions are Pepper movement, text to speech feature, autonomous life, show webpage, turn off, reset and other similar functions added to the JavaScript dashboard. This dashboard helps to simulate functionality of the Pepper Communicator

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³ [https://qiita.com/ExA_DEV/items/dd4bda65dfab1e7f5d07](https://qiita.com/ExA_DEV/items/dd4bda65dfab1e7f5d07)
app. However, at that time, the programming section was not designed for the dashboard but just implemented as default on the Pepper Communicator app.

The latest version of the webpage dashboard was tested as a prototype. This version can move the robot, text to speech in English and German, change the life status of Pepper, and change the color of eyes and ears.

5.3 Python server

Firstly, most methods used in NAO robot did not prove functional on the Pepper robot. Due to the mesh connections between functions inside of classes and fragments, debug and replacement of those deprecated functions were the most challenging process. Secondly, some of the NAOqi ports were blocked due to security reasons by Softbank robotics or replaced by an alternative port. The issue of the connection between the server and the app was solved by changing the server location from a local server on Pepper to a Linux machine. This change has some benefits and drawbacks. The benefits are that, debugging, tracking and updating the codes on the web-platform is much easier than any installation directly on Pepper. Setting up the server location on the Linux device helps to develop new components and tracks the existing issues. Moreover, debugging the error on the server and application became easier and so possible to continue the project. After this change, the Linux system serving as a bridge between application and robot made the sending and receiving of data possible (Figure 10). The drawbacks are
that, there should be a Linux system near the robot and it should be in the same network and the server needs to start manually and independently from the application. In the older version, the android app, was connected to the robot and if the server was existing on the robot, a server could run otherwise app could install and run the server on the robot. In the new version, the user needs to start and setup the server on the Linux device to connect the server to the robot first and then the user can use the app to connect to the server. In this way, the robot, Linux machine and the application should be in the same zone as router is located.

The challenge of improving the server is that the design of the application is dependent on the opinion of caregivers and the functionality is based on their need of using robots. This matter also depends on the design of application and combination of functions which transmit the data between android app and the server.

5.4 Android app

The Pepper Communicator is the name of the Android app that is based on the NAO Communicator. The foundation of application and server were both from an open source app based on the NAO robot which can be found on GitHub\(^4\). Unfortunately, this application is no longer available on Google play, however, it was not functioning on Pepper robots. Therefore, a new

\(^4\) https://github.com/NorthernStars/NAO-Com
and upgraded version of the NAO Communicator, which would be compatible with the Pepper robot was needed. The NAO communicator using the Java, Android SDK to connect to the robot allows the robot to install the server on it. After installing and starting the python server, android application can communicate through JSON to the server and read such an information like sensor, battery level, etc. The app can send a command to the server and the command can be executed by the robot (Eilers, 2015).

On the other hand, the Pepper Communicator connects to the same server, but the server is located on a Linux device. This app upgraded to Gradle 3.6.1 and API to 27 can run on Android 7.0 as minimum compatibility. In comparing to the NAO Communicator, this app is compatible to run in any languages and can support English and German as a default Language. The design of the app is modified in a way to be understood by caregivers and a format of font type, size and color are based on their preferences. The usability and affordance of the app’s items considered.

In compare to the NAO Communicator, some sections (fragments) have been deleted due to the complexity for non-technical users and some usable fragments have been added. Drive section is one of those useful components that was added to the app and enables the user to navigate the robot in the building (see Figure 11). One safety feature added to the app which prevents the robot to collide with objects and people. With this feature, the robot cannot go more than one meter in all directions and the stop button will stop the robot immediately. When users select the drive mode, the app sends a command to the server to switch the autonomous life of the robot to safeguard. By leaving this mode, the robot will automatically go back to the default autonomous life. The problems occur when the robot only focuses on the faces on the interactive mode, but does not respond to the movement commands.

In the function section and programming section, users can run and stop applications which are installed on the robot. In the programming mode users can add a list of applications (behaviors) and functions (see Figure 13). The play button sorts the list and sends it to the server (Figure 12). Users can change the languages of speaking behaviors in available languages on the robot and the Say function says the text in the chosen
language. In this section the interactions are limited to the heads and hands tactile and bumpers. The Programming mode is where *programming by example* can apply (Lieberman, 2001). This section was the most challenging part of the design and tests due to the complexity of coding and architecture of the system. The following items (command) can be sent to the server such as:

- **Say**: which can set a text with different modulation and speed voice independently from the setting on the robot.
- **Language**: which invokes the language package installed on the robot. When the app is not connected to the robot, English, German and Japanese as predefined languages can be chosen by the user.
- **Wait**: make a pause between the items. The default value is set to 5 seconds.
- **Stand up/Rest**: which puts the robot in the rest gesture or in initial gesture.
- **Run app**: There are groups of application (behaviors) which are installed on the robot. In this app four classes are defined and based on the activity of seniors such as movement, dance, music, and game. Each class has a group of application that can be selected by the user.
- **Walk to**: there are three parameters that can be selected based on x, y and around the axis of the robot.
- **Hello**: which is the greeting gesture of the robot.
- **Joints selection**: there are 17 joints in the Pepper robot that can be activated and deactivated. When the joints are locked, their movements are only possible by the software. When the user deactivates them, the selected joints can have a freedom movement.
- **Touch sensors**: this item acts as a trigger. The program will wait for a single form of the sensors that can be selected by the user. The three types of sensors that can be chosen are three sensors on the head, one sensor on the backhand and three sensors on the bumpers.
5.5 End User Programming in the app

As mentioned in the previous section, the only part of the app that was found tailorable was Programming section. The programming section is a visual programming language which is close to the timeline metaphor method. This section is capable of designing the series of commands that can be run respectively by a single press on the play button. This section could temporarily store the programs on the RAM of smartphone. When User leave this section and back there again, the series of the commands which designed by them could reload automatically if they did not close the app. After closing the app, Android system automatically wipes the cash memory that was used by the app data at the run time.

Each command in the programming section has own unique parameters that contain the command’s tag name and command’s data. For this project, programming section supplies these data on “RecyclerView” on the layout. RecyclerView is a library in Android which can create dynamic lists of elements which programmers can define. The programmer can supply the data and define where and how the data can present in the layout for the user (Android developers, 2020b). As an example, “Say” commands which is reprehensice of text to speech function on the robot carries an own tag name “Say” and three parameters such as text, speech modulation and speech speed. User can modify these parameters by clicking on the settings button on the Say item on the list.

As mentioned before, the Programming section can temporarily save on the app, but data will wipe as soon as the user closes the app. In Android there are five different approach to store data on Android smartphones. Database is one of those which designed to store structured data in the app for longer period. These data would not change by updating the app and can synchronize with a database on a cloud to be use on multiple smartphones when they connected to the internet. The Room persistence library is a private database which is the lighter version of SQLite (Android Developers, 2020a) which used in this project to store commands in the Programming section. Room had three major components such as database, entity, and Data Access Object (DAO; Figure 14) (Hagos, 2019).

![Room architecture](Figure 14: Room architecture (Hagos, 2019))
• The entity: represents a database table. In this project, tbl_program is the name of the database which store programs. Those commands which will design and store will be located in the programs_list as a single string variable (Figure 15).

```java
@Entity(tableName = "tbl_program")
public class Program {
    @PrimaryKey(autoGenerate = true)
    private int id;
    @ColumnInfo(name = "quantity")
    private int quantity;
    @ColumnInfo(name = "name")
    private String name;
    @ColumnInfo(name = "creator")
    private String creator;
    @ColumnInfo(name = "description")
    private String description;
    @ColumnInfo(name = "target")
    private String target;
    @ColumnInfo(name = "commands")
    private String programs_list;
}
```

Figure 15: Entity tbl_program and name of columns

• The DAO: is an interface to have access to the database. These accesses are such as create, read, update, and delete. To read data from database two queries mainly used. One for to get the number of rows in the table and one to read all rows to have full access to the table where all information was stored.

![Database Architecture](image)

Figure 16: Architecture of database in the app

• Database: holds the reference to the database such as entities plus converts if exists any. To make the coding process easier, the array data from commands program list converted to a single string variable to store (Figure 16). On fetch, this variable will convert to array list to be used in the RecyclerView in load program.
The most critical part of the database was how the data can be shown to the user and how they can have access, execute, or modify this data. Three solutions made to be present to the user to identify the best way of presentation.

- The first method is when users directly select the program from the database and then it plays the commands directly on the robot. From a programming perspective, this option is easier to implement in code and has less complexity in comparison to other options. The commands cannot be modified in this option, but it might help users to understand the functionality of this section in general.

- The second method is when they click on the program and the list of commands list appear in the Programming section. It is similar to create new programs in the programming section. With this option, user can modify the commands that they designed as before (see Figure 12).

- And Third method would be asking users to help the programmer to design this section. This option needs to be discussed with target group on a usability test and repeat the process till full acceptance of user gained.

Beside these programming components that marked above, one component takes into the account to give full access to the user to immediate stopping robot from movement. This button was appeared in early designed, but has never used during the usably test in pre-study phase. The main peruse of this button was to enable users to have access to the main control panel of robot where they can monitor and stop the robot for any reason. After pre-study, a layout was designed to enable users to stop robot’s movement, reboot or shut down the robot and change sound volume and language of the robot. Users can have access to the emergency button in all parts of the application. When users click on the emergency button, a dialog window displays on top of current sections that users are standing there. When the user cancels the window, in case of wrong tap or abroad their decisions, the window will disappear on the display.
6 Results

The results of the pre-study are represented in this chapter. The aim of this study was to find out how care professionals in the care home can be motivated to control the robot via a remote app and how this encourages them to create a program for the robot using the app, and whether this can motivate seniors to accept the robot as an automotive object instead of a machine.

6.1 Empirical pre-study

As explained in chapter 4, four interviews were conducted in the pre-study phase with care professionals (P1, P2, P7, P8, P9, P10, P11). Apart from P2 who had the experience of interacting with the robot and P1 who saw Pepper once in the care facility, the other participators had never seen any kind of robot before. Therefore, the interview with participators P1 and P2 was conducted without the presence of the robot because they already knew how Pepper looks like and what it can do. To start, participators were asked about the type of patients that they are dealing with in the care home. It was discussed in chapter 2 that the number of elderly people with dementia is increasing and this was confirmed by the participators.

P1: “In the beginning it was like a pure rehabilitation station, which we concentrated more on movement, but now we have dementia patients as well. It is just increasing now [...]” 5

When asked about the ongoing activities in the care home, gymnastics was mentioned as the main daily routine. This activity takes place for a quarter of an hour in the morning. Singing, movement and the memory training game were also mentioned which go well with the seniors.

