RADBOUD UNIVERSITY NIJMEGEN

CARE ROBOTS: WHY NOT ASK THE ELDERLY?

BACHELOR'S THESIS IN ARTIFICIAL INTELLIGENCE

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Abstract:

This thesis project attempts to merge robot technology and physical therapy for elderly people with temporary mobility problems. Design recommendations will be given that can be used as a blueprint to develop a robot that is able to provide psychological and physical help during rehabilitation. The robot may improve their quality of life and by physically and psychologically supporting them. Ethical issues about having a robot in close proximity will be discussed. A small number of HRI researchers, caregivers and care receivers have been interviewed to receive feedback on the recommendations. It is intended to give the care receivers and other regularly involved people a larger vote in the design of the robot as they should feel comfortable when using the robot. The results indicate care robots used during rehabilitation from temporary mobility problems are likely to be accepted and appreciated. Furthermore the robot following these recommendations is accepted and found to be useful. However, future research needs to be done about specific design recommendations. When possible these should be adjusted to the demands of the elderly.

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1 Introduction

A definition of healthcare is: "The act of taking preventative or necessary medical procedures to improve a person's well-being. This may be done with surgery, the administering of medicine, or other alterations in a person's lifestyle" (Business Dictionary, 2014). Currently elderly healthcare is in high demand. It is quite expensive and because there are not enough caregivers to meet these demands, assistance from technology is needed. Although the general idea of robots or robot-like behaviour existed for centuries as they were mentioned in for example mythology and fiction (Springfield & Merriam Company, 1966; Homer the Illiad, 800 BC; Wiener, God and Golem Inc, 1966), but actual robot technology was developed in the 20th century. Human-Robot Interaction (HRI) emerged in the second half of the 1990s and the early years of 2000 when researchers with different backgrounds like robotics, psychology and natural language started working together (Goodrich and Schultz, 2008). HRI encompasses the interaction between humans and robots (Goodrich and Schultz, 2008). Moreover, robots are currently being used for the care of elderly people, e.g. for social interaction or reducing stress, however there are not any robots to help with physical therapy during rehabilitation at home yet. Since the start of robot technology in the 20th century, the level of sophistication has increased to a degree that makes the use of robots in both elderly healthcare and in general more feasible. Robots have also become less expensive. Because of these advances, it becomes likely that robots will be used more frequently in the near future.

As Sharkey and Sharkey state, "The growing proportion of elderly people in society, together with recent advances in robotics, makes the use of robots in elder care increasingly likely." (Sharkey and Sharkey, 2010). The purpose of this thesis is to give design recommendations that can be used as a blueprint for a robot that performs multiple rehabilitation tasks for elderly people. The design recommendations that will be made shall be adapted mainly to the demands of elderly people as the focus group. More specific it will be elderly people with temporary mobility problems who need psychological and physical assistance during rehabilitation. An example is a 67 year old lady who received an artificial knee. She has to perform physical exercises during rehabilitation and when she is able to walk again she is not allowed to lift anything. The robot can help with her exercises and carry objects for her. This robot is intended to help elderly people with mobility problems due to a broken leg or receiving an artificial hip. The tasks of this robot are intended to facilitate rehabilitation. When possible, the robot can also be adapted to demands of close relatives or caregivers as well, as they will be in close proximity of the robot. When there is a conflict between demands of a care receiver and his caretaker, it should be decided how capable the care receiver is to demand something. When his mind is deteriorated, the opinion of the caregiver is more important. But when he is found to be healthy, the opinion of the care receiver is most important (this will be discussed in depth in chapter four).

The main research question for this research includes:

"What would be the design recommendations for a robot that could help elderly people with temporary mobility problems?"

To answer this question two major objectives will be discussed:

1. Theoretically investigate whether robots could be used in helping elderly people both psychologically and physically with a temporary mobility problem.
2. Investigate what should be done to ensure that robots will be accepted in helping addressing those problems.

The first objective will be discussed by answering the question: "Can robots be used in helping elderly people who suffer from temporary mobility problems?" The second objective will be discussed by answering the question: "What should be done to ensure that robots will be accepted in helping addressing those problems?". Based on the two objectives design recommendations will be made.

The remainder of this paper is divided into eight sections, starting with the background in chapter two. Chapter three discusses tasks the robot should be able to perform and covers existing design recommendations that are applicable to the robot. The fourth chapter focuses on human acceptance of robots. In chapter five the research design that is used to answer the research questions of this thesis is described. In chapter six the results of the research whether the robot from this paper will be accepted is discussed. Chapter seven covers design recommendations based on the results about this robot's acceptance and discusses more tasks of the robot that are adapted to the temporary mobility problems. In chapter eight the research questions for this thesis will be answered, and chapter nine covers the future research recommendations.

2 Background

2.1 Human-Robot Interaction

2.1.1 What does Human-Robot Interaction encompass?

As mentioned before, HRI encompasses the interaction between humans and robots (Goodrich and Schultz, 2008). This interaction can take place when robots and humans are in close proximity of each other but also when they are apart from each other, which results in two interaction categories. The first category is *remote interaction*, which means the robot(s) and human(s) communicating are not in the same space and maybe not even in the same time. An example of the latter is when commanding a robot to do a task the following day. The second category is called *proximate interaction* in which the robot(s) and human(s) communicating are in the same room at the same time. An example is a service robot that is in the same room as its user. In HRI there is a clear difference between short-term and long-term goals. As people are not able yet to clearly formalize human behaviour, this cannot be implemented in robots. This formalization will probably not be found for a long time, so implementing human behaviour in a robot is an example of a long-term goal. Of course human behaviour is not the only requirement for a system to be perceived as intelligent (a microwave or a chess-playing computer are intelligent as well but do not behave human), but human behaviour is preferred when social interaction is required. However, there are many aspects of being human that are understood, for example how our motor system works, and can thus be implemented in a robot. These implementations are short-term goals. Examples of these short term goals are assisting people and improving the robot's mobility.

2.1.2 History of Human-Robot Interaction

The idea of robots or robot-like behaviour existed for centuries already as they were mentioned in for example mythology and fiction (Springfield and Merriam Company, 1966; Homer the Illiad, 800 BC; Wiener, God and Golem Inc, 1966), but robot technology was developed in the 20th century. The word 'robot' finds it origin in the Czechoslovakian 'robota' which is translated into 'menial labourer' (Springfield and Merriam Company, 1966). HRI emerged in the second half of the 1990s and the early years of 2000 when researchers with different backgrounds like robotics, psychology and natural language started working together (Goodrich and Schultz, 2008). Their first meeting was held in 1992 and is still held annually as the IEEE International Symposium on Robot & Human Interactive Communication. Over the years its research community has broadened instead on focusing on robotics only. HRI also emerged in competitions in which the robot's task includes interacting with people.

2.2 Healthcare robots

2.2.1 What is a healthcare robot?

As mentioned before, a definition of healthcare is: "The act of taking preventative or necessary medical procedures to improve a person's well-being. This may be done with surgery, the administering of medicine, or other alterations in a person's lifestyle" (Business Dictionary, 2014). A healthcare robot is a robot that is intended to assist, restore or improve someone's lifestyle. There are several forms of healthcare robotics (RBR Staff, 2014): surgical robotics, robotic replacement for diminished or lost function, exoskeletons, robot-assisted recovery and rehabilitation, and personalized care for the elderly. The robot that will be discussed in this thesis is a combination of the latter two forms of healthcare robotics. It is intended to assist elderly people while they are rehabilitating from an occurrence that causes temporary mobility problems, like receiving an artificial knee. The combination of these two forms of robotics already exist as "assistive social robots in elderly care". Broekens et al. (2009) gives several examples of these robots and states these have a positive effect on the elderly.

2.3 Acceptance of health care robots by elderly people

As people can differ in gender, culture and age, different approaches are needed for the robot to be best suited to everyone's needs. As this thesis focuses on elderly people with temporary mobility problems, it is important to consider the attitudes of elderly people towards robots. According to Czaja and Sharit (1998), "It is commonly believed that older adults hold more negative attitudes toward computer technology than younger people". They distrust and respond with more negative emotions towards robots and prefer robots that have no autonomous features like learning abilities (Scopelliti, Giuliani and Fornara, 2005).

Dautenhahn et al. (2005) investigated how people would feel about the idea of having a future robotic companion and what the preferred roles of this robot would be. The results of this investigation showed that older people preferred a robotic companion as an assistant rather than as a friend. However in the documentary about care robot Zora (Zora Documentary, 2014), - this documentary will be discussed later in chapter two - the elderly people who use Zora are not negative about the robot at all. But there were not enough participants in that documentary to prove that the view of the elderly towards robots as companions has changed. Furthermore this documentary is not a scientific investigation, which makes it impossible to draw scientific conclusions. However, public opinion may have shifted in the last few years, so perhaps a new study should be considered. Possibilities to make the elderly feel as comfortable as possible around robots will be provided in chapter fcareour.

2.4 Laws of robotics and moral principles

Asimov (1986) stated three laws of robotics that should be adhered to when developing a robot, as these laws were designed to improve people's safety around robots. These laws were expanded to four by Khan (1998). However, these laws are developed for robots that are a potential danger to people, for example war robots, and as this is not the case with the robot that can be developed from the design recommendations described in this paper, these laws will not be discussed any further in this paper. Besides these laws of Asimov there are certain moral rules or principles that should be accounted for when designing a robot that will be used on a daily basis in close proximity with its users. The moral principles that should be adhered to are respect for autonomy, non-maleficence, beneficence and justice. The four laws of Asimov and these moral principles from Beauchamp and Childress can be found in table one. An explanation of the moral principles can be found later on.

Laws of robotics from Asimov 1. Humanity may not be injured or by inaction be allowed to come to harm by a robot 2. No human being may be harmed or by inaction be allowed to come to harm by a robot, except when that would be in conflict with the first law. 3. Orders given by humans must be obeyed unless it will be in conflict with the first or second law. 4. The robot's own existence must be protected unless it will be in conflict with the first, second or third law.	
Moral principles from Beauchamp and Childress	**Explanation**
Respect for autonomy	Perform actions intentionally, with understanding and without influencing the action.
Nonmaleficence	Avoid causing harm to other people.
Beneficence	Prevent or remove harm and do good.
Justice	Be fair, entitled and recieve what is deserved.

Table 1: an overview of the laws of robotics and moral principles

Beauchamp and Childress (2009) define autonomous actions as actions performed by someone who acts intentionally, with understanding and without influencing their action. Respect for autonomy is acknowledging someone's right to hold views and make choices. It also means acknowledging someone can take actions that are based on personal beliefs and values. Beauchamp and Childress state there are *different degrees of autonomy*, as the last two conditions (understanding and not influencing) can be satisfied by a greater or lesser extent, as they say that these conditions do not need to be fully understood or completely absent of influence for an action to be autonomous as people's actions are rarely or never fully autonomous in the real world. The degree of autonomy can be best addressed by context-dependent criteria. The principle of *non-maleficence* states that causing harm to other people should be avoided. This principle supports other moral principles that are more specific, for example 'do not kill' or 'do not

incapacitate'. Beneficence asks more of people than non-maleficence. Non-maleficence only asks to not harm other people, in other words to not perform some action that causes hurt to others. *Beneficence* demands people to perform actions that help others, as it states one should prevent or remove harm and do good. Beneficial actions like contributing to one's welfare, treating people autonomously and abstain from doing any harm are part of the heading of beneficence. *Justice* can be described by the terms fairness, entitlement and desert (what is deserved). It dictates that when you have done something good or someone has harmed you, you have a right and therefore you are due something. When you have done something bad you are denied protections or resources you have a right to. An example is being sentenced to jail: you have done injustice so you will be denied your freedom (to which you have a right). So now back to designing care robots: implications.

2.5 Care robots for elderly people

Robots are currently being used already in the care for the elderly. Some examples will be discussed. The first one is the humanoid robot *Zora*. Zora is developed by two Belgian scientists and her name stands for "**Z**org **O**uderen **R**evalidatie en **A**nimatie" (Zora Robot, 2014) (care elderly revalidation and animation). Zora is 58 centimetre tall. She is a modification of the standard NAO robot and has been adjusted by its developers to perform tasks for/with the elderly. The original NAO robot was developed by Aldebaran in 2006 and was created to be a true daily companion. An overview of Zora's sensory motor features can be found on page 14. Zora's main task is to be an interactive addition for caregivers and the existing healthcare equipment that is being used on a daily basis. She can communicate with elderly people without the need for caregivers. This is an important task, as many elderly people are deprived of communication and interaction with other people. Zora also has a second task which is being a motivator for the elderly to exercise (Zora, 2014; Zora Robot, 2014). Zora has since the use in elderly care been developed further to communicate with children with autism. Users of Zora say she is a nice addition to social interaction, but prefer contact with real people. But when there are no people available, Zora is a nice replacement as its users have more positive feelings towards Zora than it just being an object (Zora, 2014; Zora Documentary, 2014; Zora Robot, 2014).