P7: “there are just several activities of game offers for the seniors but also memory training for people with dementia.” 6

P2: “...here everything comes along well around the movement, gymnastics, games, then we have a nice university program - that goes very well with some residents.” 7

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5 „Das war hier anfangs mal wie so eine reine Reha-Station gewesen, dass wir uns mehr auf die Bewegung konzentriert hatten, aber jetzt mittlerweile ist es so, dass wir auch Demenzkranken haben.”
6 „Da gibt es halt mehrere Aktivitäten von Spielangeboten für die Senioren aber auch Gedächtnistraining für denziell erkrankte Personen”
7 „...hier kommt alles gut an rund um die Bewegung, Gymnastik, Spiele, dann haben wir noch ein schönes Uniprogramm - das kommt sehr gut an bei einigen Bewohnern”
For those patients who have difficulty to leave their room or are bedridden, caregivers will take music instruments to their room and “try to cheer them up with sounds and rhythm”. In case of dementia especially the training game worked well for them since the long-term memory could be retained after training activity.

When asked what kind of challenge the seniors are experiencing, loneliness was mentioned. Caregivers agreed that new residents often feel lonely after moving into the care home. A lack of care workers was mentioned as another reason because they do not have enough time to spend with the elderly and this makes them feel lonelier.

\[P7: \ldots the problem is very big that you get lonely very quickly and then just slip very quickly into depression...\]\(^9\)

When asked how they could deal with the situation to reduce their anxiety and depression, singing often helps seniors to overcome their feeling. Since the focus of the study was on programming the robot by care professionals as end-users, the question arose about their technical knowledge. In general, they had the basic knowledge to write their work reports on the computer. In addition, Facebook and WhatsApp are named as the typical apps they used. When asked about using other kind of technology, none of them had any experience interacting with a chatbot like Alexa, Siri, etc.

Then the topic of the interview was directed to the use of robots in the care home. One of the interviewees (P7) did not believe in the need of robots for the current generation at the care home, but he believed “that [this] will change massively over the years”\(^10\). When asked how they would imagine a robot in the care home, the answer was by lifting and carrying the elderly and leading them to their room. To understand how to design a remote app, the interviewees were asked how they could imagine to control the robot through a remote app. One said that if they used the robot without a remote app they would have to run after the robot to drive it back, which of course could be avoided with a remote app. She added that using the robot cameras can help caregivers to identify an emergency since Pepper does not have this ability to identify an emergency, especially with regard to the privacy of the seniors.

\[P1: \ldots(it) would be nice if the app would have Pepper's eyes where I can see where he is and what is going on.\]\(^11\)

\(^8\) P2: „da wird versucht mit Klängen und Rhythmus sie aufzumuntern“
\(^9\) „das Problem sehr groß, dass man sehr schnell vereinsamt und dann halt auch sehr schnell in die Depression rutscht“
\(^10\) „...das wird sich halt im Laufe der Jahre jetzt auch massiv ändern einfach...“
\(^11\) „wenn die App dann auch die Augen von Pepper hätte, wo ich dann sehen kann, wo er sich gerade befindet und was los ist“
In contrast, one of the participators saw the remote app as an additional task that could increase his workload. He mentioned that it could be helpful to program the robot to do activities by itself without the need of being controlled.

\[ P7: \text{“... if that would be the case now, that he does it on his own, so to speak, that you could program it like that, that he is following its daily process.”}^{12} \]

In addition, he agreed that a function like a time plan was helpful for the robot to carry out its activities. In addition, other participators had common ideas on how to save and use it. They wanted to create an application and save it so it could be used at different times like “activities in the morning” or special activities on Monday for example.

\[ P4: \text{“Today is day }x\text{ and we do that and that today!} \text{ And I would program it via the mobile phone in such a way that it could be used here for the next three hours.”}^{13} \]

However, some elements of the items setting were text-based design and needed to be redesigned for the user in terms of usability. For example, a user needed to input a distant number to move the robot. Although, he mentioned his opinion that the control of robot and remote app could be an obstacle in his daily work, he saw no dark future for this topic. He believed that in future the next generation of old people, would be more familiar with technology and the result would be a different one from now. He referred to the story of flying which seemed impossible at that time.

On the other hand, the interviews with participators P8-P11 were conducted in a group. They were from different care homes, in which no technology was used there. At the beginning, the functionality of Pepper as well as the applications from the different university projects which were designed for aged people with dementia were explained to them and then demonstrated for 50 minutes. Remarks about the activity in the care home, cognitive activity, and musical activity were made. In one of the care facilities, a quality inspection “where mobility and movement play an important role”\textsuperscript{14} was to be implemented in the near future.

One of the interviewees had different experiences with the use of the cognitive game. They used Kinect a few times to track down the movement of seniors in the game. These games only

\[ \text{\footnotesize 12 } \text{“Wenn das jetzt aber so wäre, dass er das jetzt quasi so alleine macht, dass man das so programmieren könnte, er hat jetzt seinen Ablauf, den er an dem Tag macht.”} \]

\[ \text{\footnotesize 13 } \text{“Heute ist Tag }x\text{ und wir machen heute das und das! Und ich würdere das über das Handy ihn so programmieren, wie er die nächsten drei Stunden hier.”} \]

\[ \text{\footnotesize 14 } \text{“...man sehr viel Wert auf Mobilität und Bewegung legt.”} \]
worked for fit seniors and not for the ones in wheelchairs. A technical failure served as evidence to make them stop the program at some point. In one of the care homes, some of the seniors participated in a newspaper group in which they sat in a circle reading the news. When asked how they could imagine a robot in the care home, the one from that care home mentioned that seniors would ask the robot about general information like the weather condition or current news. The Pepper robot with its voice recognition feature should understand it and give them information such as weather condition, weather forecast, larger daily newspaper reports, etc. Later, he criticized the robot for a lack of emotion in its voice.

\[
P8: \text{“It is difficult to read the obituaries with an emotionless voice, because they must be read in any case.”}^{15}\]

When one of them was asked if the obituaries are important, all agreed on their importance. Furthermore, they were asked to explain in which scenario, they could imagine the robot in their care facilities.

\[
P9: \text{“So with this face recognition, it is also nice when I imagine that I am sitting outside in the living area and he comes by and says "Oh hello, Mr. [X]. And he knows that I like to sing "Do you want to sing with me?"”}^{16}\]

Another interviewee could only imagine one scenario in which the robot would be put at the entrance of the care home to welcome the visitors and ask them if they are interested to interact with robots.

\[
P10: \text{“... some residents who are simply happy about the movement or find him funny (interact with him), but otherwise he just says to every entering guest "Welcome to our beautiful nursing home".”}^{17}\]

6.2 Results of prototyping test

In this section, the two user tests took place along with the design tests. The result of these tests will be discussed as well as the technical changes made afterwards. As indicated in chapter 5, the python server needed to be located in the Linux device instead of the robot. This step increases the complexity of settings for the user and should be avoided, but it makes it easier

\footnotesize

15 P8: „Schwierig ist dann eben mit einer emotionslosen Stimme halt die Todesanzeigen zu lesen, weil die müs- sen auf jeden Fall gelesen werden. Aber so im Sinne von alltäglichen und oft erwünschten Informationen zum Zimmer, zur Person oder was auch immer.”


17 P10: „... manche Bewohner die sich jetzt einfach an der Bewegung freuen oder finden den witzig, aber an- sonsten sagt der jedem Gast, der reinkommt “Herzlich Willkommen in unserem wunderschönen Altenheim”.”
for developers to understand the relationship between interaction of the user and the response of the server to the user’s request. This decision was made after consulting the developer of the python server to install and run the python server on the Linux machine and then establish a connection to the robot through the external server instead of having the server on the robot. This method has made debugging much easier. There were two ways to update the server: 1) on the robot through the application update feature which was not functional because of some technical issue or 2) manually copy and paste in the directory of the robot which made it tough for the developer to proceed in the design phase.

Before testing the actual remote app, a prototype was presented to the participators (P3-P7). The JavaScript dashboard supported the functionality of the items on the remote app. Participators were asked to describe their opinions and feelings about the design and possible functionality of each item developed at that time. The JavaScript dashboard was never used by the participators directly, but used by the observer to execute the commands that the participators gave to the robot via the app.

At first, the “speech” section has been tested for design and possible features that can be added to this section. Participators were asked for their opinion on the history feature and how it should look like. Participator P3 found it interesting to be able to choose between saving and not saving. She suggested saving some basic sentences as a template, such as greetings, but not all of the sentences that they entered.

After explaining the “LED” section to the participators, they were asked to give their opinion on this section. In an early design in the NAO Communicator, users had a variety of options to change the color of the LEDs and some animation patterns like dance animations, etc. Also, there was no restriction on choosing such colors like red, pink, magenta, or some mode like anger and fire animation which were a combination of changing colors to red and orange to simulate fire. None of the participators were happy to use this feature. When Participator P4 changed the color to red, she mentioned “it looks like an eye infection” and participator P3 describes it as:

![Figure 17: the former LED section](image-url)
The “drive” section (see 5.4 Android app) was the next to be examined. All participators agreed that this feature is simple and practical. Participator P3 and P5 decided to use it to move the robot around to test it. When the user tapped the app screen, the observer was moving the robot with the JavaScript dashboard based on the selection of the user.

The “programming section” is the most complex part of the remote app to test. It needs to be explained in detail to the participators. After explaining the functions on this section, the participants were asked to give their opinion on the design and functions. This section was imported originally from the NAO Communicator and integrated step by step to the needs of the user (Figure 18). This section is the only one where users must enter via icons without subtitle on the app. However, on the settings they can see the respective function and how they can optimize it. The participators were asked to give their opinion on the icons of the items and whether it is understandable or not.

Figure 18: The Original design of Programming section

As the symbols were clear for all the participants, none of the symbols changed. In fact, some of the symbols assigned to different items. The triangle shape icons were refer to sensors, which was originally designed as running behavior (the robot program) on the Choregraphe software. It assigned to running program again after implementation of run behavior (program).