Figure 1: a NAO robot (Source: Stefan Roschi 2014)

2.5.1 Aldebaran Robotics

Aldebaran was created in 2005 by Bruno Maisonnier who dreamed about building humanoid robots for the benefit of humankind since he was a child. He believed the key to success would be for the robots to be able to interact with humans. Currently, NAO robots are applied in the domain of home care, entertainment, assistance and autism therapy.

2.5.2 Documentary of Zora

This documentary is about Zora being used in a Dutch elderly home. Zora is accepted by the elderly very soon and they say they do not feel like they are talking to a doll. They know it is a machine but their emotional need for social interaction is bigger than the feeling whether they are talking to a human or a machine. It is admitted the social interaction with Zora is appreciated, but interaction with a human is preferred.

A disadvantage of this documentary is that it shows a small amount of users, so the conclusions taken from this documentary cannot be trusted. Furthermore it only shows people who are happy and content with Zora, but it is possible there are people in the elderly home who do not approve of Zora. This cannot be concluded from the documentary.

People who do not approve of using robots in elderly care state it is not right to make users pretend they are talking to something with a mind of its own with which they can build some form of relationship. Zora's developers claim users are not being fooled as they can decide for themselves whether they would like to use the robot for social interaction or not.2.5.3 Other examples of robots used in elderly care

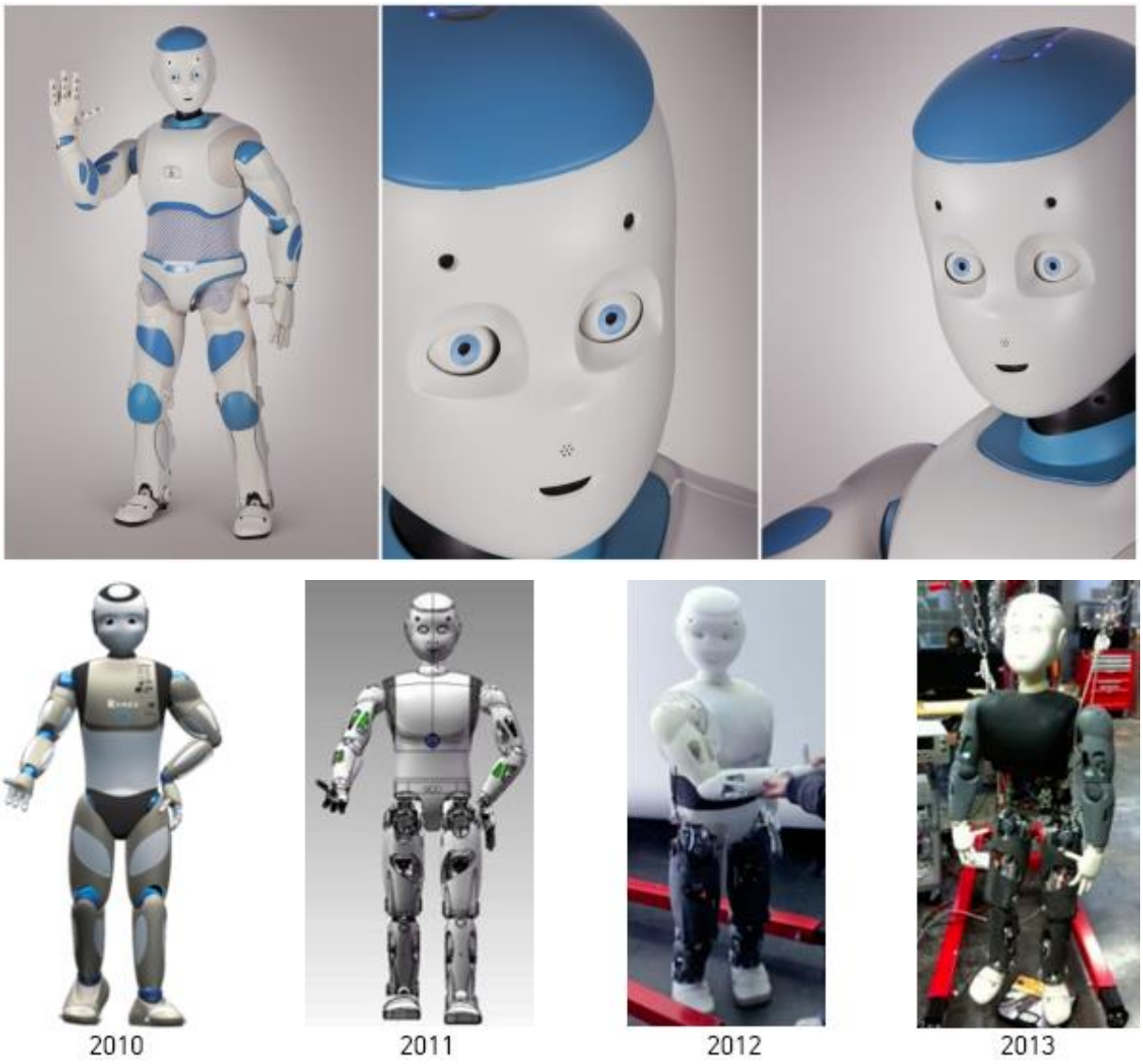

Figure 2: Top: the development of Romeo from 2009 to 2012. Bottom: the current look of Romeo. (Source: Project Romeo, 2014)

Another example of a care robot is *Romeo*. Romeo is a humanoid robot like Zora, but is taller as it is 146 centimetre tall compared to Zora that is 58 centimetre tall. The development of Romeo knows two phases: it started in 2009 and was finished in 2012 but a second project was launched in 2012 to focus on areas that could not be covered in the first project but were necessary for the acceptability of the robot in people's homes (Project Romeo, 2014). Several industrial and academic partners work on project Romeo, including Aldebaran. For the first version, Aldebaran developed the physical platform for Romeo. Romeo has soft facial features that make him look like a friendly boy. Since Romeo remains in its development stage, not everything about his sensory motor features is known yet. But the known features can be found on page 14. He is developed to be able to assist the elderly with several tasks, so they can live independently in their own homes for a while longer. Examples of these tasks are helping people who have difficulty walking or fetching objects from another room.

Figure 3: Paro, the seal robot (Source: Paro Therapeutic Robot, 2014)

Paro is a third example. Paro is not exactly a care robot as it does not provide care itself but is used in care institutions (Paro Therapeutic Robot, 2014). Its name stands for "com**PA**nion **RO**bot". It looks like a baby seal and acts like a real animal as it is able to make sounds and move its legs and head. Paro is 57 centimetre tall. It is developed by a Japanese company called AIST and has been in use throughout Europe and in Japan since 2003. Paro's sensomotoric features can be found on page 14. Paro's degrees of freedom are now known but not extremely important as well, as Paro only needs to be able to move his limbs to indicate emotion instead of using them to perform tasks. Its main tasks are stimulating interaction between caregivers and their patients and to reduce stress. It is mainly used in the domain of animal-assisted therapy (AAT) as a replacement for real animals as it has advantages over real animals. For example it does not need any food and there is no chance of infection (Burton, 2013). AAT's goal is to improve the social, cognitive or emotional functioning of a patient and is for example used by elderly people who suffer from dementia.

Figure 4: Asimo walking down the stairs (Source: Asimo 2014)

A last robot that needs to be mentioned is not a care robot but is still an important humanoid robot. This robot is called Asimo (**A**dvanced **S**tep in **I**nnovative **MO**bility) and is developed by the company Honda. Honda focuses on developing robots that can interact with humans and perform tasks in human situations that can improve the quality of our life. Asimo is a little bit smaller than Romeo as it is 130 cm tall. Asimo's sensomotoric features can be found on page 14. Asimo is highly developed perform motoric task like climbing the stairs or retrieving objects of different shapes and sizes. It can walk and even run at a speed of 7 km per hour (Asimo Specs 2014). At an interacting level Asimo is able to understand relatively easy voice commands and respond to them. It is also capable of facial recognition, which is a useful design recommendation for this thesis as there may be several people around the robot and its main priority must remain to be the patient.

Zora		Asimo	
Input sensors	**Degrees of freedom**	**Input sensors**	**Degrees of freedom**
Contact sensors: chest, head, hand, foot	Head: 2x	Torso: gyroscope, accelerometer	Head: 3x
Position sensors: magnetic rotary encoder, 36x	Arm: 5x each	Camera: head	Arm: Shoulder: 3x Elbow: 1x Wrist: 7x each
Audio: head, 4x	Pelvis: 1x	Antenna	Hand: 13x each
IR: front, 2x	Leg: 5x each	Force sensor: hand, foot	Leg: Crotch: 3x Knee: 1x Ankle: 6x each
Sonar: front, 2x (2x emitters, 2x receivers)	Hand: 1x each	Audio: head, 5x	Hip: 2x
Camera: head, 2x			Waist: 1x
Intertial unit: gyrometer, 2x, accelerometer, 1x			

Paro	Romeo
Input sensors	**Degrees of freedom**
Tactile sensor	Eye: 2x each
Light sensor	Foot: 1x each
Audition sensor	Backbone: 3x
Temperature sensor	Fingers: 1x each
Posture sensor	

Table 2: an overview of sensomotoric features of robots Zora (Source: Zora Specs, 2015), Asimo (Source: Asimo Specs, 2014), Paro (Source: Paro Therapeutic Robot, 2014) and Romeo (Source: Romeo Specs, 2015)

2.6 Robot evaluation tools

According to Bartneck (2009) there are five key concepts in human-robot interaction: anthropomorphism, animacy, likeability, perceived intelligence and perceived safety. *Anthropomorphism* means human characteristics, - cognitive, behaviour and appearance - are assigned/attributed to the robot. For example when a robot has a humanlike face it is expected the robot can listen and talk. *Animacy* means the robot has to be lifelike, because this can involve users emotionally, which makes them easier to influence. Lifelike in this instance means movement and intentional behaviour are perceivable. There is a certain overlap between animacy and anthropomorphism as they both involve appearance, so what is the difference between them? When talking about the concept animacy it is discussed whether the robot seems lifelike, while with anthropomorphism the discussion is about how much the robot looks humanlike, with human

characteristics, but not necessarily lifelike. *Likeability* is needed because it has been reported that people have positive impressions when the robot looks likeable, which makes for more positive evaluations. However this likeable is a broad description, so what does this involve? The robot's appearance is important as this influences its likeability, but further research is needed to determine what is the best appearance for a robot to be likeable. Other factors are important for likeability as well, for example its operationalization. *Perceived social intelligence* is limited yet, because the field of Artificial Intelligence has not been able yet to formalize human behaviour and this formalization is needed to generate intelligent and humanlike behaviour for the robots. *Perceived safety* is very important as people must feel safe while interacting with robots. This can for example be measured by one of the measuring methods described in chapter two.

There are several ways to measure the user's perception and cognition. A first method is to *observe the behaviour* of the participants. This method is reliable and possibly also objective. *Physiological measurements* like heart rate and skin conductivity are a second method to measure the behaviour of the participants. A disadvantage of this method is that these measurements are not able to distinguish between arousal originated from anger or joy. But in combination with other physiological measurements like for example facial recognition the state of the participant can be measured, which removes the mentioned disadvantage of using physiological measurements. Adding *neuroimaging* as a measurement, for example an EEG measurement, will improve the results. EEG measures the brain's electrical activity and can among other things be used for emotion recognition (Bos, 2006). So putting neuroimaging and physiological measurements together should give a solid outcome about the user's feelings. A last measurements method is *questionnaires* which will measure the user's attitudes. This method has a big disadvantage as the questionnaires can only be taken after the experiment, which might change the user's response as they for example will adjust their response to be socially acceptable. When questionnaires are being used as evaluation tool, it should be taken into account that different types of items can be used for questionnaires when comparing results with other questionnaires. For example when a participant has to answer with a value between 1 and 5 (Likert Scale), his answer can differ when asking 'Do you trust robots?' or saying 'I trust robots'. It is also possible that another questionnaire uses 1 as 'completely agree' and 5 'completely disagree'. So when comparing the results of questionnaires it should be verified whether the same grading is used for all the compared questionnaires. An adapted version of questionnaires as a measurement method will be used later in this thesis. It was intended to use only questionnaires but due to circumstances the questionnaires have been adapted to the interviewee, which made it a personalised questionnaire. Further explanation can be found in chapter five and the appendix. An overview of the robot evaluation tools can be found in table three.

Key concepts in HRI	
Concept	**Explanation**
Anthropomorphism	Being assigned human characteristics
Animacy	Being lifelike
Likeability	Being readily or easily liked
Perceived intelligence	Appearing intelligent
Perceived safety	Make people feel safe when interacting
Measuring methods	
Observe behaviour	
Physiological measurements	
Neuroimaging	
Questionnaires	

Table 3: An overview of robot evaluation tools

Main points chapter two:

- Forms of HRI (remote, proximate)
- Laws of robotics, moral principles
- Examples of robots
- Robot evaluation tools

3 Existing design recommendations

3.1 User centred design

According to Mutlu (2006), the design of Human-Robot Interaction can be divided into the following three dimensions: *robot attributes* (like appearance or the sound of its voice), *user's personal factors* (like age and their attitude towards robots), and the *nature of the task* that is being performed (for example cognitive or autonomous tasks). The design of the robot should be user centred, because the robot is developed to assist users in their daily life. The users should be able to operate the robot after only a small introduction.

3.2 Robot capacities

The most important criterion when developing a robot is the user demand. According to figure 3 from Mast et al. (2009), -this figure can be found on page 20- several tasks from the robot that can be developed with the design recommendations from this thesis are positively demanded by elderly people. Examples are the 'reach for object' and the 'appointment reminder' tasks, although the latter will be limited to reminding when to do rehabilitation exercises. The physical therapy task is not mentioned in this figure, as the research from Mast is about demanded and rejected services by elderly people and informal caregivers and not about rehabilitation of the elderly. But parts that will be used during the physical therapy task, like reminding them when to exercise, and supporting them when starting to walk, are some of the demanded services that can be found in the figure.

There are other important factors to consider when developing a robot (Mast, 2009). One of them is the *necessity* of a robot, which questions whether or not the task can be done with simpler technologies. *Technological feasibility* is a second factor that researches whether it is possible to develop the robot in such a way that it can perform the requested tasks. A third factor is the *enabler capability*, which researches whether a task can be extended into another useful task.

This thesis will use certain assumptions about the robot's capabilities that can be made because other robots have been developed that were able to perform tasks that required these capabilities. For example the robot Asimo is capable of climbing the stairs (Collins et al. 2005), so no design recommendations will be made for these motoric and sensor issues. Other design recommendations that will be given in this chapter and chapter seven will mostly be about the robot's appearance and actions: what should the robot look like and how should it react so the users feel comfortable around it. Furthermore ethical issues about using robots and their capabilities will be discussed in chapter four.

3.3 Assessment of adequacy

As mentioned before, according to Beauchamp and Childress there are four moral principles that should be respected. These principles are respect for autonomy, nonmaleficence, beneficence and justice (Beauchamp and Childress 2009). The robot that holds to the requirements of this thesis can be of great help to people, but there are several things that should be accounted for before this robot can be used. The first and most important thing is that the robot should not be able to *harm* people in any way, either physically or mentally. For example people might need to be stimulated or even pushed a bit when being encouraged to exercise, but this pushing has to be a positive support. Also insults may never be used as a motivator as this might hurt the patient mentally. *Spatial awareness* is extremely important for robots that will be in close proximity of people, as it is not supposed to walk into them as they might get hurt. This is also in accordance with Asimov's laws of robotics that have been discussed in chapter two.

In a human-robot relationship certain rules should be adhered to. These rules are veracity, privacy, confidentiality and fidelity (Beauchamp and Childress 2009). *Veracity* refers to the fact that information given to the patient should be comprehensive, accurate and objective. This applies in a health care setting, as this robot is a health care robot. This rule must be used mostly with the informational role of the robot as the information it provides should be comprehensive, accurate and objective. The exercises explained during physical therapy should be very accurate as well as the user may do the exercise wrong otherwise. Besides the information the robot gives, also the information that is given about the robot itself should hold the above requirements, as it is important for patients to know what the robot exactly can and cannot do. This brings us to the rule of *privacy*. For example when the patient does not know the robot is able to send exercise results to the doctor then the patient's privacy is violated when the doctor uses this ability. This situation also involves the *confidentiality* rule, as this rule states that we have some control about the information that doctors generate about us. Lastly there is the rule of *fidelity*, which is about the faithfulness between two people. In this instance it means the robot may tell no lies and no lies may be told about the robot when information is given about its capabilities.

3.4 General requirements

Several assumptions are made that are necessary for the robot to be able to function as required. For example it is taken for granted the robot is able to *pick up different objects*. This assumption can be made as there already are robots that can hold different objects, though these robots may have different forms. For example there is this robotic arm that is able to catch any reasonable object you throw towards it, size and shape can differ per object (Robotarm Catching Objects 2014). Furthermore there already are robots that perform fetch-and-carry tasks, for example the robot discussed by Green (2000).

Another assumption is that the robot is able to *communicate with people through speech*. For the four tasks that will be mentioned in this paper only basic ability of speech is needed. This basic speech is for

example already used by care robot Zora. It should also be mentioned that whole conversations with a certain level of intelligence are impossible for now and it probably will not be possible any time soon. The interaction between the robot and its user will be proximate as they will be in the same room during interaction.

As the robot may need to retrieve some object from a different floor, it should be able to *climb the stairs*. Robot Asimo is capable of climbing the stairs (Collins et al. 2005), so it is assumed to be possible to build a robot that is also capable of climbing the stairs. It should be mentioned that these stairs need to be straight as Asimo is not able to climb spiral stairs yet. But it is believed that this will be possible in the near future. The Nao robot is able to climb a spiral staircase (Oßwald 2011), but this takes a lot of time and this must be improved before being a useful addition to the tasks mentioned in this paper.

3.5 Tasks for the robot

To be able to help the user while rehabilitating, the robot of course must be able to perform several tasks. It will be able to perform four tasks, and two of those tasks are tasks that other robots can perform as well but are necessary for people with mobility problems. The first one is *retrieving a requested object* for the patient. For example when the user asks for a glass of water the robot will go get it. It will also be able to reach for objects from different heights, for example on the ground or on top of a cupboard. As its second role the robot will *provide the patient with information*. Users may have questions about their medicines or possible restrictions while rehabilitating. Many of these questions will be basic questions that can be answered by the robot. Now the patient will soon have his questions answered and he will not be required to speak with (an assistant of) his doctor. These tasks are known to be requested by elderly people as this is shown by Mast et al. (2009) in the figure on the following page.

3.6 Controlling the robot

As is said before, according to Green most users prefer speech to interact with the robot but other forms of interaction like touch screen or gestures are acceptable as well (Green et al. 2000). It may be useful to be able to interact with the robot in another ways as well, for example when it is in another room. A *tablet* can be used to accomplish this. With some simple buttons the robot can be called and the tablet can be used for other means as well. For example it can show the exercise during physical therapy. There already are physical therapy apps that can be used (Fysio Therapy App 2014). Using this tablet enables remote interaction as well, as the robot can remind the care receiver through the tablet when to do his exercises. It is not necessary anymore for the robot to be in the same room.

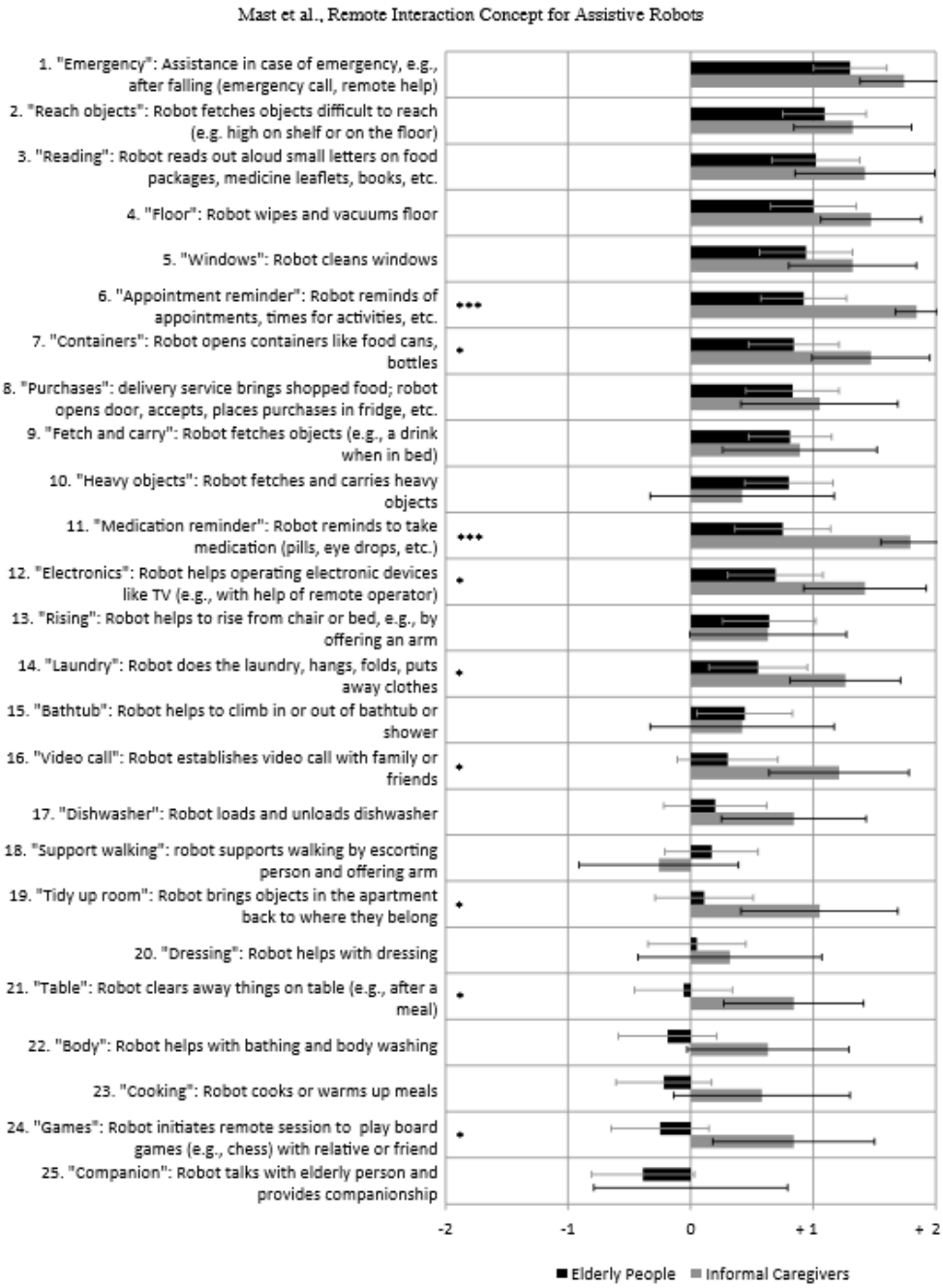

Figure 5: Demanded and rejected robot services by elderly people and informal caregivers. (Source: Mast et al. 2009)

Main points chapter three:

- 3 components for HRI-design (robot attributes, personal factors, nature of task)
- Robot capacities (necessity, technological feasibility, enabler capability)
- Assessment of adequacy (moral principles, HRI rules)
- General requirements
- Tasks for the robot
- Controlling the robot

4 Acceptance of robots

The background chapter already mentioned that there are different aspects that influence the acceptance of robots in daily life. Examples of these aspects are age, gender and culture. Elderly people have a harder time accepting robots than younger people. The approach of men and women towards robots is also different. They expect different tasks and qualities from robots in daily life (Kuo, 2009). Furthermore culture also matters. In Japan robots are far more accepted than in the western countries (Kaplan, 2004).

4.1 Acceptance of robots

Before knowing how to increase robot acceptance, it should be stated what acceptance contains first. Acceptance is stated by Davis (1989) to consist of three parts: intentional, behavioural and attitudinal acceptance. *Intentional acceptance* is the way the users plan to act with the technology. *Behavioural acceptance* is the actions of the users when using the product or technology. *Attitudinal acceptance* is the positive evaluation or beliefs of the users about the product.

People are suspicious of robots as they do not know very much about them. By improving their knowledge of robots and showing them what robots will be capable of and what is impossible for them, they can adapt their expectations to what is possible. This adaptation and knowing what to expect might improve their acceptance towards robots.

As this thesis focuses on elderly people as a target group, possible solutions for improvement of acceptance by elderly people will be discussed. It should be mentioned it is possible these improvements may differ for people of different ages.

4.2 Acceptance of robots by the elderly

As mentioned in chapter two elderly people tend to be more negative and less motivated to accept robots than other people. But, contradicting most other previous research, Ezer et al. (2009) found that elderly people were willing to have a robot in their home and they seemed even more willing than younger adults. This might be because the paper is quite recent. People already know more about robots and what they are capable of than ten years ago. When people do not know anything about robots, they might as well be taken as a threat. When seeing them less as a threat people can start to appreciate the advantages of robots which increases the acceptance. But robot acceptance is still in its early stages and even though knowledge improves acceptance, elderly people have less access to this knowledge, for example as they may not have a computer to look things up. So searching for ways to improve knowledge about robots is still important. This may lead to greater acceptance.