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18 P3: „Ich würde sagen, dass bringt Unruhe, weil er klimpert ja eh mit den Augen und wenn die dann noch die Farbe ändern, ich glaube das kann dann auch erschreckend sein, für manche. Ich bin ja kein Horrortypen-Mensch, aber wenn so einer im Dunkel, sage ich jetzt mal, oder der kommt mit so knallroten Augen, wie der Teufel.“

19 „Also ich muss jetzt sagen, ich fand es jetzt auch nicht kompliziert oder sowas ne. Das war übersichtlich, was jetzt wozu gehört und so durch die Bilder halt auch nochmal sehr verständlich einfach und ich fand es auch sehr leicht zu bedienen. Und ja, wie gesagt, von Aussehen her fand ich es auch sehr gut, weil es übersichtlich war und diese Bilder auch dazu waren.“
The use of LEDs icon assigned to Sensors as it could be representative of Solar sensors. In the redesign phase, some more features added to this section that needed specific symbols to be assign to it. As an example, “status” and “function” sections were not fully understood by all the participators. It seemed complicated to them. One of the confusing segments was “Player volume” and “system volume (Master Volume)”. The volume level on the player volume on the Pepper is depended on the system volume. That meant when the level of the system volume was low during the interview, nothing was heard after increasing the player volume. Therefore, some functions designed in the former NAO Communicator app, such as “Change robot name”, “add custom event” and hot spot, were understandable for developers and a technical person, but not for care professionals.

In the TA test, when users were asked to stop the robot from unwanted actions, one of them went to the app’s emergency section and then he chose the option “turn off robot”. The reason for that was on the early design of this window, the shutdown button was the biggest one with a red background. During the stressful situation of needing to stop the robot immediately it took the user’s attention before all the other buttons; however, in most of situations, it was just needed to stop the robot instead of turning it off. Especially, when the robot starts to roll on autonomous mode turning off the robot might have some negative impact. After changing the design, both the restart and shut down buttons became blue and had the same size while the abort button became bigger and its background color changed to red.

6.3 Intermediate evaluation

The evaluation phase took place in two user-test cycles with one single social care (P2) as an end-user. In comparison with other participants in the user tests in the design phase, the social care that had seen Pepper several times during the last two years had the best idea of Pepper’s functionality and a clear understanding of how to use the robot. In the first cycle some of the main functions as well as the interface of the app were tested. The aim of the second test was to test the app as a whole by the users and to test the scenario on “programming mode”.

6.3.1 First cycle

In the first cycle, the basic functions on the remote app (Pepper Communicator), such as “Drive” section, “Text-to-speech” section, “LED” section, “Function” section and “Status” section, were examined. However, the programming mode, which was the main idea of the app could not be tested due to crashes, but the general experience with the application as a short
cycle testing tool was satisfying. This user test took place in the activity room of the care home where seniors did some activities at that time. This was an opportunity for the participator to test the app in the interaction of the seniors with the robot.

The first problem occurred when the participator wanted to read the text on the app. He could not read it without glasses and had to wear them all the time during the test. After setting up the server, the “Connect” section gave explanations to the participant and the participant was asked to connect the app on the smartphone with the server (which was connected to the robot after setting up). Some usability issues were identified in this section. The participator could not realize if the app was connected to the server due to a lack of feedback from the app. In the next task, the participant was asked to move to another section of the app where he could use the text-to-speech function. In the pre-study interview, he had criticized that Pepper was not loud enough to be heard by aged people. This time he could increase the volume of Pepper himself. He also found the “voice speed rate” and “voice modulation” features interesting because some seniors have difficulty hearing high frequencies and can understand deeper voices better. The most enjoyable moment for him was when he could move Pepper to one of the seniors and entertain him with a joke. He thought it was fantastic and a completely different experience to be able to control the robot himself. However, the program crashed several times when he used some letters of the German alphabet like Ä, Ö, Ü and ß. The lack of ability to deal with these letters in the UTF-8 format on the server was the cause of the crash. One of the feedbacks drew the attention to the speech section in which “text-to-speech” can be found and the user can choose different voice settings. He asked if he could type “Go forward to Mr. X” and Pepper would go to the person named in the text command of the application’s text editor.

Some German terms used in the app have been poorly translated from English. This caused a lot of confusion to the participator and needed more explanation. As an example, the common term of “autonomous mode” in the Pepper robot already explained in chapter 5 changed to “robot life status” to better understand the term.

Another issue that occurred during the test was when the robot was in “interaction” mode and focused on people, it did not respond to any movement commands. The user needed to switch the autonomous mode to safeguard or to solidity mode to be able to send movement commands; otherwise, the robot would remain stationery. Instead, the participator was asked to change the autonomous mode to another segment and back to drive segment to move the robot. This procedure confused the participator. Instead, the design of the app was changed so that when the
user activated the drive section, the app sent a command to change the status of the robot automatically to safeguard.

This showed clearly that the participator with experience in interaction between robot and seniors had a better understanding on how the remote app could be used during the activity between robot and seniors. He really understood why he should navigate the robot, use speech mode or navigation mode, and saw it as an additional help in his job.

6.3.2 Second cycle

In the second evaluation, all segments of the app were tested. All components and segments of the Pepper Communicator were functional. Because there were gaps between two evaluations, the participator needed again more explanation about the app because he could not recall what he had done in the previous evaluation. After a brief description, the participant was asked to connect to the server and go to different sections of the app to test its functionality and therefore the functionality of the robot.

This time, the programming section was tested without any issue. Although the remote app was capable to run in English and German, all terms of the app should be presented in the chosen language. However, the programming section was the only section that needed to be run in English. This was because the server used that tag name that had to be sent by the app and only in English. This issue was resolved after the test had already taken place. All the elements in this section were translated and explained to the participator in a few minutes. Then the participator was asked to follow some scenarios to find out whether he understood the functionality of this segment or not. There were some usability issues on some of the segments like the “move to/walk forward to” segment that was not designed well (Figure 19). When the participant was asked to get involved with the design of the interface for this segment, he preferred to express his opinion instead.
For the first time in this study, a combination of data collection, such as screen recorder, app and server logs were used to identify any single issue related to the code and usability. During the test some, the app crashed several times for some unknown reason. The participator could realize that the app is disconnected and was able to connect to the robot without any help. He could understand how the app and the robot are functioning this time. Those errors were diagnosed during the system log analysis and resolved later. After conducting the last evaluation of this study, the participant was looking forward to interact with the app and requested to solve the issue that had led to the interruption.

**P2 (second evaluation):** “That would also be the second phase or like when I realize there are people who are interested in something very much and then I could say, yes, I would say, what kind of topic did we have? About history. Then I could enter it here. History of something, history of Siegen, history of Australia, or whatever. I could program that and there would be a group, say, "Today Pepper will guide you through the program and tell you something about Australia."”

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20 „Das wäre ja dann auch die zweite Phase oder wie, wenn ich merke, da sind Leute, die interessiert irgendwas sehr gerne und dann könnte ich sagen, ja, ich sag mal, was hatten wir für ein Thema? Zu Geschichte. Dann könnte ich das ja hier eingeben. Geschichte irgendwas, Geschichte von Siegen, Geschichte von Australien, was weiß ich. Das könnte ich ja programmieren und da wäre eine Gruppe, sag so "Heute führt euch Pepper durch das Programm und der erzählt euch was zu Australien."

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51 | Results
6.4 Results of final appropriation

The main results of the evaluation rounds are described in the following sections. This includes the results of TA tests with scholars and the discussion in the workshop after the tests and continues with the two-month on-side observation with the app by the care staff and the final interviews about their thoughts after using the app.

6.4.1 Evaluation with scholar

In the preliminary study, a prototype test was carried out with the scholars. After the test, the design phase was in progress until the final evaluation. At this point, the new TA test was done to determine the usability of the app and how helpful the app can be in the care home. After a brief introduction to the app, the test took place. The aim of the test was to know how they can use the app, whether they understand the programming section and in what scenario they can imagine using this section.

One of the users (P12) had a technical background and was able to follow the scenario without much difficulty. He was open to communicate his thoughts and what he anticipated. He could easily summarize what he had learned in the introductory session and knew exactly what to do to connect the robot via the app. When asked in the TTS segment, what he thought of other features that could be fit into this section, he mentioned that it could be useful if the user could write the text, the app could send the translation to the robot, and then robot would say the translated text written by the user. He pointed out that there were too many buttons in this section, but after repeated use he became familiar with them.

On the other hand, the other user (P13) was able to connect to the robot in the workshop. Although, the connection was disrupted by changing the network, the network indicator in the app indicated that P13 was still connected to the robot. At first, she did not try to connect to the robot assuming she was connected because the signal indicator was still green (connected). In the TTS section, P13 was encouraged to use this feature. When she pressed the say button, the robot did not respond. After a brief pause, she realized that Pepper was muted and tried to turn up the volume on the setting. In the meantime, the narrator gave her some hints, but she had already used the higher volume. Then she tried to change the pitch and speed of say function and found it convenient that she could adjust the pitch and the speed of the robot’s speech.

In both tests, P12 and P13 were asked to imagine that the robot was exhibiting undesirable behavior such as moving around or if something went wrong with the robot how they could
stop it. Both said they would try to disconnect the app. When the narrator mentioned that this would not prevent the robot its behavior, they tried to use different approaches to keep the robot from its action. P12 used the emergency button on the screen and pressed the shutdown button which turned the robot off. In contrast, P13 used the function section and pressed the abort button, which stopped the robot from the movement. Additionally, she said she would put the pepper on stand-by mode in case.

One of the main features that needed to be tested was the programming section. Before the test, users were asked to give their opinion on this section and guess what they could do with it and how it would make them feel. P12 explained it as follows:

P12: “I tried a little bit of that earlier. [...] I find very simple and very clear. So, you have these icons at the top, which have different functions assigned to them. And as soon as you click on them, they appear at the bottom in that order. Exactly, and at the bottom there is this play button that you should be able to use to start the sequence.”

Then he made his first program and tested it. When the narrator asked about his first program, he said it worked pretty well, better than he had imagined. But, he had struggled to clarify the priority of the execution of the items in the list, especially if he wanted to scroll down the list. He accidently touched the area reserved for sorting the position of items in the list. When asked if this section was complicated for him, he responded:

P12: “I have an affinity there. That is why I think maybe I figured it out a little bit quickly. But in principle, I think it is learnable.”

On the contrary, the other participants could guess the meaning of items, but could not understand how they were related to each other. P13 said a little frustrated: “Somehow I do not really know how to deal with this”. When she was confused, the narrator stepped forward and described the purpose of this section and encouraged her to guess what the symbol of the items meant. She replied:

P13: “So here I do not know at all in part what that is supposed to be. What are those triangles supposed to mean there? Run App. So now I kind of do not know what to do with that. Here the mouth or the flag. Or even the

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23 P13: „Also irgendwie komme ich hier gerade nicht so mit klar.“
hourglass. That is actually self-explanatory. Yes, stand up is probably, any movements; Good stiffness, settings?"24

She suggested that some short explanations might help the user to understand it better or a short video which explaining and demonstrating the function behind this section as an idea. The regular 5 to 6 inches smartphones were used in all previous usability and prototyping tests. With regards to the hygiene protocol, each participant got one smartphone except one participant which got one 10-inch tablet due to the limitation. That was the opportunity to ask the participant who was using the tablet about the design and elements on the screen. From P13’s point of view, the items on the screen were too small and the huge unused space on the screen could have been used in other ways.

6.4.2 Results of observation in the field

This section presents the results of two rounds of introduction to learning the app and one round of introduction to programming, as well as the results of the field notes obtained by the on-site observer team.

First introduction session

In the briefing session, each participant had a smartphone to interact with. After explaining the app, the participants were asked to open the app and try to connect one by one. They were introduced to an additional application that was required to start the server.

When P18 tried to connect to the robot, the app indicated that the server cannot respond due to the socket server’s occupancy. The reason was another young social care (P17) who was already connected to the server and the robot. The mechanism of the app and the server is such that multiple devices can attempt to start the server, but only one device can connect to the server and robot. P17 was able to understand how the app and its connection to the robot work, and without direct hints, she managed to connect to the robot. The test continued with P18 who, due to her responsibilities, wanted to learn more about it than the other participants. She had a little trouble understanding the technical person because she could not read his facial expressions as he had to wear a mask. During the test, the connection between the server and the app failed for some unknown reason and so the app crashed. This failure increased in the more complex parts of the app. The problem could not be identified on the first attempt at troubleshooting.

24 P13: „Also hier weiß ich teilweise überhaupt nicht, was das sein soll. Was sollen diese Dreiecke da heißen? Run App. Also weiß ich jetzt irgendwie nicht, was ich damit anfangen soll. Hier der Mund oder die Flagge. Oder auch die Sanduhr. Das ist eigentlich selbsterklärend. Ja, Stand Up sind wahrscheinlich irgendwelche Bewegungen. Gut Stiffness, Einstellungen?”
One of the caregivers (P21) had joined the session late and paid less attention to it. It seemed that the information was too much for her. She later complained that it was confusing for her and she could not learn it on the first attempt. She mentioned “it should be learning by doing” not just an introduction in how to learn.

The second introduction
In the second introduction to app, an online meeting was arranged via Skype. This time, the second app could run the server, but the app could not connect to the robot. This problem was later diagnosed as network issue with the Mi-Fi on the robot overlapping with the frequency of a strong network in the care home. It was solved by changing the frequency to a higher bandwidth and changing the network channel. After that, care staff used the app for a while and their comments and observations were recorded in the protocol files.

The third introduction
The third introduction took place briefly after quarantine. Only the head of social care staff (P18) took part in the introduction to programming. She tried out all sections of the app for two hours. During her test, a visitor came along with the manager of the care home to see the robot. P18 used the app to show them the recent applications (behaviors) which were added to the robot. She was able to move the robot in front of them and closed the running app when it was no longer need. The test was paused for a short discussion with them and after they left the programming section was tested. At first, P18 had some trouble to understand this section and expected the robot to respond immediately to the chosen segment. After being told what this section meant and how to get the benefit from it, she began developing her first program. After a few test errors, she asked if she could save the program and use it later. At her interest, the saving and loading of the program feature in the app was shown and described to her. She also asked if it can be synchronized on the other smartphone, which was not implemented in the app at the time. This was the first time a user requested this feature. Prior to this, the synchronization of the database had not been implemented due to the low demand. P18 said that she was overwhelmed with the information and began to write down what she had learned in that session. The symbols in the programming section were not clear to her and she asked for a description file, but later she started drawing them on paper and wrote down the description for each item. At the end, some troubleshooting was discussed and how to solve certain problems if they arise.

Field notes
This section shows the general use of the app by the care staff. It is described by the observatory of the university team involved in the study.
There were a few moments when the Pepper robot did not work. One day the robot was unable to boot and the care staff had no solution to get it working. They were afraid they had broken the robot. They tried to use the app, but it also did not work. The on-site observer had to call the university technician for troubleshooting. He recommended following the troubleshooting by turning the robot off completely by pushing the emergency button and trying to restart the robot after a few minutes. His advice was followed and the robot started to boot up. After the boot up procedure, the robot recognized one of the caregivers and greeted her. At that point, the observer reported that neither the Mi-Fi nor any of the smartphones had been charged. After charging the smartphones and the router, the care staff tried to launch the server and connect the app to the robot. The server was running and they were able to connect to the robot, but the robot did not respond to their commands. At that point, the second introduction was requested by the care staff.

One of social cares faced the issue of moving the robot in the axis. The robot was facing her and when she wanted to move the robot to the right side of the room, she tapped on the right button on the app, which eventually moved the robot to the left side of the room. The robot preformed the correct commands, but the movement on the right side of the app is based on the robot’s orientation, not the user’s perspective. That means, if she was facing the robot and wants remotely move the robot to the right side of the room, she should tap the left button, since the right side of the room is located on the left side of the robot. She believed that in time and with more practice, she would understand. Another issue reported in the protocol is that one of the care staff complained that she could not move the robot in the curved collider. Sometimes they wish the robot could move diagonally to pass curved colliders. Basically, the design made it possible for the user to move the robot along the X and Y axis.

Another report indicated that care staff had some difficulty moving the robot around the table. There is a blind area that the robot’s sensors cannot cover and, in fact, the robot continues to move toward that object. They request if there was anything in the app that could prevent this unwanted movement towards an object like a table or a desk. In fact, it happened in one of the usability tests recorded by the camera. There was some kind of issue that the care staff had to deal with in order to move the robot into rooms with narrow paths. Robot kept stopping on the way and they had to tap the move forward button several times until the robot passed the door and entered certain rooms. At this point, the nurse who was supposed to bring the robot to the

25 The footage can be found on the movie from the second mid-evaluation TA test: 2020.02.20 Usability test 01.MTS from 12:35” to 12:55”
cafeteria was rolling the robot herself instead of using the app. She used the app when she wanted to play the anthem of a resident’s favorite football club.

6.4.3 Evaluation with professionals

The result of the interviews carried out at the end of the thesis is described here. From a total of eight interviews, the four interviews with the three caregivers who used the app frequently were analyzed. The head of the social care staff was interviewed twice before and after the Christmas break. The result of this section is divided into five different categories.

Staff experience with robot

The word that almost all participants used to describe their experience with the Pepper robot was amazing. The young participant (P17) did not think that they “could do so much with the robot in a nursing home”\(^{26}\). They all assumed that the residents would be skeptical of the robot and did not expect so much from it. The robot was originally supposed to stay in the care home for 6 weeks intervention. However, after positive feedback from staff and residents, its stay was extended to 8 weeks, 10 weeks and 3 months respectively. Regarding the extension, P19 mentioned that at the beginning she was excited about what Pepper can do in the care home, then when the interviewer asked her if the robot should stay longer in the facility, she replied:

\[
P19: \text{"Of course I would like to have Pepper used every day over a longer period of time. Or that it would just be part of my everyday work. Not all day now. But at times for certain residents, for certain offers. And then maybe the variety of offers, i.e. the variety of Pepper offers would be increased a bit."}^{27}\]

Impact of the robot on the residents

The acceptance of robots by the residents was evidence of much research in the field of robotic in care homes as well as pre-study of this thesis. However, two reasons led to further research in this field at this point again. The first reason was the change of facility and its end-users to a new care facility what had not previously had any experience with this technology. The feedback from the residents was crucial in encouraging the of care staff to use the robot and the app. And the second reason was the pandemic, that which made it important to study how the effects

\(^{26}\) P17: „[... ich hätte tatsächlich nicht gedacht,] dass man so viel mit dem Roboter anfangen kann im Altenheim."

of the current situation could change the residents’ view of the robots compared to previous studies.

Most residents in the care home who had interacted with the robot were positive about the robot and accepted it at the end, except for one resident who opposed almost everything that was new to him. It was reported that some of the residents were not interested about the robot in the beginning, but got used to it in the end. One of the seniors who was previously not interested in most things except his cell phone, started singing with the robot after a while. One of the seniors, a hardcore fan of a German soccer club, was happy when the robot played anthem of his favorite team, even the next day.

It was a tradition in the care home that the staff sang Christmas carols to the residents and also sang them with the residents. During the pandemic, the care staff were prohibited to sing for the residents. It is all because of the aerosols that can get into the air. Of course, this did not apply to the Pepper.

P18: “[…] most of the residents were also incredibly happy. And also, those who seem bedridden and maybe a little depressed. Then the robot came, then it was blown away. They were just so happy to see for themselves how these people, who are actually disinterested in playing something or having something read to them, simply look forward to it. Yes, just being able to do something with this robot, I think that is incredibly positive.”

Caregivers experience with the app

According to the head of social care staff, the app has been frequently used by the care staff. There was no pressure on them to use the app. It was up to them to decide whether or not to take the smartphone with them. Some preferred not to take the smartphone with them as an additional device. P18 believed that some of the care staff did not want to use the app because “they did not want to deal with the technology any further.” Other staff thought differently and found it more convenient to use the app.

P17 stated that her use of the app was mainly limited to the time when she had difficulty starting the robot and that she would prefer to control the robot from the computer. When that did not

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28 P18: „die meisten Bewohner haben sich auch wahnsinnig gefreut. Und auch die, die bettlägrig und vielleicht ein bisschen depressiv wirken. Der Roboter kam dann, dann war es wie weggepustet. Die haben sich dann einfach mega gefreut und selber zu sehen, wie diese Menschen, die eigentlich desinteressiert sind, irgendwas zu spielen oder was vorgelesen zu bekommen, sich einfach darauf freuen. Ja, mit diesem Roboter einfach mal was machen zu können, das ist dann wahnsinnig positiv, finde ich“

29 P18: „weil sie keine Lust hatten, sich mit der Technik noch weiter auseinanderzusetzen.“
work, she used the app. When the interviewer asked her the reasons, she mentioned that these were personal like:

P17: “So I was actually afraid that it would fall down somehow or something. And then something would break. But, I did not dare to really move it in somehow.”

When the interviewer asked her, what should be changed in the app in order to make it easier for her to use, she said she had no problems using the app and that it was easy to understand expect that “arithmetic and time was a problem”. When participants were questioned what needs to be changed in order to increase usage of the app, most of them mentioned that they need to get to know the robot first and then probably use the app.