4.3 Possible opportunities to improve acceptance

The first opportunity is mentioned above: by *providing people with knowledge* they learn to understand the robot and its capabilities better, which may get them out of the unknown and more accepted. The next step after knowledge will be *live experience*. When people are able to see what a robot can do before deciding whether or not to use it for themselves can improve acceptance as well, as they know what to expect after the introduction. Heerink (2011) found that users with more experience appreciated the idea of using a robot more than users with less experience. So providing people with knowledge and/or introducing them to robots before asking them to use robots may improve their acceptance of robots. Beer et al. (2010) stated: "The following categories of variables have been identified in the literature as potentially impacting robot acceptance: robot function, robot social capability, and robot appearance." *Robot functionality* is important as the tasks the robot can perform influence robot acceptance. When the robot performs tasks the user likes it to do they accept it better than when the user does not like the task to be done by a robot. This category has influence on intentional acceptance (Davis, 1989), as the robot will perform tasks that are required by the user. Whether this task is performed well, will influence the attitudinal acceptance of the user. The *social capability* of the robot is another factor that may influence acceptance, in this case attitudinal and behavioural acceptance, as variables of this capability like nonverbal social cues or expression of emotion may influence the expectations of the user. But when users expect some social capability of which the robot is not capable, this can negatively influence the use and acceptance of the robot. Also the social capabilities should be advanced enough, as acceptance can be low it is not believable. The *robot's appearance* is expected to be of importance as it influences the attitudes about and influences of robots (so it influences attitudinal acceptance). Ezer et al. (2009a) found that the preferred tasks to be performed by a robot are age-related. As the autonomy level of a robot is an important factor of human-robot interaction (Yanco and Drury, 2002), it is expected to have impact on robot acceptance as well (Beer et al. 2010). Huang et al. (2004) distinguished three important components for determining the level of autonomy. These are the *complexity of the environment* (objects in the robot's navigation path), *the difficulty of the task* (one request vs. many requests) and the *nature of human interaction* such as team dynamic. Those components influence one or more of the acceptance aspects from Davis (1989) as well. All three of them influence attitudinal acceptance, while the difficulty of the task also influences intentional acceptance and the nature of human interaction also influences behavioural acceptance. A combination of one or more of these components is required of the robotic system to show a certain level of autonomy to be able to function proficiently. This autonomy level is important for acceptance as it may affect the robot's perceived usefulness. It should meet the expectations of the user as the robot otherwise may be seen as not useful which decreases the acceptance. Mast et al. (2010) found that people would like to *have the feeling of control over robots* so they prefer autonomous robots with pre-programmed tasks over robots with learning abilities. This feeling of control can be described as the robot being predictable as well. When the actions the robot will perform are predictable people can have a feeling of control over the robot.

However the robot having learning abilities are necessary for the combined physical therapy and psychological task, as the robot will then be in close contact with the users, physically as well as emotionally, and should be able to adjust its behaviour to the wishes of the user. For this adjustment learning abilities are necessary, but these abilities may be brought to a bare minimum as the fetching task and informational task can be pre-programmed. An overview of these possible opportunities to improve acceptance can be found in table four.

Possible opportunities to improve acceptance
Providing knowledge
Providing live experience
Performing preferred tasks
Giving the user appropriate social cues
Appearing likeable
Satisfying the desired level of autonomy
Being (semi)-autonomous to provide a feeling of control / being predictability

Table 4: an overview of opportunities to possibly improve robot acceptance

4.4 Advantages of using robots for the care of the elderly

There are many positive results shown of robots being used for elderly care. For example when using Paro it was found that *stress was reduced* and *interaction between users and caregivers or other people was increased* (Paro Therapeutic Robot 2014). It was also shown that *user's vital organs reaction to stress improved* (Wada and Shibata 2007). Tasks of the caregivers will be done by robots instead, which gives the caregiver the chance to *focus on the more important tasks*. Also robots can be used to *reduce the users dependence* on caregivers. This can be a big advantage as caregivers might not always be able to give sufficient care. *Mobility problems can be overcome* with the help of for example assistive robots. An extra advantage is that *work gets easier for the caregivers*, as they will not hurt their backs while moving patients from one place to another and thus are able to provide the care receivers with better care. Caregivers may profit from the robot as well, but its tasks should be adapted to the needs of the care receiver with mobility problems. Using care robots gives people the opportunity to *live longer in their homes independent of others*, as the robot can do the chores they have problems with doing themselves. The robot can be used when relatives live in another country as well, as it is a possibility to use monitoring robots to interact with them. This can also be done with social media, but not everyone, especially from the older generation, will have a computer. And when the robot will already be used to help in the house it need not be a bad thing if it also *enables long-distance interaction with others*.

4.5 Disadvantages of using robots for the care of the elderly

The robot's abilities, for example its speech capability, may give the idea of intelligence or a perceived social relation with the robot. This may create a *misunderstanding* between the capabilities of the robot and the expectations of the user. These misunderstandings may give the feeling of the robot being not useful which will decrease the acceptance. A negative side effect of using robots is that it may be possible the *users let the robot do things they otherwise would do themselves*. So people should be motivated to do things themselves instead of making the robot do it, so they get some exercise and will not be sitting in a chair all day long. Having a robot in close proximity brings ethical issues. According to Sharkey and Sharkey (2010) there are six main concerns: first of all there probably will be a *decreased amount of human contact*. Even simple chores like cleaning will reduce the opportunity for human contact, as no human cleaner will be needed anymore. This is an important concern, as the welfare of the elderly may suffer when there is (almost) no contact with other humans. Also *feelings of loss of control and objectification* are increased when robots are used intensively in elderly care. When people are moved around by robots they might feel like they are objects and thereby reduce their well-being. *Privacy will be infringed* when a robot will be in close proximity most of the time, especially when this robot can monitor and supervise. *Loss of freedom and personal liberty* is another concern when using robots in elderly care. When robots will be used as supervisors to for example prevent the cooker being left on, the robot will probably be autonomous enough to turn the cooker off itself, what might give the user the feeling of being unable to prevent something himself. *Infantilisation and deception* are also concerns and should be prevented according to Sparrow and Sparrow (2006). The elderly can be deceived into believing they can have a relationship with a companion robot that is able to interact with them. By making the elderly interact with a robot they can feel infantilised as well, which is something we do not want. And a last concern is the *amount of control people should have over robots*. Empowering the elderly by making them mobile is a big advantage as they will be less dependent on others, but it can also give them the power to make the robot do undesired things, like throwing them off the balcony. A good balance between this empowerment and preventing undesired outcomes should be found. The mental state of the user should be checked upon whether this person would not give dangerous orders to the robot. People whose mental state has been deteriorated should thus be less empowered to give orders to the robot than people whose mental state has not been deteriorated. Furthermore the amount of help needed by the user can be taken into account. A user who is very immobile and needs help with almost everything should be helped where possible, but to stimulate other users to do things for themselves as well, they should maybe be less empowered. Opponents of using robots in elderly care claims artificial intelligent objects (like robots) *are not able to perform human care as well as people* (Coeckelbergh 2010). They also claim *certain emotional and social needs cannot be fulfilled by robots*, as a robot can give but is not able to also experience care. A summary of all the advantages and disadvantages can be found in table five.

Advantages	Disadvantages
Making the caregiver able to focus on more important tasks and thus provide the user with better care.	Making misunderstandings occur between the capabilities of the robot and the expectations of the user.
Reducing dependence on caregivers	Doing tasks the user should do himself.
Overcoming mobility problems	Decreasing the amount of human contact
Reducing stress	Causing feelings of loss of control and objectification
Increasing interaction between user and others	Infringing privacy
Improving the vital organ's reaction to stress	Making users feel like they lose freedom and personal liberty
Making work easier for caregivers so they can perform better.	Being infantilising and deceiving
Enabling users to live longer at home independent of others	Not being able to perform human care as well as people.
Enabling long-distance interaction with relatives	Not being able to fulfil social and emotional needs

Table 5: an overview of the (dis)advantages of using robots when caring for the elderly

4.6 Discussion advantages versus disadvantages

Contrary to the claim that the use of robots can decrease the level of human contact, it can also increase this level when people together interact with one robot. This robot can be a *conversation starter* in which owners of these robots can talk about them and other people can ask questions. It may also be possible to implement an *interaction measuring system* in the robot. When it sees the user has not had much interaction with other people it can encourage this interaction. Furthermore the before mentioned concerns should certainly be taken into account, but are *not all as straightforward* as claimed. For example humans in general have a great ability to anthropomorphise objects or imagining things are capable of more things than is actually the case. An obvious example is pets. People tend to believe their cat or dog understand what they are saying, while they really do not understand a thing at all. When you say enthusiastically 'Look, Sally's coming!', the dog will remember you sounded enthusiastic when someone else came and thus look at the door, but it is merely the tone what triggers its reaction, the dog does not understand what was said. People do know that animals cannot understand what we are saying, but do not care about it. So as long as people know they are interacting with a robot, why should it be a problem when they feel better with this interaction than without it? Furthermore when asking people whether they would want to interact with a robot they will not be infantilised. They may even think it is cool they are interacting with a real robot and it is not like they are given a playing doll. As long as people are completely able to think for themselves they can also decide for themselves whether they would like to interact with a robot or not. Others do not have to decide that for them. Of course the question remains how capable elderly in need of care are of making decisions. However, as the robot

following the design recommendations from this thesis will be a tool for physical rehabilitation and not a tool for cognitively impaired users, this will not be discussed further in this paper.

4.7 Elderly people whose mental state has been deteriorated

When people get older, there is a chance their mental state will deteriorate as they might suffer from dementia or Alzheimer. When this happens, they might not be able to make important decisions for themselves as they might be *confused* at times when the decisions need to be made. This also raises several questions about using robots when caring for them. For example when using Paro they may not *understand* it is a robot they are holding instead of a baby seal. But there is also the question what is more important, because when using Paro improves their life, even when they think it is a real baby seal they are holding, the advantage may be found to outweigh the disadvantage. We are talking about humans and their rights and values, so perhaps it should not be decided by a *care giver* whether the advantages outweigh the disadvantages, as care givers may not be objective enough because the robot eases their workload as well. The decisions about these advantages versus disadvantages should be made by a *close relative* when the user is not able to decide it for himself anymore. One might ask whether an *expert* is not more able to decide whether this person would have advantage of using the robot, and this may certainly be true when there is no close relative to decide. But an expert is completely objective, which may be a good thing, but the effects the robot may have on the user are also dependent of the user's personality. This personality being a factor in the effectiveness of the robot may cause that a different outcome is preferred to the outcome which the expert thinks is most likely. On the other hand experts can include personality features in their decision. Perhaps the best decision would be to combine the opinions of the expert, the close relative and the care giver, as they all have important opinions and a combination of these opinions should give a preferable outcome. Future research should be done to find whose opinion is preferable in which situation. It is a possibility to investigate medical decision making models to find preferred outcomes, as these decisions require multiple opinions as well.

It is also a possibility to *ask elderly people their opinion in advance*, like asking someone whether he or she wants to be a donor. Hopefully the outcome is not important, but might it be, then the user has had the opportunity to decide for himself. This idea may seem farfetched right now, but as the development of robots in general but also of care robots continues the idea of using robots will become more widely used. An overview of the advantages and the disadvantages of using robots in elderly care can be found in table five.

4.8 "Robot licence"

According to Nass (1995), people have the tendency to assign human qualities and personality to objects and other non-human entities. Because of this tendency it is easy to create an object that appears to have

a personality. Furthermore it is shown by Broadbent et al. (2007) that the emotional reaction people have to a robot depends on the behaviour of that robot. Nass and Lee (2001) have shown people prefer a robot with computer personalities that agree with their own personalities. So it can be stated that people with different personalities require different treatments. It should be researched what treatments are preferred for different styles of personality. When introducing robots to be used in daily activities it is convenient to provide the user-to-be with information about the robot. But again people differ in the (amount of) information they require. Some people only want to know what the robot can do, as other people would like to understand how the robot performs its tasks before they accept it. Researching what kind of information different personality styles require can be very useful for this purpose.