P17: “I think you just have to dare to do it. So, you have to be open to it and invest time in it. Get to know the robot, get to know it yourself, introduce it and then just do it.”

Caregivers usage of the app

The participants were asked about their use of the app and how and in what situation it could help them and which part of the app they used most often.

P19 mentioned that she had a slight back problem. The time the app was delayed she had to push the robot to get it to different rooms and that brought stress to her. From her point of view, the move function was the most usable part of the app due to her back problem.

P17 mentioned that in the case the robot did not start, she tried to start the robot with the smartphone and it ended up working. She mainly used the app to control the autonomous mode, to put the robot in crunch position for transport, or to wake the robot up. P18 made the same statement as P17 namely that just driving the robot was the most valuable feature in the app that could help her to tap a button (on the screen) to move the robot. She found the limitation range in the drive section useful as this feature could prevent the robot from walking towards an object or person. In this section, a range of 30 to 90 cm has been set to move the robot, and then the robot is stopped. She liked that:

P18: “[...] you could simply set a range of about 30 to 90 centimetres. How you trusted yourself not to hit the corners. And that was just so relaxed because you push a button and it rolls, you push the button and it rolls. And

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30 P17: „Also ich hab auch tatsächlich Angst gehabt, dass er irgendwie runterfällt oder so. Und dann, dass da irgendwas kaputt geht. Aber so. Ich hab mich nicht getraut, so wirklich das irgendwie zu bewegen.“

31 P17: „Also war Rechnen und Zeitproblem“

32 P17: „Doch ich finde, man muss sich einfach trauen, das zu machen. Also man muss offen dafür sein und Zeit darin investieren. Den Roboter kennenlernen, selbst kennenlernen, vorstellen und dann halt auch tätigen.“
Results

you could just walk next to it, be a little bit careful that it doesn't necessarily tip over. But it was just so really relaxed when he was moving himself. That was really good.\textsuperscript{33}

In addition, she claimed that using the app to move the robot was easier and had a better impact on the residents too. The residents were delighted and said “Oh, he can suddenly drive himself now”\textsuperscript{34}. From their point of view, moving the robot without the obvious help of the care staff had a better effect on the residents.

The TTS section was another part of the app that was often used. In this section, the text temporarily written by the user can be stored and then saved in the app for later use. However, no text synchronization was implemented to exchange the phrases between different smartphones. P18 spent some time making several examples, but mentioned that they cannot be used in different smartphones. She added that it might be more useful for the user to write the text on TTS based on the residents’ responses. The app could contain some pre-written sentences that the user can simply click on instead of having to write them themselves. Pepper would then say the sentences to the residents. If the robot asks the resident how they are doing, for example, the app offers a standard answer from which the user can select a suitable one and play on the robot.

P18: “Would that be good, if you could feed them the remote with standard phrases like that. How are you doing today? That is yes. But you also have to react when the person says, “Oh, I’m so tired today. Then there should actually be some standard sentence that you can select for this possibility of the answer sentence.”\textsuperscript{35}

Caregivers programming experiences

This section was the fragment that the first level of tailoring could apply to customize the use of robots. Since this section caused great confusion among the care staff, only a social care worker was trained. P18 was asked if she could use this section and create her own program. Moving the robot was enough for her and she did not want to deal with individual variants

\textsuperscript{33} P18: „[...] sondern dass man einfach eine Reichweite von ca. 30 Zentimetern bis 90 Zentimeter einstellen konnte. Wie man sich das zugetraut hat, dass da die Ecken nicht erwischt. Und das war einfach so entspannt, weil man drückt auf einen Knopf und er rollt, man drückt auf den Knopf und er rollt. Und Man konnte einfach daneben hergehen, hat ein bisschen geachtet, dass er nicht unbedingt umkippt. Aber es war einfach so richtig entspannt, wenn er sich selbst bewegt. Das war richtig gut.”

\textsuperscript{34} Quoted from one of the seniors by P18: „Och der kann ja jetzt plötzlich selber fahren“

\textsuperscript{35} P18: „Wäre das gut, wenn man denen die Fernbedienung füttern könnte mit so Standardsätze. Wie geht es Ihnen heute? Das ist ja. Aber man muss dann auch darauf reagieren, wenn der Mensch sagt “Och, ich bin heut so müde”. Dann müsste eigentlich dafür für diese Möglichkeit des Antwort Satzes irgendeinen Standardsatz da sein, den man auswählen kann.“
within the app. During the training session, she was also able to create and save her first program, but could not find the context to use it.

In the second interview, she stated that she had tried to show this section to other employees. So far, they had managed to learn the app and take advantage of its benefits, but the time pressure during the Christmas holidays and staff fear of breaking something kept them from learning more in the programming section. She added that if there had been more time and opportunity to practice, it would have been more convenient to use.

P18: “using the app would certainly like to do a lot more if the programming was a little less stressful. It was just too much effort in the daily doing. It was too time-consuming. You cannot program something while you are standing with people that you cannot do that. […], this programming process was still too complicated.”

When the user was questioned what needs to be changed in the programming section to make it less complicated, training was mentioned as an option. She suggested to slow down the process of learning the app and programming it and dividing the staff in two groups based on their technological understanding. The first session of learning was overwhelming for anyone with no programming skills. Another point that the participant mentioned was the pictograms and that the symbols in this section were not self-explanatory enough. It appeared to be very uncomfortable for the care staff to program the robot when sitting in front of the residents.

36 P18: „[…] wie gesagt, also die App nutzen würde man sicherlich gerne sehr viel mehr machen, wenn das Programmieren etwas unstressiger ist. Es war einfach zu viel Aufwand im täglichen Tun. Das war zu zeitintensiv. Man kann ja auch nicht etwas programmieren, während man bei den Leuten steht, dass das geht nicht. […], also dieser Programmiervorgang war dann noch zu kompliziert.“
7 Discussion

The Pepper Communicator was the goal of the project described in this thesis, which is concerned with the following research question:

How can the use of the EUD framework supports the care professional with taking the lead of the social care robot? And how can the care professional program and modify the components as an end user and in what level of complexity can they do it?

The research questions that were drafted during the planning of the design phase will be answered here in order to draw implications for the concept of a remote-control app for the care staff to control a humanoid robot. In the following sections, Discussion of the results (7.1), Design implications (7.2) as well as Limitations of the research (7.3) are discussed.

7.1 Discussion of the results

7.1.1 Examination of robots in the care home

As discussed in chapter 2.2, robots that can be used in care facilities can be categorized into three classes (Broekens, et al., 2009). The interviews of the pre-study phase that were carried out with care professionals indicated that their expectations and ideas concerning the robot’s capabilities were strongly related to those rehabilitation robots which are able to assist the caregivers in their daily work routine by lifting up the patients or grappling a glass of water, etc. Furthermore, one of the caregivers wished the robot to be able to patrol the care home to check if everything is in order to decrease some of her workload.

On the other side in the focus group, the care professionals’ expectations of the robot in the care home were focused on the therapeutic relationship. After the Pepper robot was introduced to them, their attention was directed to the robot as a service type robot which can offer some basic things or could be used to greet people at the care home’s entrance. From their perspective the future of a companion robot looks critical. The cost of the robot was another factor that was pointed out by one of the cares professionals. She wished more personal would be hired instead of being replaced by a robot. Although, it was mentioned the robot is not meant to substitute the care staff, but to assist them in their work, they pointed out that these kinds of robots cannot help them in their job routine. Their expectations of robots were summarized to care robots. That is why Wynsberghe (2013) has differentiated social robots from care robots as the role of care robot is based on therapeutic relationship rather than on companionship. Turja et al. (2018)
describes expectations on robots in care homes with regard to statements made by others as follows:

“Robots are expected to alleviate the shortage of care professionals (Zsiga et al., 2013) and to increase the autonomy of elderly people (Sorell & Draper, 2014).” (2018, p. 300)

The care professionals who were mostly dealing with patients with severe health restrictions expected Pepper to be able to lift up the patients rather than to be a companion robot.

By contrast, the demands of the social care staff were mostly related to companion robots as they have the potential to serve people with dementia (PwD) or those residents who are dealing with loneliness. The social worker seems to be more open to accept the robot and argue that it can fill a gap in the care stuffs’ work. In the pre-study, they showed interest in using the companion robot to deal with PwD or those who suffer from loneliness. Because of that, the direction of this thesis slightly shifted in order to cover the impact of the robot on this groups. Interview and observation result clearly verified how the Pepper robot could serve the care home’s residents and become a game changer in their well-being. The magnificent outcome occurred during the pandemic caused by COVID-19, when the number of care home visitors was limited strictly, the amount of social activities like singing were decreased while the inhabitant’s loneliness increased. During this time, they reported Pepper eased the residents’ mind.

7.1.2 Examination of designing app for care staff to control the robot

The ten weeks intervention course by Carros et al. (2020) increased the seniors’ reliance on the robot. In fact, at the end of their study some seniors seemed to be sad about Pepper leaving. Their result was influenced by the social care staff who was responsible for the residents in the care home as well. Indeed, compared with pre-study interviews made with him, where he was more pessimistic about using the app to control the robot, study of Carros seemed to encourage him to be more active and collaborate during the mid-evaluation. The findings described in the result section validates the results of Carros’ work showing that the care home residents’ acceptance of the robot has direct impact on the care staffs’ trust on the robot. At the beginning, most of the employees in the new care home, where the final evaluation took place, was uncertain whether the robot would be accepted by the residents or not. When the residents began to show interest in interacting with the robot the care staffs’ acceptance of Pepper increased too. So much that they were looking forward to work with it for the next time. The Pepper robot has a medium to high degree of autonomy and a high degree of HRI based on the scale offered from
Leenes (2017). Hence, the Pepper robot can be run completely autonomously, or can be totally or partly under the control of the user via a third-party platform, such as a remote control, a pc application, etc. In order to determine, whether the care staff can control the robot or not, it was import for them to become familiar with Pepper.

In the pre-study interviews, the participants were asked which platform is more convenient for them to use and control the robot with, and in which platform they are more familiar to work with. In most of the care homes, the care staff was supposed to write a daily summery on the PC system and some of them indicated that they have some difficulties working with the PC. The result of the interviews from different phases pointed out that some of the care staff do not like to carry additional weight with them when they carry the robot. As they are prohibited to use their personal smartphone on duty, they are not comfortable to carry any devices. But, as mentioned by the head of social workers, various staff had carried and used the robot as they found it more convenient to use it. Also, the way they used it made a better impression on the residents. The use of the app was based on their interest to control the robot. Therefore, for those who had some IT skills carrying the smartphone with the robot was the better choice for them.