Information that should be given to everyone in advance is information about the tasks the robot can perform, possibly with examples and explanations. Also information of its capabilities is very important, as people need to know what it is capable of but especially what it is not capable of, so they will not be disappointed which can lead to disapproval. Again is can be useful to use examples to make sure the content is understood. A difference in provided information is for example either only showing how to use the robot, or explaining why these actions have to be performed as well, because some people only want to know how to work with the robot while others prefer to understand how it works as well. Haselager (2013) discusses that users need to acquire a robot licence the same way as one needs to acquire his driver's licence. This 'robot licence' can be used to ensure the user has received all the information he wants to know and to confirm the capabilities of the robots are understood to prevent misunderstanding.

Main points chapter four:

- Aspects of acceptance (intentional, behavioural, attitudinal)
- Variables that influence acceptance (robot function, social capability, appearance)
- Components for autonomy (complexity of environment, difficulty task, nature of HRI)
- Advantages, disadvantages, people with deteriorated mental state, personality styles

5 Research design

Several people with different backgrounds were interviewed: one caregiver, one care receiver and two scientists.

5.1 The questionnaire design

The original idea was to give the interviewees a questionnaire with statements which they had to grade from 1 to 5. 1 meaning they completely disagree with the statement and 5 meaning they completely agree (Likert Scale). But, maybe apart from the scientists, it was concluded the interviewees probably would not know very much about robots in advance so explanation would be needed for them to be able to accurately grade the statements. This resulted in a personalised, exploratory interview. Furthermore it was not intended to influence their opinions when talking about robots so open questions about their opinions were asked as well. The interview started with the question what the interviewee would expect from a robot when being told a robot could be developed to help during rehabilitation of an elderly person with temporary mobility problems. So no information about the robot itself was given to possibly influence their opinion. After this question the tasks of the robot were explained and the interviewee was asked to grade the statements. When a statement was not clear or when it appeared to be an illogical statement, explanation about the statement was given. Finally after grading the interviewee was asked the same question as the one at the beginning of the interview, namely what was expected of the robot. This was asked to find out if the opinion was changed now that there was provided more information about the robot's possibilities.

5.2 Statistical techniques

The main question to be investigated from the interviews is whether a robot to help at home will be accepted. The mean and standard deviation are thus calculated from the questionnaires to measure the acceptance. These two measurements will be calculated per interviewee, per subject (tasks, acceptance, design) and in general. It will be investigated whether there are any mentionable differences between the subject and the categories of interviewees. As this thesis strives to give design recommendations for a healthcare robot that will be accepted by the elderly, the goal of the questionnaires was to find the level of acceptance of the robot. To find this level of acceptance, it was believed only the mean and the standard deviation resulting from the questionnaires were needed. The mean is important as it shows how the robot will be accepted by people with different backgrounds. The standard deviation is very important as well as is shows how constant this mean is. When the standard deviation is small, it means the opinion about particular subject is very constant. A large standard deviation means the opinions are more varied and suggests maybe adjustments should be made.

The outcomes of some statements in the questionnaire are swapped. These statements can be found in the appendix. The statements were composed in a way that was believed to influence the interviewee as little as possible. However, this resulted in some statements with a positive influence and other statements with a negative influence. For example the first statement above is stated in a negative way, while most statements (for example 'I trust a robot with a humanlike face') are positive. Therefore, when investigated this would result in an average mean. To properly investigate the results, the outcomes of the negative statements are swapped (1 becomes 5, 2 becomes 4, 3 remains 3). The results found in appendix A are the original answers given by the interviewees to the combination of positive and negative statements.

Main points chapter five:

- Questionnaire
- Statistical techniques (calculation of mean and standard deviation)

6 Results

The interviewees were provided with the same pictures that can be found in chapter two and chapter seven.

6.1 Interview with the caregiver

This person started as a caregiver and is now Manager Verpleging en Verzorging, so he is able to give calculated answers and sees whether there are possibilities for robots in elderly care or when it is more a burden than a helpful tool. The very first thing he said was it would be hard convincing the elderly to use a robot, as their acceptance of robots is not very strong. According to him they do not believe the robot will be able to do many things, but he states his experience has shown those people would be more willing to accept robots when they were able to see them before using the robots themselves, for example by a demonstration. He found all four tasks very useful but was neutral about the question whether it would be useful if it would be done by a robot. The psychological task combined with the physical therapy task was found very useful as positive stimulation is important. Also the relevance by doing this through a robot is useful as well as compliments during the day improve people's self-confidence. He believed it was no problem when the robot would push the user to exercise, as long as this pushing would be as a positive stimulus. He sees a future in using robots, as it can be a solution to the shortage of money for (elderly) care. Another advantage is that the robot does not get ill and performs its tasks without impulsive input. It can be used very well as an addition for care, but absolutely not as a replacement. Thus the intention of using the robot is important. The robot is preferred to look humanoid, but not human, although a human voice is preferred over an artificial voice. Privacy is not believed to be an issue and he does not feel he is capable of answering the question whether the robot may touch the patient. This decision has to be made by the patient himself. The amount of noise is more important than the speed in which it can retrieve objects. The robot is allowed to make noise but it should not be so loud it becomes annoying as it is not believed people will keep using the robot when it makes a lot of noise. A larger robot (ca. 1.40m) is preferred over a small robot (ca. 0.50m) because it will be at comfortable height when you are sitting in a chair or on a sofa. When the robot is proved to be effective it will even be possible the robot will be missed when the patient is fully rehabilitated.

6.2 Interview with the care receiver

This care receiver is an older woman (74 years old) and received an artificial knee some time ago. When first asking what she would've wanted the first thing she said was she needed something to get objects for her from difficult heights as she was not able to use her knee much in the beginning. Also using it for daily chores like cleaning the house would be nice, because she was not allowed to lift anything. It

would also be extremely useful when the robot would be able to retrieve objects that were out of reach because that was already hard while getting older but was even harder when she were not able to stand stable on both legs. So her request looks similar to the fetching task mentioned in this thesis. When explaining the other three tasks invented she found those were very useful as well. The fact that these tasks were done by robots were in her opinion useful but not necessary. She did not think that using robots made a difference, as there were caregivers nowadays who seemed robots as well as they did not say much of show any emotion while doing their work. The robot was allowed to push during the physical therapy task as you will not learn anything new while not trying hard. The outcomes for the questions what the robot should look like and sound like were the exact opposite of the answers the caregiver had given. The robot was allowed to have a humanlike face but it was preferred to have a robotic voice. She also preferred it looked humanoid as it would be nice to be helped by a pair of arms and legs instead of other possible forms. She did not feel her privacy was invaded and also did not mind the robot touching her. I was very surprised by her positive answers towards the robot so I decided to ask a little more about privacy. It was asked whether she would mind having a robot wash her, but she said in time of need when I am not able to do it myself I do not really care. The size of the robot was unimportant as long as it will be smaller than she is. It was even allowed to accidentally bump into objects once in a while. She preferred the robot to feel sturdy and hard as it should obviously feel like a robot and not like a human. But on the other hand it was preferred to be warm: human temperature, while the caregiver preferred room temperature. After showing several pictures of different kinds of robots she preferred a humanoid robot and felt least comfortable around the humanlike robot. This is in contradiction to the answer to the question whether the face of the robot should look humanlike or robotic, but I assume this is because she does not know what the possibilities are and I expect she meant the robot to look humanoid but still robotic, so not humanlike. But a humanoid robot was still preferred over for example a tablet that showed a smiley. Furthermore the question was asked whether she would mind the fact that the robot would act like it was caring for her and present in the moment while it was only doing pre-programmed tasks, so it might mislead the user by giving the idea of building some form of relationship while this would not be the case. She answered it was logical this was not true as you knew you were using a robot and when feeling happy with it why bother about it. Overall she was very positive towards using a robot and she even admitted probably missing it when it would be gone after rehabilitation as it would be a comfort to have a helping hand around. This may be a subject for further research.

It should be mentioned this care receiver is a close relative to whom robots are not completely alien as she learned about them through my studies. The results of the questionnaire showed she was not afraid of them and open to use them. This reinforces the idea that (elderly) people are more capable of acceptance when they have more knowledge of robots and their capabilities. Especially when another elderly person who heard phrases of the interview started to ask questions. This person at first seemed

more reluctant about the idea of having robots around, especially when he found there would not be a supervisor around for the robot. But when he was told more about the capabilities and possibilities about robots and especially care robots he seemed more receptive to the idea of robots. He also mentioned society evolves and that the people in it should evolve with it and if that meant accepting robots in daily life he would do so.

6.3 Interview with two scientists

One scientist is a PhD student who studies the development of people's trust towards autonomous robots and in what way appearance, behaviour and performance influence their perception of robots. The second scientist researches how people talk and express themselves in social conversation and how this knowledge can be used to develop systems that are more socially and emotionally aware. Both scientists were positive about the tasks and found it useful these tasks were performed by a robot. Both of them believed that both kinds of face and voice of the robot (human / robot) would be trusted by the users, but there was a small preference towards the human appearance. They did not believe the privacy of the caregiver or the care receiver would be invaded by the robot. They differed in the opinion whether a humanoid would be trusted more than a robot with different forms. One scientist thought its appearance would not really matter, as the other said it would be easier to communicate with something where you did not have to search for the location of its face, as people always look at someone's face while interacting. So the humanoid robot was preferred as it had its limbs at expected places. What really stood out was that both scientists were not completely comfortable with the robot touching the patient during physical therapy exercises. One scientist disagreed, while the other was neutral as he thought it would be fine but did not feel like it would improve the physical therapy task and when it is not necessary, it should be avoided. I think this they both were reluctant because robots are not perfect and there can always be a mistake that may hurt the user by accident. It is also difficult to determine when a touch is pleasant and when it is too hard, as some people are more sensitive than others or a bruise causes extra pain when being touched. The question whether speed or sound is more important was answered differently as well. One scientist answered for herself she believed the sound would not be very annoying so she preferred the speed, as the other scientist said it was dependent on the situation. It should be researched further what amount of sound and speed are acceptable and when it will become annoying (for example too loud or too slow). The robot should then be adapted to the best possible outcome: being as fast as possible while not being annoyingly loud. Both scientists found it would be important when the robot would feel hard and sturdy, but comfortable as well. This comfort could be found by insuring the temperature of the robot to be warm. An approach for 'warm' would be between room temperature and body temperature.

The robot will push the user during physical therapy exercises, so both scientists were asked what would be the best way to do this. The robot can for example ask whether the user really is not able to continue

anymore when ending the exercise early. This question may encourage the user to do one more exercise when feeling he is capable of doing one more. When saying he really cannot continue, he should not be pushed so the robot will leave it at that question. This approach is completely aimed at the wishes of the user. Another approach is measuring for example facial expression or heart rate and according to these results decide whether the user should be able continue. One scientist mentioned a combination would be best, as you can measure whether the user is able to continue but you still have to listen to the user. The other scientist said the first approach will be fine as you otherwise need extra measuring equipment which costs more money and is not necessary.

6.4 Conclusions formulated by the interviews

When it is not necessary, touching the patient should be prevented as the scientists did not feel completely happy about it. But again the care receiver is the most important factor when it comes to making decisions about the robot, so further research needs to be done about how elderly people would feel when being touched by the robot. But before that research is done touching the patient should be prevented. Furthermore a larger robot is preferred over a smaller robot, as it will be more comfortable to interact with a robot that will be at eye level. It was stated both by the caregiver and the care receiver that the robot will probably be missed when the rehabilitation period is over.

When people accept robots in their close proximity, they can be very curious about the robot as it is new to them and thus be very positive about it. But after some time this curiosity will wear off as now the robot is not as new anymore and they know most things about it. When this first curiosity is gone, it is important to keep them interested in the robot, as they otherwise might stop using the robot. This interest can be kept by making the robot use different sentences instead of always saying the same thing. Or being able to play a small game like ‘I spy…’ may keep interest as well.

The overall conclusion that is taken from these interviews is that robots can be used in caring for the elderly very well, but it should be insured that the robots need to be an addition to receiving care from a human caregiver to make things easier for the care receiver instead of being a replacement of human caregivers. Furthermore, although research has mentioned otherwise, acceptance of robots by elderly people may be a little more difficult to accomplish but is certainly possible.

6.5 Conclusions from statistical analysis

The results of the investigation can be found in table six. It is very important to mention that no conclusions can be taken from these results, as the number of interviewees was too small for the results to be significant. Still, an analysis will be presented as this will give an illustration of possible outcomes. What stands out is the fact that the robot in general is accepted most by the care receiver, as it has the highest mean. This is preferable, as the care receiver is the one who will use the robot in the future. However, the fact that the highest standard deviation can be found from the care receiver as well, provides us with the knowledge that there is more diversity between what is preferred and what is not. It should be investigated further what is not preferred, so this can possibly be adapted. But it is also possible this diversity arises because the care receiver probably knew or understood the least of robots of all interviewees. More knowledge possibly reduces the diversity and makes for a smaller standard deviation and thus a more stable and/or different opinion towards robots. Another remarkable result is the fact that the caregiver has the lowers standard deviation, which means he has the most stable opinion about using the robot. This stability was expected to be highest with the scientists, as they have the most knowledge about robots in general and their capabilities for this project. In general it can be concluded all interviewees were positive towards the idea of using the robot. When comparing the results per subject it is found that the tasks for the robot are appreciated a lot as it scores a high mean and a low standard deviation. But also acceptance and design score very well. When reviewing the general results for the mean and standard deviation (3.75 and 1.10 respectively) it can be concluded that all subjects for the robot were accepted by all interviewees. From the three different categories (tasks, acceptance and design) the tasks scored highest and had the lowest standard deviation as well, which shows the tasks for the robot are appreciated. It is remarkable that the means with their corresponding standard deviations of the categories are constant (the highest mean has the lowest standard deviation, the lowest mean has the highest standard deviation), while this is not the case for the interviewees. The design, having the lowest mean with the highest standard deviation, can be improved to increase acceptance of the robot that can be developed by following the design recommendations from this thesis. It should be mentioned these numbers can only be used as an indication and not to draw conclusions as there are only four interviewees, which is too little for drawing conclusions, but also because the questionnaire was personalised and adapted to the interviewee, which may unintendedly have influenced the interviewee's opinion. For following research this problem can be solved by giving every interviewee an information package in advance so no conversation will be necessary during the questionnaire.

	Mean				Standard deviation			
	Tasks	**Acceptance**	**Design**	**General**	**Tasks**	**Acceptance**	**Design**	**General**
Caregiver	3.73	3.36	3.41	**3.50**	0.47	0.81	0.67	**0.65**
Care receiver	4.64	3.75	3.50	**3.92**	0.67	1.16	1.57	**1.14**
Scientist 1	4.64	3.44	3.50	**3.86**	0.67	1.01	1.37	**1.02**
Scientist 2	4.09	3.78	3.33	**3.73**	0.54	1.20	1.50	**1.08**
General	**4.27**	**3.57**	**3.44**	**3.75**	**0.69**	**1.01**	**1.29**	**1.10**

Table 6: results calculated from the questionnaires

Main points chapter six:

- Description of interviews
- Conclusions from interviews + statistical results

7 New required design recommendations for rehabilitation

7.1 Design recommendations

When developing a robot several things should be taken into account. Different focus groups may prefer different requirements. These requirements can be divided into different categories. The first category is *technical aspects / conditions* and this category holds two requirements. One or several motors are needed as the robot must to be able to walk through the house, including stairs, and be able to pick up objects and put them down somewhere else. The *amount of noise* the robot produces while performing this task should be taken into account as it should not disturb the user. For example stronger motors can be used to make the robot walk faster, but the question is whether it needs to walk as fast as possible and whether it will not be better to make it walk a little less fast and thus reduce the amount of noise. This was found in the result of the questionnaires. This recommendation will have effect on the care receiver and on other people nearby (e.g. caregivers and/or close relatives). This recommendation can improve attitudinal acceptance (Davis, 1989) as people may positively evaluate the robot when the amount of noise it makes is not disturbing. Second, the robot will need to walk and move relatively smooth as it otherwise may drop objects while retrieving them for its user, so many *degrees of freedom* at the joints are required. It will also be able to cover a large kinematic workspace (reaching high, low, far, near) when having many degrees of freedom, which is useful when retrieving objects as well. This can be found in chapter two where several examples of robots are discussed. An overview of their sensors and degrees of freedom is given. It can be seen that Asimo requires many more degrees of freedom to be able to perform his tasks than Zora. This is expected, as Asimo needs to perform tasks autonomously while Zora has social interaction as its main task. The care receiver will be affected by this requirement as he receives his requested object, but other residents are affected as well. If the object breaks when being dropped accidentally, the other resident (probably a caregiver or a close relative) needs to clean it up as the care receiver is immobile and cleaning things up is no task of the robot. This recommendation can improve acceptance because it makes to robot able to perform preferred tasks better and provides the robot with a higher level of autonomy.

Another category is making sure *the user feels comfortable around the robot*. There are several requirements to achieve this feeling of comfort. For example Prakash (Assistive Robots 2014) found that elderly people prefer a robot with a humanlike face for decision-making tasks, while younger people liked a mixed robot-human appearance better. For social tasks both groups preferred humanlike faces. So for our focus group it can be concluded that a *humanlike appearance* is recommended for the design of the robot. It is mentioned before (e.g. in chapter four) that appearance is an important factor for robot acceptance. The results of the questionnaires show this appearance is again preferred to be humanlike. Humanlike means the robot should have human forms like two arms and two legs and all its features at expected locations. This design recommendation has effect on the care receiver and surrounding people.

As the users should feel comfortable around the robot to get the best results, they should not be afraid or reluctant to touch it. To insure people are not reluctant about touching the robot, it should *feel pleasant to the touch* so for example it should not feel too hot or too cold. Opinions of the interviewees differed on the exact temperature varying between room temperature and body temperature, but they were in agreement that a warm touch was preferred over a cold touch. This can for example be achieved by using materials that quickly adapt to the temperature of its surroundings when developing the robot. This is the first recommendation that will mainly have an effect on the user of the robot, as only the user will probably touch the robot when necessary during rehabilitation exercises. The robot should have a *friendly appearance (face)* as this increases robot acceptance and willingness to use it. The interviewees were shown some pictures of different robots so they knew what robots could look like and a humanlike face was preferred. A *humanlike face* is a face with human features like two eyes, a nose and a mouth at expected locations. Another option was a non-humanoid robot (a robot with abstract, non-human forms), but a humanoid robot was preferred. So the robot should have human forms like legs and arms and a face with two eyes, but it should be clearly visible it is a robot. However, the robot's face should not look exactly human as this can be intimidating for people. This was found when a picture of robot Ishiguro, who looks the same as his developer (Ishiguro 2014), was disliked by everyone. One could therefore position the robot's eyes, nose and mouth like it is a human face, but use a different skin colour or a different shape for its nose. Beside the issue of its appearance, there is also the question *what the robot's voice should sound like*. It was found by Kuo et al. (2009) that elderly people liked the voice of robot Charles because it was very clear. For their research they used the Festival speech synthesis system. This system is created by Taylor, Black and Caley (1998) and in the experiment of Charles used on every sentence to create and audio file (.wav) and a phonetic transcript. This same system can be used as a design recommendation as the focus group is elderly people, the same group that liked the voice of Charles, which was generated with the same algorithm. In chapter three it was stated that communication through speech should be taken for granted. Also speech, besides many other aspects, is important for robot acceptance, which is discussed in chapter four. In the questionnaires it was asked whether a robotic or a humanlike voice was preferred and the results showed the humanlike voice was preferred by most. These preferences for a humanlike voice, face and appearance are expected as it is stated in chapter four that people tend to assign human qualities and personality to objects. These recommendations will have effect on the care receiver but on the surrounding people as well, as everyone in close proximity of the robot will be influenced by its appearance when looking at the robot. For all the recommendations in this category can be said that they

Figure 6: Hiroshi Ishiguro and his mechanical doppelgänger (Source: Ishiguro 2014)

improve intentional and attitudinal acceptance as people positively evaluate the robot and possibly plan to interact with it more often. These forms of acceptance are improved by using the following possibilities: appearing likeable and/or giving the user appropriate social cues .

The third category contains *tasks the robot should be capable of* to be able to perform the tasks that are and will be discussed in this paper. An important requirement is the *robustness and balance* of the robot. People might stumble while doing their exercises and as the robot will help them it must also provide support. So it is important the user can grab the robot to gain balance instead of both falling down on the floor. This falling down of the robot should be prevented at all costs as it might fall on top of the user and thereby hurt him. The robot's balance is very important for the fetching task as well. It should be able to carry objects of different weights without falling due to an incorrectly divided weight. This requirement can be seen as a general requirement, as a robot is intended to never fall down, but this requirement is extra important when working in close proximity with users as the user may be dragged along, which must be prevented at all costs as it contradicts the laws of Asimov, moral principles and other rules that are discussed earlier in this paper, namely to not harm someone. This requirement is mainly effective for the user as he may be in such close proximity to possibly be dragged along. It is less expected for a caregiver or close relative to be nearby enough to be dragged along during the robot's fall.

A superb *spatial awareness* is required as well as it is not desired for the robot to walk into objects, because this object might be the user or something valuable. Other people may be able to move away, but as the users of the robot will have mobility problems they may not be able to move away fast enough which can result in the robot walking into them and this can hurt the user. So the spatial awareness of the robot is very important. This recommendation was mentioned at the general requirements but was found important enough to be mentioned once more, as the statement about this requirement was answered with higher rates than other statements during the questionnaire, which resulted in the belief this requirement is very important. This recommendation will mostly affect the robot's user but other residents may benefit from this recommendation as well as it can be very disturbing when an object is knocked over by the robot. It is also important the robot is able to adapt to human motion. This can be done by using *compliant motion*. When the user stumbles into the robot, for example when exercising, it should not just stand still as this may hurt the user. It should move along with the movement and slow down the user's fall for him to regain his balance. A robot that is already capable of this compliant motion is Twendy-one (Twendy-one 2014). This robot is developed to support daily human activities. The user of the robot is highly affected by this recommendation as it will prevent him from falling onto the floor. Several laws, principles and rules are discussed in this thesis about not causing harm to people, both intentionally and unintentionally. This recommendation prevents to unintentionally

Figure 7: Twendy-one

harm the care receiver when he is falling and will mainly have effect on the care receiver as he will be the one to accidentally fall into the robot during exercises. The design recommendations in this category improve intentional acceptance as users will plan to use the robot more when it is capable of performing more required tasks. This intentional acceptance is improved by the robot being able to perform preferred tasks and satisfying the desired level of autonomy.

The last category contains *socially required features*. Kuo et al. (2009) found in their experiment that "Some older participants found it difficult to understand and follow the instructions that were given [by a robot] in a short amount of time". As the robot that can be built from these design recommendations will instruct people during their rehabilitation exercises, it should be ensured the *users understand the given instructions*. This can be done by asking whether everything has been completely understood after every step of the instruction. But constantly asking whether something is understood can be found extremely annoying, this depends on the focus group and the user's personality. So it should be researched what different focus groups and different styles of personality prefer. Another solution may be to pause after the introduction before explaining the next instruction, which gives the user time to ask questions without being interrupted by the next instruction. The adaptation to different personality styles is discussed in chapter four. This recommendation will mainly affect the user as he will be the one to receive instructions from the robot about the rehabilitation exercises.
It may occur that the *elderly feel patronised by their caregivers* (Mast et al. 2009). It is not desired that this feeling occurs when using a robot as well. So when there is interaction with the robot, it should be accounted for that the robot will not communicate in a patronising tone. This again can be solved by applying different styles of communication to people with different personality styles. The robot should be able to adapt its interaction to the personality of its user. When someone cannot hear very well it should talk more slow and more clear than when its user has excellent hearing. This recommendation follows from chapter four, which discusses adaptation to different personality styles. This recommendation will have effect on the user as he will be the one to interact with the robot. It is useful when the robot is able to *recognise faces*, as its user may be in a room with other people in it as well. Asimo is an example of a robot who is capable of facial recognition (Asimo 2014). The robot should then know to whom it should for example give the requested object it went to retrieve. Also when the user is living with a partner the robot should know who needs its help. This does not mean it should ignore the other user. When it does not have to do anything for its user and the user's partner asks to retrieve an object, the robot can certainly do so. But the requests of the user must be its first priority so when two requests are made at the same time the user's request should be answered to. This recommendation follows from chapter two. In this chapter Asimo's ability of recognising faces is discussed and it is mentioned it would be useful for the robot from this thesis as well. However, it cannot be seen as a general requirement as it is not necessary to recognise faces to perform the four tasks in this thesis. The design recommendations in this category influence behavioural and attitudinal acceptance,

as users can adapt their actions to the socially required tasks of the robot, which will influence their positive evaluation. This behavioural and attitudinal acceptance is influenced as the robot will give the user appropriate social cues and will satisfy the desired level of autonomy. An overview of all design recommendations mentioned in this paper can be found in table seven.