The results of two studies was compared with the findings from the result section in order to determine which aspects can influence the relation of HRI. In the study of Graaf and Allouch (2013), it was pointed at culture aspects as well as at gender, age and education aspects that can influence the relation of HRI and its acceptance. They compared their result with the results of Shibata, et al. (2009). From gender perspective, the result of Graaf and Allouch pointed out that female persons are more likely to be anxious to interact with the NAO robot. In contrast, the study of Shibata indicated the female are likely to interact with Pedro robot. Despite to the fact that, both studies cover different types of companion robots, in this thesis, there was no clear evidence that would confirm that the gender could affect the relation of HRI. P12 was the only exception whose technical knowledge was far further than other participants, which cannot be generalized. However, from age and education perspectives, the results could confirm that the younger generation is more likely to understand the functionality of the robot and app easier than the older generation. An example of that was the use of the “drive” section where the user can move the robot by arrow buttons on the screen. Among the young scholars none reported any difficulties. They performed the given task for transporting the robot from point A to B smoothly. But that was not the case for some experienced participants. They requested subtitles
for the buttons saying which one is assigned to the right, left, forward, and backward movements. General speaking, the design of the app was reported as simple and clear, but only P20-P22 reported that their fear of technology keeps them from interacting with the app. As long as Pepper was on autonomous mode, they were confident to be around the robot and to let him to interact with the residents. As soon as the robot showed any failure, they were asking other care takers for troubleshooting.

7.1.3 Challenges of programming the robot by the care staff

After establishing the importance of the use of the remote app to control the robot, the second part of the research question needed to be investigated: “How and in what level of complexity can the care professional program and modify the components as an end user?”. The first investigation took place in the pre-study interviews by questioning the care professionals on which platform they wish to control the robot. As explained in the previous section, the participants preferred to have all functions in one smartphone. Based on the studies of others, the most common platform for EUD and EUP were designed for desktop PCs or web services. Only few studies had designed the EUP for the smartphones due to a small degree of freedom to design on small screens. Some researchers offered hybrid tech to overcome the screen issue which uses a combination of the desktop application or webserver and smartphones. The web design is another trick to overcome this issue as it can be launched on almost all devices which support web browsers.

On this study the focus was on an Android app which were more convenient to be used by the care staff as they are familiar with the platform in first place. Also, they can carry a smartphone easily by themselves when they are with the robots. By choosing the Android smartphone, one question remained without answer: how to design EUP for such a small screen? To reduce the complexity of programming and to keep the app as simple as possible. The chosen programming method was a combination of timeline and rules metaphors. On these metaphors the parametrization level could be used to enable users to modify some parts of the system to control the robot. This section requires caregivers to have a basic awareness of the system. This goal was achieved in the middle of the evaluation, but could not be used any further due to the cancellation of the final evaluation in the first care home. In fact, this section was only used during the usability test to familiarize the users to the functionality of this section and to improve the design. It also brought new ideas to improve the functionality of the app. As an example, in the first mid-evaluation test, P2 asked if he can write “Go to Mr. X” on the TTS
section. This is basically the programming by nature language that was mentioned earlier in chapter 2 where users write or say what they want and the transcription of that will be analyzed where upon the system executes the command. That idea could rise a problem on how to prevent end-users to be confused by the main purpose of this section which is that the robot is supposed to say the text that is written in the textbox on the screen. That could increase user’s confusion to use this function and not to be distracted, to use that example. It could confuse other users and needed to be designed in a way that this specific user can use the benefit of this feature without disturbing other end-users to use the primary designed function of TTS section. Indeed, it could be used in the programming section in a way users instead of selecting the symbols on the app, say which function they need and set the configuration entries on their command.

In early design of Nao Communicator, a “custom event” function existed which allowed the user to create a “AlMemory” key in the robot in (Eilers, 2015). With that, users could create their own program on the robot to make a trigger action event where users by clicking on the key event could trigger the action on the behavior program to be executed on the robot. As a matter of fact, by using the second application such as Choregraphe, users could add new features to the tools and use it in the programming section. Nonetheless, the use of this feature could rise two major problems. First of all, it forced the user to use a desktop application to create a behavior on the application. Secondly, they needed to know what AlMemory is meaning, how the mechanism of the event is working, and how they should add that to the program. Creating new features is quite challenging even for the developers themselves and most of the time they need to check the manufacturer libraries in order to use the proper elements. This feature was hidden after user’s confusion occurred in the first round of the mid-evaluation and since then it was never used again. Moreover, the Recomposition level requires users to understand how the elements in the system are working and they must have some programming skills to be able to use this feature beneficially (Won, et al., 2006; Ludwig, et al., 2017).

In fact, the programming function was introduced to the young scholars to measure their understanding about this feature. Unlike the former usability test, no definition was provided to them and they were asked to share their thoughts about this section. The goal was to determine whether this section is self-explanatory or not and how the information regards to explanation should be given to them as well as to the potential users. Surprisingly, P12 had a great overview regards to the functionality of the programming section and from his point of view, everything was in a way that he expected. For him all the symbols were self-explanatory and when he made his program based on the given task, he faced no difficulties to perform the tasks. When he was
questioned, what he liked about this section, he mentioned that it was easy to understand and to learn. On the contrary, P13 could not understand what she was supposed to do in this section and nothing was self-explanatory to her. In fact, she recommended that the app should offer some hint and a manual guide could have helped her to understand this section. The results from final interviews also confirmed that for P13 e.g. the section was not self-explanatory. He mentioned that a tutorial for this feature is needed. In general, some sort of training sessions for the care stuff were planned as part of the final evaluation, but due to the second lock-down the training sessions were discontinued.

At the beginning of the study, the manual guide of the Pepper robot was given to the care facility, but it was never used by the employees. Therefore, the thought was that it does not make sense to provide a manual guide to use that app. The results of the interviews concerning the use of the robot showed that the staff were aware of basic functions which were provided in the Pepper manual guide, but as the app did not have any information in the programming section, they did not dare to use that section as they assumed that they might damage the robot.

7.2 Design implications

The result of the study showed that even a lack of confidence can keep users from showing interest in dealing with the app and the robot. But, when the robot was on autonomous mode, they felt less responsible for the robot in comparison to when they wanted to control the robot via app. The following sections provide some implications for future use.

7.2.1 Use of small Talk

As mentioned by P18, it could be useful if the app would offer some pre-written phrases that users can easily pick one and use in a specific situation. The TTS section offers a function for the user for saving some samples and playing it on their request. However, this section did not offer a differentiation in precise categories in order to simplify different input. An example for that was mentioned by P18. He pointed at when the robot is greeting people and asking them “how are you doing?” they most likely say: “we are doing good” or “we are bored”. Then the app could offer some proper pre-written texts that can be easily selected by the staff. This could allow the robot to have a fluent conversation with the residents.
7.2.2 Reliability of network connections

The use of Pepper Communicator is highly relying on the network. The app and the server communicate on the network. Therefore, it is essential for both that the network remain stable before the robot starts to work. In the lab, this was the case. The network was reliable and the communication between the server and the robot was smooth. In the care home these conditions were not given. This was proven in an area with massive networking disruptions, disturbing the connection of Pepper. At the big fairs and during conferences quite often the robot could not connect to the network. So far, it could not affect the robot’s connectivity in the small area such as the care facility. Since the robot needed to be controlled remotely and be used in the different section of the care home a MiFi was used to solve this issue. However, MiFi has produced a weaker signal in comparison to the standard router which was used in the lab. Because of that, the signal on the default setting got lost and the connection was disturbed often.

7.2.3 Resident robot interaction effect on staff

The summary of the results from the field notes (6.4.2) and final interviews (6.4.3) is: the relationship between the acceptance of the robot by the inhabitants has a direct impact on the opinion on and acceptance of the care staff about the robot. The results of the observation and the final interviews clearly proved that the more the residents enjoyed to interact with the robot, the more the caregivers got convinced to use the robot in the care. P17 claimed that some residents were quite happy when Pepper was singing for them.

7.2.4 Influence of different learning experiences and practices on the robot use

Human are different from each other and so they are also in the process of learning. Education, age and personal interests can influence the process of learning. Some of the participants needed to repeat the lesson and practice quite a lot when the technician from university was present. P18 suggested that the participants should be divided into two groups to differentiate the slow learners from others. In one of the training sessions, P19 as a fast learner was getting bored waiting for other participants to finish each step. While P18 and P20 struggled with figuring out how to connect to the robot, she was already connected. The personal interest in technology can enable users to learn the system faster than others. P12 was the only participant who clearly understood the mechanism of the programming section without any help; although, it was the most complex part of the app. In a questionnaire completed before the test, he indicated that he is using gaming consoles, a voice assistant service and a smart watch.
As a result, people who are slow learners when it comes to technology need more attention and repetition of testing and learning sessions to be able to program the robot. The regularity of those sessions is a key factor in preventing participants from forgetting what they have learned. In the mid-evaluation, it came to a gap of four months between usability tests. Therefore, some functions of the app needed to be explained again in order to recap what P2 forgot. As a result, a regular plan was created to meet at the first of each month aimed to check the demands of the users from previous test.

7.2.5 Use of correct terminology of the care takers

The terminology elderly and related terms such as seniors, older adults, elderly care home, etc. should not be used in the care home as the inhabitants are more diverse now. A variety of people in different ages is living in the care home. So, the residents are not necessarily seniors as some of them are living there due to a sickness, personal reasons, etc. E.g. while the study took place there was a 22 year old coma patient living in one of the care facilities.

7.2.6 Use of a predefined checklist for app control and troubleshooting

As mentioned before when the robot was delivered to the care home, a manual guide was given to be read by the staff. No one attempt to read the booklet as they were busy with their duty. Even though, when the robot did not function, they did not use the manual guide for troubleshooting. Instead, they made the robot working via app. The server only can have access to the data from the robot when the robot is fully booted up. If it does not start properly, there is few chances that almost any third-party devices like Android apps can connect to the robot. There are different ways to reset the robot and try to start it again. A predefined checklist can be added to the app when the app cannot connect to the server in order to inform users about existing issues and to offer some troubleshooting hints to them to fix the problem. As an illustration, the app can guide them to check the network that the robot and the app are connected to. If they are connected to a different network, it can inform them by sending a gif file that shows them how they can fix it. Often, the MiFi battery level was on critical level and the router could not turn on.

7.2.7 Icons and symbols

According to the results from prototype testing, all of the symbols and icons used in the app were simple and clear for the participants. The programming section was introduced to the user in the second phase of the mid-evaluation. In the test, the icons were described to the participant
(P2) and the functionality of the items was introduced to him. At the end, the user was asked to describe his thoughts about this section and whether the symbols and icons were clear enough or if he wished to change them. The participant could understand the symbols, but this was after introducing the section to him. On the final TA tests, the participants were asked for their opinion about the symbols in the programming section. One of them claimed everything was in order. On the other hand, another participant could not understand the meaning of the symbols and asked the narrator to help her. Even though, the coordinator of the test explained all of the icons’ and items’ function, which was not clear enough for the participant. P18 was the one who tried to use the app during the time that Pepper was in the care home for three months. The app was introduced to her and she wrote down some notes with drawing the symbols. At the end, it was still unclear to her why the triangles should refer to launching the behaviors (robot programs) on the robot. In fact, the same icons and symbols were used in the app, they were originally used in the Choregraphe software from SoftBank robotics. These symbols and icons did not change, since there were no demands on that before the end of the study.

7.2.8 Anxiety of changing eye color of robots

The eye color of Pepper which could change on the LED section was the most critical point of this app. In the usability test, one of the caregivers tapped on the different colors and pattern on the app to check what the eye colors looked like on Pepper. The participators (P3-P6) were concerned that the color red would cause anxiety in seniors and that even changing colors that resemble red like yellow, orange, magnate, etc. could frighten them. One of the caregivers (P8) stated that the blinking of pepper’s eyes seemed unnatural to him. Due to these comments, some LED color animations like “angry”, “mischievous”, and colors like, red, etc. were disabled for the user and later completely removed from the app after further comments from the first evaluation cycle (Figure 17: the former LED section).

7.3 Limitations of the research

A number of potential limitations that need to be considered in this thesis are listed here. First of all, due to the small number of participants and using a qualitative research method, the outcome of this study results cannot be generalized. In total, six usability tests conducted with eight participants, which all needed to be in German, transcribe and translate to English. Then
the English translations needed to be checked with the original sources to make sure the impression and meaning of the context would not change in the translation process. Secondly, the need of users will change over the times and it is quite challenging to predict all the different needs in the design phase (Paternò & Santoro, 2017). Some technical limitation and inconvenient issues are worth being to mentioned below.

7.3.1 Technical limitations

The Pepper robot showed the great potential to be used in care homes to cheers up the residents in those facilities. But, this robot had some limitation too. There are four microphones located in the head of the robot besides two fans which are responsible to cool down the circuit board. The problem of that is the fans producing too much noises which can decrease the quality of the audio on the microphones. This issue makes it slightly difficult for the voice recognition algorithm to understand correctly what people are saying. Especially, for those seniors who speaks slowly, it is quite hard for the robot to understand them. This challenge could be overcome by using the chat bot which can cancel the noises. On the other hand, for some seniors the machinery voice is not clearly recognizable as they are not experienced.

The robot uses some infrared and sonar sensors to identify the object around itself. The 3D camera enables the robot to see the object and recognize the distance of object and people to itself. But none of those can cover the area beside the robot’s hip. If the robot is close to the table which columns are far from each other, the robot cannot recognize it and quite often it moves against the table. In the robot settings, the approximate safe distance can be controlled by the user. This feature could be added to the app, but a fear of wrong configuration and its consequences might have had discouraged the end user to interact with the robot. So, this feature was set to .50 by means robot would stop in case it detects any object that is less than 50 cm to it. The higher volume of safety would prevent the robot to move in narrow spaces and lower settings would cause the robot to hit the object.

7.3.2 Influence of the Covid-19 pandemic

The year 2020 was quite challenging for all individuals, especially for the residents and the staff in the care facilities. The impact of this event, changed the orientation of this thesis as well. The ground study of university of Siegen in the field of the robot in the care home began in August 2017 in a care facility in Germany. Most of the pre-study and the mid-evaluation of this thesis took placed in the same care home as well. The staff and the residents of the care home was
familiar with the robot and the procedures of evaluation related to the technology and robotics. One of the social-care workers was able to interact with the robot and for a period of six months while the robot was in that facility. The final round of appropriation was planned from February to end of summer 2019 to repeat the usability tests and to conduct two workshops together with seniors and staff aimed to practice the use of the app. For the second phase of the study, a study plan was created in order to determine which programming approaches - discussed in chapter 2.2- can be used to help the staff to program the robot. However, by the first lock down, the access to that care home was prohibited and the study was postponed for a couple of months. Later on, the study in that care home was completely cancelled.

With another care home being interested in the robot project, the entire project needed to be realigned in order to gain the acceptance of the users primarily and secondarily to familiarize the care staff as end users to the robot and the app. Programming a robot or device by the end-user requires their understanding of how the system is functioning. Therefore, some delay was necessary to introduce the app to the staff in order to avoid the rise of the workload of the care staff. The process of familiarizing the care staff to the app could continue. The care staff were already overwhelmed by the technology in the care home and learning additional technology to control the robot was time consuming. Even though the use of the app by the staff showed some success, by the second lock down, visits by the technicians became challenging and running the introduction sessions for the programming section remotely was not indicated due to the time plan of the thesis.
8 Conclusion and Outlook

This master thesis provides an attempt to give an outlook on the opportunities and limits of the Pepper robot as a social assistant robot and Pepper Communicator, as a remote app, to control this robot. By applying a Design Case Study as well as End User Development, this thesis aimed to get a clear picture of what the future of care homes with robots could look like and how care professionals as end users can control and program the robot to increase the well-being of the residents. This leads the following question:

*How can the use of the EUD framework supports the care professional with taking the lead of the social care robot?*

With the aim of answering the first question, it can be stated that the use level of the app was proved to be effective to have the robot in control by the care staff. An easy understandable app designed to reduce the technical complexity and thus simplified the use of the robot so that it could also be handled by care givers who do not have a high understanding of technical issue. The majority of the care staff claimed that the interface was easy to use and understand. The empirical study identified some issues that had to be considered during the design and evaluation phases. One of the key factors to get the acceptance of the users to apply EUD was to avoid the complexity of the app as much as possible. During the design process, the complex functions and tools that caused the confusion of the users were improved. Moreover, the confusing segments in the app were identified in that process and have been fixed for the next process. The result of the observation indicated that the app was mainly used to navigate the robot inside the facility and from room to room. It made a good impression on the residents that because of controlling Pepper via app it seemed it is moving by itself, and that thus the robot felt less like a machine to them. This made it easier to gain the acceptance of the residents. In the last phase of the evaluation, Pepper was serving the group in the activity rooms as well as individual residents in their private rooms. The robot needed to be moved quit a lot which was made a lot easier by the app. It could act as a backup plan for the care staff in order to deal with critical situations. In fact, it was mainly used for troubleshooting when the robot did not work as expected or when it could not stand up. As the matter of fact, the real demands of the care staff became apparent in the observation phase when developers worked closely together with the care staff to improve the quality of the users’ experiences and to fix the bugs inside the app. The second research question
“How can the care professional program and modify the components as an end user and in what level of complexity can they do it?”

needed further investigation on training of the care staff to increase their awareness of the robot functions. The evaluations along with the usability tests illustrate the possible sections in the Pepper Communicator app in which tailoring can be applied. These are the “TTS” and the “programming” sections which are the most potential tailorable parts of the app in terms of content and tools perspective that can be configured by users in the Parameterization level. In the TTS section, users could create a text, save and delete it. However, there is no option for users to edit the text or to restrict the access for other users if needed. On the other hand, adjustments can be made in the programming section intending to create and modify specific contents for residents of a care home by using the items and tools included in this section for the inhabitant. This allows users to define a schedule or a routine chart which contains a set of activities (music, movement, dance, etc.) that can be stored on the server and run on the robot with a single click on the remote app. It allows care professionals to arrange a group of activities existing on the robot and other caregivers could use those created programs if needed.

After finalizing the development of the Pepper communicator, an appropriation phase was carried out with the intention of increasing the knowledge of care professionals about the robot’s features. It is in contrast with the concept of the gentle slope in which users do not have to understand the system as Ludwig (2017) mentioned. However, the finding of the results clearly pointed out that the users did not want to deal with programming the robot as they might break the robot or hurt persons around with the wrong settings. In the care home, the care stuff needs to see the system as a gray box in order to create a program for the robot, to save and to modify it over a longer period of time. Taken together the discussion in 0, the lack of IT knowledge, time and care staff’s self-confidence as well as the high complexity of the robot itself and its programming section, were the primary reasons why it was more problematic for the care staff to program the robot in comparison to the app. Also, important factors for this were changing the end-user in the middle of evaluation and cancelation of training sessions due to the pandemical situation.

The Pepper Communicator implemented some essential features to support the basic needs of users to control the robot. Indeed, the server-client service, which was the backbone of this platform, illustrates potential for implementing different innovations including many other changes and extensions. The server has the possibility of communication with IoT devices that can be controlled by the end-user through the robot and the app. For illustration, a fall detection
gadget (Saadeh, et al., 2020) can be used to detect when residents fall down aimed to alert the robot and the caregivers. So that, the caregivers can response to the emergency situation immediately. Chatbot (M.Dahiya, 2017) is another software application that can communicate with the client-server to provide a fluent conversation between the people who are interacting with the robot and the system which can understand what they say and then respond in an appropriate way. This can be done by adding programming by natural language features to the TTS section or by creating a new section for this in order to make it possible for the care staff to talk to the app. Then the app’s analysis could help to execute the commands in the robot by the server. The TTS section can be sorted that a trigger-action programming method is used to program in a way to response to certain sentences that people say and develop some predefined phrases are fitting to what someone is saying to the robot. These two ideas combined can make the programming of the robot via app more meaningful as the care staff get more options to control the environment around the robot and the residents.
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Appendix

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A Pre-Study Interview guideline

1. Basic Information about the person
   1) How old are you?
   2) What religion do you follow?
   3) Which profession do you have?
   4) How many patients do you have in this facility?
   5) Which kind of patients do you have here?
   6) Which kind of treatment methods are there for dementia patients?
      • Which methods do you use or what courses do you offer?