Design recommendations	
Existing recommendations	**Explanation**
Technical aspects / conditions	
Amount of noise	While performing its tasks the robot's motoric parts cannot make too much noise as this can be annoying for the user.
Many degrees of freedom	To be able to perform exercising tasks and grab and carry objects for the user, many degrees of freedom are required.
Making the user feel comfortable	
Humanlike appearance	The robot should have humanlike features (2 arms, 2 legs, torso, head).
Friendly appearance (face)	Users should feel comfortable around the robot, so the robot should look comforting. A humanlike face is preferred.
Sound of voice	The robot's voice influences user's feeling of comfort as well.
Feel pleasant to the touch (temperature, structure of the material from which the robot is made)	When practising to walk, users may need to touch the robot. A pleasant touch is thus important so people aren't reluctant to hold on to the robot.
Required tasks the robot should perform	
Stair climbing (existing)	To be able to retrieve requested objects from different levels in the house.
Grab objects from different sizes and shapes (existing)	Requested objects will have different shapes.
Being robust and balanced	The robot must be able to transfer objects of different size, shape and weight.
Superb spatial awareness	It is not allowed to walk into objects, as this may be the patient who can get hurt.
Compliant robot motion	When accidentally having human contact the robot should move along with the person's movement to prevent hurting.

Socially required features	
Communication through speech (existing)	Speech is preferred as interaction tool over other possibilities.
Facial recognition (existing)	When several people are in the room, the robot should know whom is its user.
Interaction	Users need to feel respected by the robot, so interaction must be equal and not patronising.
Understanding	It is important to assure the given instructions are understood.

Table 7: summary of all design recommendations. Existing recommendations are discussed in chapter three. The remaining recommendations are discussed above.

7.2 Other tasks

In chapter three two tasks for the robot were mentioned. Those tasks were tasks that could already be performed by other robots but were necessary for the purpose of this robot (retrieving objects and providing information). There also are two other tasks necessary for the robot to be able to help elderly during their rehabilitation that have not been done by other robots before. Those tasks have been created by using the results described in chapter six. Another task (and the third task in general) of the robot will be to *motivate patients to exercise and help them when necessary*. The robot can be a motivator by telling the patients when to do their exercises and by encouraging them to do their best and giving them feedback about the effects of their training. It may also be possible for the robot to send results of these exercises to the doctor or the physical therapist of the patient so they can monitor the patient's recovery. The second role (and the last role in general) of the robot is being *supportive and comforting* for the patient. The original idea was to make this a psychological task, so the patient can talk with the robot about problems when there is no one else around to talk to. For example talking about the rehabilitation not going as well as expected. The care robot Zora for the elderly is an example of a care robot for communication (Zora 2014). But even Zora is only capable of basic communication. To have a conversation with a robot in which someone can discuss things that really bother them is not possible yet and it will probably be a long term goal instead of something that can be achieved in several years. So this task is adapted to converge with the physical therapy task: while exercising the robot will ask the patient to work hard, but will be a motivator and support as well. Afterwards it can say the patient did well to motivate to work hard again the next time. But not only after exercising, but during the whole rehabilitation process support can be important as the patient may feel better after hearing positive things, which may improve the rehabilitation. So now the psychological part is providing the patient with positive support through the whole rehabilitation trajectory instead of only during physical therapy exercises.

Key points chapter seven:

- Design recommendations that can be divided into four different categories (technical aspects/condition, making the user feel comfortable, required tasks, socially required features).
- More tasks for the robot

8 Conclusion

When assembling elderly care with robot technology through Human-Robot Interaction it results in care robots for the elderly. These robots already exist, but there are no robots yet to help elderly people with temporary mobility problems through their rehabilitation at home. This thesis strived to research whether this will be possible via two sub-questions and one research question. The first objective addressed in this paper can be discussed with the question "Can robots be used in helping elderly people who suffer from temporary mobility problems?". Initial experiments have shown that the reactions towards robots in elderly care are positive. Examples are given in chapter two. Furthermore, the results from the interviews have shown that a robot that is able to perform physical and psychological tasks to help people with temporary mobility problems is appreciated.

The second objective from the introduction of this paper can be discussed with the question "What should be done to ensure that robots will be accepted in helping addressing those problems?". The results from the interviews give an indication of the general acceptance of the robot, as all interviewees seemed willing to accept the robot in their daily life. Furthermore several possibilities were suggested to improve acceptance of robots by elderly people, as this focus group is known to be the least willing to accept robots in their lives. This unwillingness did not result from the interviews, as the care receiver seemed the most willing to accept the robot, but as mentioned before, no conclusions can be taken from these results. Furthermore, even when acceptance is not lowest in the focus group, possibilities to improve acceptance in general are always important. Examples of these possibilities are providing knowledge and giving appropriate social cues. All possibilities can be found in chapter four.

All things previously stated makes it possible to answer the main research question for this thesis: "What would be the design recommendations for a robot that could help elderly people with temporary mobility problems?". The recommendations are designed in such a way that the robot is able to perform four tasks, from which two tasks are general tasks that are requested by elderly people and the other two tasks are created following the research in this paper. The general tasks are retrieving objects and providing information and are described in chapter three. The adapted tasks are providing help during physical therapy and psychologically support the care receiver. These tasks are described in chapter seven. An overview of all design recommendations can be found in chapter seven as well. An example of these recommendations is making the robot appear humanlike, as in having human forms and human features at expected locations. This humanlike appearance is preferred for its body, its face and its voice. Another example is providing the robot with many degrees of freedom to enable it to move and walk as continuous as possible, as this will improve its capability of performing tasks.

It was found in the interviews and stated by Sharkey and Sharkey (2010) that, when used as an asset for caring instead of a replacement, robot technology can have huge advantages for the elderly. Acceptance

of robots is very important. When people do not trust or accept a robot, they will not use it as they probably do not feel safe around it. In order to enhance the acceptance people should know as much as possible about the robots, especially about its capabilities, so they do not overestimate it and thus feel negative about the robot. So when the limitations of robots are known people can modify their expectations and feel positive about them. And when using careful guidelines and foresight to improve people's knowledge, their lives can certainly be improved by robots. It should be mentioned that the opinion of the care receivers is most important when it comes to robot acceptance, but the caregivers should not be forgotten as they may need to work with or in the neighbourhood of the robots as well and may feel threatened by them.

In this thesis, the opinions of the care receiver and caregiver are of great importance, as it is strived to give them a larger vote in the design recommendations, because they will be the ones using the robot. It is believed that, when possible, adjusting the robot to the wishes of the users, acceptance will improve once more. This theses gives design recommendations, but using the opinion of caregivers and care receivers can be seen as a policy recommendation. Listen to the users to improve the development of robots and their acceptance!

8.1 Limitations

The results from the research in this thesis are positive, but only four people from three different categories (caregiver, care receiver, scientist) were interviewed and this number is too small to make conclusions about the outcomes. Future research will have to show whether the project is truly appreciated. Furthermore, the robot will not be tall enough to be able to retrieve objects from all possible heights. It will be approximately be 1.50m tall, so it will not be able to grab objects from the top of a cupboard. But as it is intended to help while rehabilitating, it is expected it will not have to retrieve objects from such heights, as objects that are needed regularly probably lie at a more convenient location. Of course it is possible to increase the length of the robot, but it is believed it will become more intimidating which may decrease acceptance. This can be found in the interview, where the care receiver stated the robot's size did not matter, as long as it would be smaller than herself. Therefore a smaller robot is preferred. During the development of the questionnaires, adjustments were made per interviewee to ensure they knew enough about robots to understand the statements. This resulted in personalised questionnaires. This personalisation of the questionnaires resulted in a decreased reliability, as unintended influence was possible through this personalisation. It would have been better to give every interviewee the same information package about the robot in advance, containing all information the interviewee with the least knowledge (in this case, and probably often, the care receiver) was expected to need. This would have resulted in everyone having the necessary amount of information needed to fill in the questionnaire, so no personalisation would be needed and reliability of the results

would not have been decreased. Furthermore, the number of questions asked about the design of the robot could have been extended to get a better opinion about preferences regarding the design of the robot.

8.2 Future research implications

There are many areas for future research as this is a subject that is quite new and can be improved a lot. Every subject of the interviews (tasks, acceptance, design) creates possibilities for future research. Some of these possibilities will be discussed in the following chapter.

Key points chapter eight:

- Objectives from the introduction
- Main research question
- Importance of user's opinions
- Limitations from this research
- Future research area's

9 Future research

9.1 Tasks

It can be examined whether there are *other tasks for the robot to perform* that are useful while rehabilitating from mobility problems as well. When the robot is proved to be effective, it maybe can be transformed into a robot that can *provide help for a longer or unknown amount of time* instead of only during the rehabilitation period. Furthermore, it can be examined *what is preferred in a robot's functioning*: it being as quiet as possible, or being as fast as possible, or a comfortable combination of both. Research has to be done to what is stated as comfortable. This research should be targeted at the opinion of the elderly, as they will be the ones using the robot.

9.2 Acceptance

A remarkable difference occurred when the question was asked what the robot should sound like. The caregiver and both scientists preferred a human voice over a robotic voice, but the care receiver preferred the robot voice and it was also mentioned earlier in this thesis that research had shown that elderly preferred a robotic voice. So research about why this difference occurs and more research about the opinion of elderly people can be done. It has to be *stated what is meant by a robotic voice* exactly as this may influence the opinions of people as well.

9.3 Design

As mentioned in the conclusion, only four people from three different categories were interrogated. Their answers about the appearance of robots often corresponded, but the number of interviewees is too small to make any significant conclusions. So further research in the area of *the robot's appearance* is required as well. Also mentioned in the conclusion was the fact that the robot is not able to grab objects from great heights. So further research can be done to *extend the reach of the robot* so it can grab objects from bigger heights. A possible solution may be using a small stair, but then a small stair is needed and will probably be an unnecessary obstacle mostly. So a solution in which the robot can for example stretch its arms will be best.

9.2 Overall future research

The roles mentioned in the thesis are discussed focusing on the robot as a support system for daily family living in a household. However, with these tasks it can also be used in hospitals, to go get objects for a doctor, or motivate people in a rehabilitation centre to do their exercises. The robot may be expanded as well to make it usable for a broader audience. Research of personality styles is very important for this expansion as the robot needs to be able to adapt to the interaction that is preferred by its user.

Key points chapter nine:

- Expanding the tasks of the robot
- Further research on the subject of robot acceptance
- Further research on the subject of the robot’s design
- Expanding the field of users

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Appendix A: Interviews

Interview with caregiver

When being told robots can be developed to be used in elderly care, what would you expect?

Tasks	totally disagree				totally agree
The fetching task is useful	1	2	3	**4**	5
The use of a robot for this task is practical	1	2	**3**	4	5
The informational task is useful	1	2	3	**4**	5
The use of a robot for this task is practical	1	2	**3**	4	5
The physical therapy task is useful	1	2	3	**4**	5
The use of a robot for this task is practical	1	2	**3**	4	5
The psychological support task is useful	1	2	3	**4**	5
The use of a robot for this task is practical	1	2	3	**4**	5
The combo of physical and psychological is useful	1	2	3	**4**	5
The use of a robot for this task is practical	1	2	3	**4**	5
The robot may be severe while exercising	1	2	3	**4**	5

Acceptance					
I would feel threatened by the robot in my working area	1	2	**3**	4	5
I would use the robot as an asset while caring for the elderly	1	2	**3**	4	5
I think the robot will be useful	1	2	3	**4**	5
I trust a robot with a humanlike face	1	**2**	3	4	5
I trust a robot with a robotlike face	1	2	3	**4**	5
I trust a robot with a humanlike voice	1	2	3	**4**	5
I trust a robot with a robotic voice	1	**2**	3	4	5
The robot should look humanoid (torso, legs, arms etc)	1	2	3	**4**	5
I think the robot invades my patient's privacy	1	**2**	3	4	5
I think the robot invades my privacy	1	**2**	3	4	5
I am comfortable with the robot touching my patient while doing physical therapy	1	2	**3**	4	5

Design

The robot should respond as quickly as possible	1	2	3	**4**	5
The robot should be quiet	1	**2**	3	4	5
The amount of noise is more important than the speed	1	2	**3**	4	5
A robot of 1.40m is too tall	1	**2**	3	4	5
The robot is allowed to walk into objects by accident	1	**2**	3	4	5
It is important the robot has a good balance	1	2	3	**4**	5
The robot should feel sturdy when touching it	1	2	**3**	4	5
The robot should feel warm	1	2	**3**	4	5
The robot should feel cool	1	2	**3**	4	5
I feel comfortable around a robot with basic shapes (rumba)	1	2	**3**	4	5
I feel comfortable around a humanoid (but distinctly mechanic) robot (asimo, nao, twendy one)	1	2	3	**4**	5
I feel comfortable around a human-looking robot (android, Ishiguro)	1	**2**	3	4	5

After finishing this interview, do you still expect the same things as were mentioned at the beginning of the interview?

Note: the answers to the open questions have been processed in the interview chapter.

Interview with care receiver

When being told robots can be developed to be used in elderly care, what would you expect?

In which area's you would've preferred help when receiving your artificial knee?