2. Activities
   1) Which kind of activities do you have on the station?
   2) What do you think are the most fun activities for the patients?
   3) Do the patients play a few games?
   4) Do patients play with each other in the room or here in the common room?
   5) If you are considering new activities, how do new activities come about?
   6) What they used to like to do so much in the past?
   7) How often do such activities change?
      • Are new activities added or disappearing?
      • Who mainly supervises these activities?
      • Is it mainly this cross-group service then?
   8) Is it then obligatory for the inhabitants to participate?
      • Are there any exercises where there is a duty?
   9) How do you manage your time to assist seniors?

3. Technology and media
   1) What personal experiences do you have with technology or even with computers?
   2) Which kind of programs do you have here?
   3) What kind of experiences you have had so far with social robots? (Pepper)
      • If yes: what did you think of the first time you saw him?
• What activities have you seen the robot perform so far?

4) What do you think of the first time you saw him?

5) How do you see the future of robots in nursing homes? Could you imagine that?

6) Could it be imagined from the care point of view that a human robot also helps in care?

7) Do you think the seniors would interact with the robot as well?

8) Do you think that a robot can help with the working techniques you have to make them easier?

4. Robot use and configuration

1) If you have the ability of controlling Pepper, what would you like to do with it?

2) Could you think how to use and control such a robot-like Pepper with an interactive app on your smartphone?

3) Do you think it would be valuable to use such an app to configure the robot according to the needs of the patients/guests?

4) What would be the main needed features and your demands for this robot activities?

5) How about speech features, to talk with the robot?

6) How could you imagine robot navigation in the institution?

7) Are there specific procedures in your facility related to this?

8) Are there other aspects related to this?
B Design test interview guideline

Basic Information

1. Tell us something about yourself (education, age, profession)
2. Do you have any experiences to work in care homes?
   - What kinds of activities (did they offer/did you participate) in?
   - What specific technology were used in the care home? For e.g. robot, Alexa, Smart home system, etc.?

Problems/Challenges

1. What problems or challenges are faced by seniors on day to day basis?
2. What is done by the management to attract more seniors?
3. What problems do they face in getting information about artefacts?
4. Is there any language problem by seniors like accent or intonation differences?
5. Do you think language barrier exists for seniors (speechless, deaf)?

Technology

1. What experiences do you have personally or in the context of your work with technology/computers?
2. What is your experience with Social robots?
3. What is your general opinion on hominoid robots?
4. Could you imagine to do activities with a hominoid robot?
5. Have you ever seen how seniors interacted with robots? How was your feeling about it?
6. Have you ever interacted with real robot (Social robot, Alexa …)?

Control the robot

1. If you have the ability of controlling Pepper, what would you like to do with it?
2. Do you think can you use and control such a robot such as Pepper with an interactive app on your smartphone?
3. What would be the main needed features and your demands for this?
4. Which feature of robot can be imagine by you?
5. How it could help care takers to aim help seniors?

Suggestions

1. What is “care home of the future” like in your opinion?
2. What technological innovation can help to attract more seniors?
3. What improvement do you think can make this care home more attractive?
C Evaluation interview guideline

1) Introduction
   1. How old are you
   2. Which profession do you have?

2) Technology
   1. Are you using smartphone
      i. [If yes?] which type is it (Android, iPhone, windows)?
   2. Which application more often you are using

3) Robot
   1. Have you ever controlled Pepper robot?
   2. How would you like to control Pepper?
   3. In which way, would you like to use Pepper?

4) Pepper Communicator
   1. How did you like the app?
   2. How did you like the navigation between the tasks?
   3. Did you like the color pattern?
      i. What should change
   4. Were the fonts big enough to see without trouble?
      i. Which text did you find hard to read?

5) Affordance
   1. Is there any term that you could not understand it?
      i. What is your suggestion about the term behind the functionality?
   2. Is the pictures help you to understand the functionality of items?
D Evaluation procedure

Preparation:

- Define test scenarios
- Tasks should describe to give oral instructions to users
- Permission to record audio and video before start
- Ask for permission again at the beginning of test when camera is recording.

Scenarios / Tasks:

- Roles:
  - A German native speaker role as Moderator
  - I role as system observer

- Tools:
  - Sounds recorder: to capture high quality sound and noise cancelling
  - Record button should press two times
  - Camera with tripod to record user hand and smartphone in way to capture how user is interacting with app
  - Camera should record full size of smartphone
  - Better to fix smartphone on the table
  - Smartphone and tablet
  - check size
  - check graphic design
  - check orientation
  - Personal smartphone to take pictures of environment
  - Screen recorder
  - “Screen recorder no add” installed
  - 3 seconds threshold
  - Show touch
  - Capture audio

Execution:

- Introduction, clarification, consent
  - Introduce, explain the scientific context and epistemological interest,
  - affirm anonymity,
  - explain Thinking Aloud,
  - provide opportunity for questions,
  - have any consent forms signed.

- This User Test is part of Study of Mehrbod Manavi to aim writing his Master Thesis in Human Computer Interaction about Robotic in the care home
To aim further study and analysis we record audio and video of your hand when you are interacting with the app.

We will give you the plan and we ask you to follow the instruction and later we will ask about your feedback.

User experience
  o Design
  o Which element need to improve
  o Usability
  o Color
  o Font
  o Size

If you have any question during the test do not hesitate to ask please.

**Carry out test**

- Introduce tasks, then let users execute them. It is important that the moderator refrains from participation (but is on hand if help is needed, esp. when requested).
- Important: encourage users to talk about his thought, if necessary!
- Documentation
  - Task of observer!
    o Notes
    o Audio recording
    o Video recording
    o Capture smartphone screen
    o monitor the server and app (in case of failure)
    o save server and app logs

**Interview:**

- Semi-structured interviews
- Do not interrupt unnecessarily.
- No suggestive questions.
- No pre-formulated answers.
- No pressure! Rather take a passive role.
- Data collection
  o Recordings (mainly only audio)
  o note taking

**Analysis (After Test)**

- Using social-scientific methods
- Again, there is no standard procedure here.
- Conventional methods include e.g.:
- Social scientific analyses
- Coding
- Iterative refinement
- etc.

• Critical Incidents
  - Identify particularly important errors and prioritize.

• These should emerge from the comparisons as well as from a comparison with the tasks.
E Pepper Communicator

Figure 1: Using Termius to start the server

Figure 2: Find and connect smartphone to the server and robot.
Figure 3: Main Menu and drawer menu

Figure 4: Text to Speech section
Figure 5: Transition of changing the state of autonomous life from one to another.

Figure 6: State of robot joints, red = off; green = engage; yellow = part of joints might be dative.
Figure 7: “Function section” and the existing app categories that exist on installed on the robot.

Figure 8: “Programming section”, Empty page, full page and playing app.
Figure 9: “Programming section”, items’ configuration.

Figure 10: “Programming section”, “Run App” configuration.
Figure 11: “Programming section”, items’ configuration.

Figure 12: “Programming section”, “Sensor” configuration.
Figure 13: “Programming section”, Save and load programs page.

Figure 14: “Programming section”, Save and load programs page.
Figure 15: The emergency button (former design on the center and the newest design on the right)
F Brief survey for the workshop

- Name: ______________________
- Alter: ______________________
- Technischer Hintergrund: __________
- Spielekonsole: No/Nein Yes/Ja
- Sprachassistent (Alexa, Siri, etc.): No/Nein Yes/Ja
- Soziale Robotererlebnisse: No/Nein Yes/Ja
G TA test scenario

• Was würden Sie hier zuerst tun, um den Roboter zu steuern? /What would you do first here to control the robot?
  * Wenn Connection nicht die Option war, fragen Sie warum. /If Connection was not the option ask why.
➢ Klicken Sie auf Verbindung. /Click on Connection.
➢ Klicken Sie auf SUCHEN NACH NETWORK-GERÄTEN /Click on NET SCAN DEVICES

• Sagen Sie mir, was passiert ist, als Sie auf die Schaltfläche geklickt haben. /Tell me what happened when you clicked on the button.
➢ Klicken Sie auf den Roboterkopf. /Click on the robot head.

• Sagen Sie mir, was Sie denken. /Tell me what you thinking
➢ zurück zum Hauptmenü. /Back to main menu
➢ Klicken Sie auf Text-to-Speech. /Click on Text-to-Speech.

• Was können Sie hier sehen? /What can you see here?
  * Convince them to try all the options and let them freedom to explorer and discover more

• Wie würden Ihnen die Einstellungen gefallen? /How would you like the settings?
➢ zurück zum Hauptmenü. /Back to main menu

• Stellen Sie sich vor, mit Pepper geht etwas schief und Sie wollen es stoppen. Was würden Sie tun? /Imagine something goes wrong with pepper and you want to stop it. What would you do?
➢ Streichen Sie nach links, um auf dem Bildschirm zu schreiben, oder klicken Sie auf das Einstellungssymbol (drei Zeilen übereinander). You can activate it in two way. Swipe left to write on the screen or by click on the settings icon (three lines on top of each other).
➢ Klicken Sie auf Programmierung. /Open the interaction menu again and click on programming.

• Sagen Sie mir, was Sie hier Ihrer Meinung nach tun können? /Tell me what you think you can do here?
➢ Versuchen Sie diese: /Try these:
  ➢ Klicken Sie auf einige der oben aufgeführten Punkte. /Click on some of items listed in top.
  ➢ Versuchen Sie, sie wenn möglich zu modifizieren. /Try to modify them if it possible.
  ➢ Und versuchen, sie zu betreiben. /And play them.
I Final interviews questions

The interviews questions related to use of the app:

1. Wie hat dir die App gefallen?/How did you like the app?
   − Was hat dir in der App nicht gefallen und wie soll es sich ändern? /What you did NOT like in the app and how should it change?

2. Welchen Teil der App fanden Sie am praktischsten? / Which part of the app did you find most practical?
   − Hat es den Umgang/Steuerung mit dem Roboter erleichtert oder erschwert?

3. Wie haben Sie den Programmierbereich gefunden? Ist es schwer zu verstehen? /How did you find the programming section? Is it hard to understand?

4. Wie leicht oder schwer würde es den andere Pflegekräfte oder Mitarbeiter des sozialen Dienstes fallen die App zu steuern? / How feasible is the app to use by other caregivers to control the robot?

5. What make it easier for you to convince you to use the app more?
Confirmation

Hereby I confirm that I have composed the present thesis independently. I only have used the sources and means specified in this thesis. Especially from the internet, I only have used the denoted references. I have taken note of the section in the examination regulations concerning attempts to cheat.

I confirm that the electronic version of the thesis which I deliver is identical to the printed version with respect to the content. I agree that an electronic version of the thesis will be stored for purposes of inspection of plagiarism.

(Date)

(Signature)