Tasks	totally disagree				totally agree
The fetching task is useful	1	2	3	4	**5**
The use of a robot for this task is practical	1	2	3	4	**5**
The informational task is useful	1	2	3	4	**5**
The use of a robot for this task is practical	1	2	3	**4**	5
The physical therapy task is useful	1	2	3	4	**5**
The use of a robot for this task is practical	1	2	3	4	**5**
The psychological support task is useful	1	2	**3**	4	5
The use of a robot for this task is practical	1	2	3	**4**	5
The combo of physical and psychological is useful	1	2	3	4	**5**
The use of a robot for this task is practical	1	2	3	4	**5**
The robot may be severe while exercising	1	2	3	4	**5**
Acceptance					
I think the robot will be useful	1	2	3	4	**5**
I trust a robot with a humanlike face	1	2	3	**4**	5
I trust a robot with a robotlike face	1	**2**	3	4	5
I trust a robot with a humanlike voice	1	**2**	3	4	5
I trust a robot with a robotic voice	1	2	3	**4**	5
The robot should look humanoid (torso, legs, arms etc)	1	2	3	4	**5**
I think the robot invades my privacy	1	**2**	3	4	5
I am comfortable with the robot touching me while doing physical therapy	1	2	3	**4**	5
Design					
The robot should respond as quickly as possible	1	2	3	4	**5**
The robot should be quiet	1	2	**3**	4	5
The amount of noise is more important than the speed	1	2	**3**	4	5
A robot of 1.40m is too tall	1	**2**	3	4	5
The robot is allowed to walk into objects by accident	1	2	3	**4**	5

It is important the robot has a good balance	1	2	3	4	**5**
The robot should feel sturdy when touching it	1	2	3	4	**5**
The robot should feel warm	1	2	3	4	**5**
The robot should feel cool	**1**	2	3	4	5
I feel comfortable around a robot with basic shapes (rumba)	1	2	**3**	4	5
I feel comfortable around a humanoid (but distinctly mechanic) robot (asimo, nao, twendy one)	1	2	3	4	**5**
I feel comfortable around a human-looking robot (android, Ishiguro)	**1**	2	3	4	5

Note: the answers to the open questions have been processed in the interview chapter.

Interview with two scientists

Interview with the first scientist

Tasks	totally disagree				totally agree
The fetching task is useful	1	2	3	4	**5**
The use of a robot for this task is practical	1	2	3	4	**5**
The informational task is useful	1	2	3	4	**5**
The use of a robot for this task is practical	1	2	3	4	**5**
The physical therapy task is useful	1	2	3	4	**5**
The use of a robot for this task is practical	1	2	**3**	4	5
The psychological support task is useful	1	2	3	4	**5**
The use of a robot for this task is practical	1	2	3	**4**	5
The combo of physical and psychological is useful	1	2	3	4	**5**
The use of a robot for this task is practical	1	2	3	**4**	5
The robot may be severe while exercising	1	2	3	4	**5**
Acceptance					
I think the robot will be useful	1	2	3	4	**5**
A robot with a humanlike face will be trusted	1	2	3	**4**	5
A robot with a robotlike face will be trusted	1	2	3	**4**	5
A robot with a humanlike voice will be trusted	1	2	3	**4**	5
A robot with a robotic voice will be trusted	1	2	**3**	4	5
A humanoid looking robot will be trusted more than robots with other appearances (legs, arms, torso)	1	2	**3**	4	5
I think the robot invades the patient's privacy	1	**2**	3	4	5
I think the robot invades the caregiver's privacy	1	**2**	3	4	5
I am comfortable with the robot touching the patient while doing physical therapy	1	**2**	3	4	5
Design					
The robot should respond as quickly as possible	1	2	3	4	**5**
The robot should be quiet	1	**2**	3	4	5
The amount of noise is more important than the speed	1	**2**	3	4	5
A robot of 1.40m is too tall	1	**2**	3	4	5

The robot is allowed to walk into objects by accident	**1**	2	3	4	5
It is important the robot has a good balance	1	2	3	4	**5**
The robot should feel sturdy when touching it	1	2	3	4	**5**
The robot should feel warm	1	2	3	**4**	5
The robot should feel cool	1	**2**	3	4	5
I feel comfortable around a robot with basic shapes (rumba)	1	2	3	4	**5**
I feel comfortable around a humanoid (but distinctly mechanic) robot (asimo, nao, twendy one)	1	2	3	4	**5**
I feel comfortable around a human-looking robot (android, Ishiguro)	1	**2**	3	4	5

Design recommendations and assumptions

It is allowed to assume the robot can walk the stairs	1	**2**	3	4	5
It is allowed to assume the robot can get different objects	1	2	**3**	4	5
It is allowed to assume the robot can communicate through speech (thus possibility of social interaction)	1	2	**3**	4	5
The robot can recognise different objects	1	2	3	**4**	5

Is it a satisfactory approach to use the concept of Romeo and adjust it to be able to perform the tasks invented?

How do I make the robot push the patient just hard enough while exercising? Does it just ask whether the patient really cannot continue or should it measure certain features to decide whether the patient should be able to continue? (or something else?)

Are there any other assumptions you believe I should make?

Are there any additions or opinions you would like to mention?

Note: the answers to the open questions have been processed in the interview chapter.

Interview with the second scientist

Tasks	totally disagree				totally agree
The fetching task is useful	1	2	3	**4**	5
The use of a robot for this task is practical	1	2	3	4	**5**
The informational task is useful	1	2	3	**4**	5
The use of a robot for this task is practical	1	2	**3**	4	5
The physical therapy task is useful	1	2	3	4	**5**
The use of a robot for this task is practical	1	2	3	**4**	5
The psychological support task is useful	1	2	3	**4**	5
The use of a robot for this task is practical	1	2	3	**4**	5
The combo of physical and psychological is useful	1	2	3	**4**	5
The use of a robot for this task is practical	1	2	3	**4**	5
The robot may be severe while exercising	1	2	3	**4**	5
Acceptance					
I think the robot will be useful	1	2	3	**4**	5
A robot with a humanlike face will be trusted	1	2	3	4	**5**
A robot with a robotlike face will be trusted	1	2	3	**4**	5
A robot with a humanlike voice will be trusted	1	2	3	4	**5**
A robot with a robotic voice will be trusted	1	2	3	**4**	5
A humanoid looking robot will be trusted more than robots with other appearances (legs, arms, torso)	1	2	3	4	**5**
I think the robot invades the patient's privacy	1	**2**	3	4	5
I think the robot invades the caregiver's privacy	1	**2**	3	4	5
I am comfortable with the robot touching the patient while doing physical therapy	1	2	**3**	4	5
Design					
The robot should respond as quickly as possible	1	2	3	4	5
The robot should be quiet	1	2	3	4	5
The amount of noise is more important than the speed	1	2	3	4	5
(he couldn't grade these statements as he felt it depended on the situation and the user)					
A robot of 1.40m is too tall	1	**2**	3	4	5

The robot is allowed to walk into objects by accident	**1**	2	3	4	5
It is important the robot has a good balance	1	2	3	4	**5**
The robot should feel sturdy when touching it	1	2	3	4	**5**
The robot should feel warm	1	2	3	**4**	5
The robot should feel cool	1	**2**	3	4	5
I feel comfortable around a robot with basic shapes (rumba)	1	**2**	3	4	5
I feel comfortable around a humanoid (but distinctly mechanic) robot (asimo, nao, twendy one)	1	2	3	4	**5**
I feel comfortable around a human-looking robot (android, Ishiguro)	1	**2**	3	4	5

Design recommendations and assumptions

It is allowed to assume the robot can walk the stairs	1	2	**3**	4	5
It is allowed to assume the robot can get different objects	1	2	3	4	**5**
It is allowed to assume the robot can communicate through speech (thus possibility of social interaction)	1	2	3	**4**	5
The robot can recognise different objects	1	2	3	4	**5**

Is it a satisfactory approach to use the concept of Romeo and adjust it to be able to perform the tasks invented?

How do I make the robot push the patient just hard enough while exercising? Does it just ask whether the patient really cannot continue or should it measure certain features to decide whether the patient should be able to continue? (or something else?)

Are there any other assumptions you believe I should make?

Are there any additions or opinions you would like to mention?

Note: the answers to the open questions have been processed in the interview chapter.

Appendix B: Statements with swapped values

I think the robot invades the patient's privacy	1	2	3	4	5
I think the robot invades the caregiver's privacy	1	2	3	4	5
A robot of 1.40m is too tall	1	2	3	4	5
I would feel threatened by the robot in my working area	1	2	3	4	5
The robot is allowed to walk into objects by accident	1	2	3	4	5

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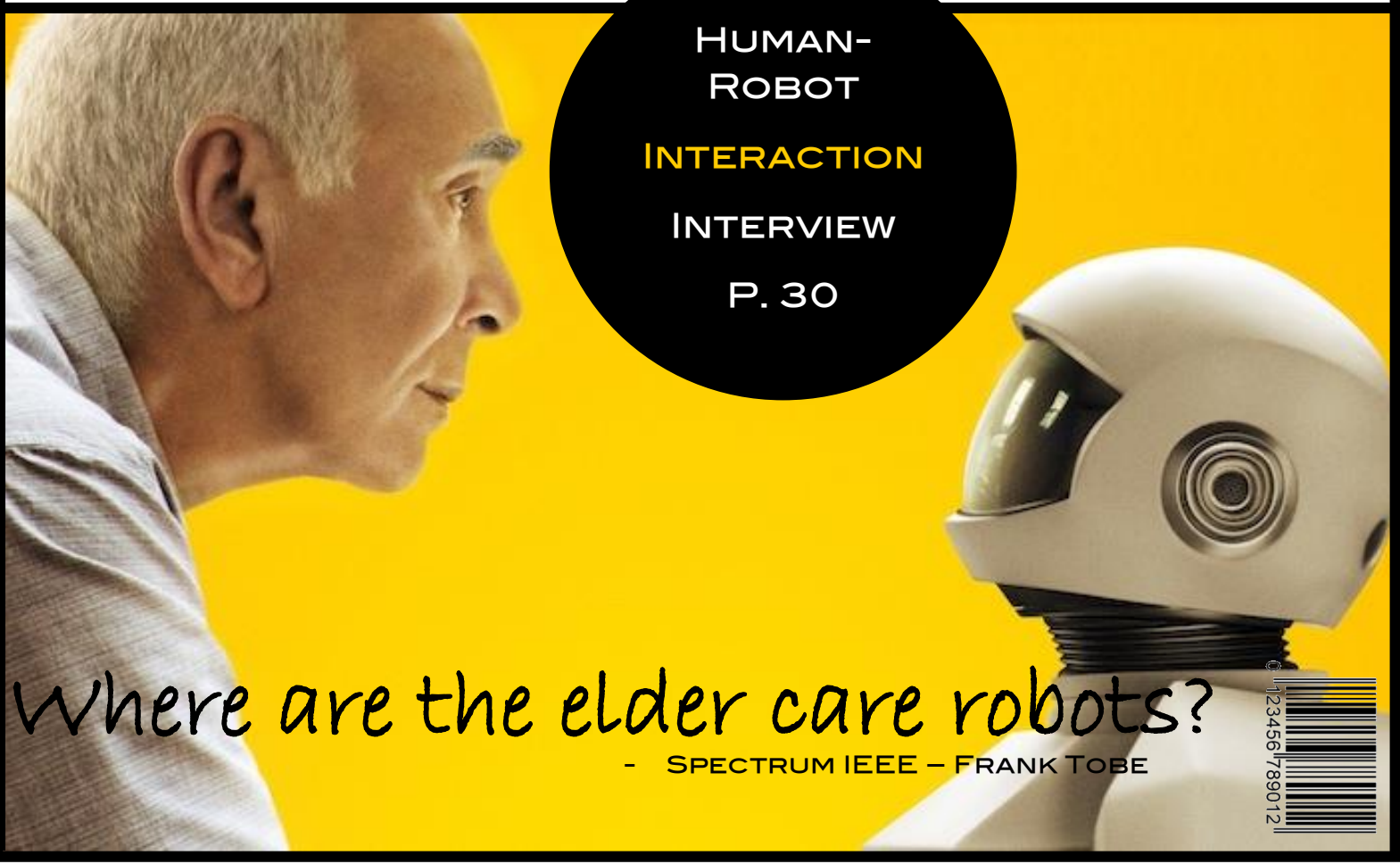
Robotics & People

ZORA P. 10

DESIGN RECOMMENDATIONS FOR A ROBOT HELPING ELDERLY PEOPLE WITH TEMPORARY MOBILITY PROBLEMS

ANOUK VAN MARIS FINDS OUT!

HUMAN-ROBOT INTERACTION INTERVIEW P. 30



Where are the elder care robots?

- Spectrum IEEE – Frank Tobe