Effect of Robot-User Personality Matching on the Acceptance of Domestic Assistant Robots for Elderly

Merel Brandon

Human Media Interaction, University of Twente

Human Interaction & Experience, Philips Research

Supervision:

D. Lowet; Philips Research

Prof. Dr. D.K.J. Heylen; University of Twente

Dr. E.M.A.G. van Dijk; University of Twente

Prof. Dr. V. Evers; University of Twente

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Abstract

Lack of acceptance of social assistive robots by elderly could obstruct this technology to bridge the gap between demand and supply of elderly care. Two experiments were conducted with 22 older adults (63 to 87 years old) in a home-like room of the Experience-Lab of Philips. The aim of the first experiment was to test the effect of user-robot personality matching on the acceptance by elderly of a robot that provides agenda and medication reminders. The second experiment explored the mechanism behind robot personality preferences.

The results of the first experiment show that the perceived sociability was significantly higher for the extravert robot compared to the introvert robot($p<.05$). Sociability is the most prominent characteristic of extraverted people (Tapus & Matari, 2008). Therefore, we concluded that the designed personalities were recognized. In line with previous studies we found that the feeling of social presence ($p<.05$) and the perceived enjoyability ($p<.01$) were higher for the extravert robot compared to the introvert robot. Contrary to our expectations, results indicated marginally significant more anxiety for the robot with a similar extraversion level compared to a robot with a complementary extraversion level. On the other hand, the results of our second experiment indicate that similarity attraction influenced the preferred personality of participants. The reasons that participants provided for their robot personality preference suggest that the role that participants believe the robot should have (e.g. a companion or a service oriented machine) and the appreciation of expressed self-confidence influenced their robot personality preferences. The appreciation of expressed self-confidence seems to be related to similarity attraction.

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1. Introduction and Motivation

Demographic trends are forcing radical changes in elderly care. Due to the birth peak after the second world war and the decrease of birth rate in the sixties and seventies, the proportion of the western population that is 65 years or older is growing. In the Netherlands in the year 2040 there will be more than 1.7 times as many people 65 years or older than in the year 2010. However, the number of people in the working population (people between 20 and 65 years) stays more or less stable (Garssen, 2010). Moreover, the life expectancy grows. People are getting older due to advances in health care. In 2010, 4% of the Dutch population was 80 years or older. In the year 2050 it is expected that 10% of the population is older than 80 (Garssen, 2010).

Although robots could contribute to a solution of the growing gap between demand and supply of elderly care, acceptance of these robots by elderly people is a necessary condition. A study with 66 older adults, between 65 and 92 years old, shows that intention to use a robot is correlated to age. Younger adults in this study were more willing to use a robot than older adults (Heerink, 2011) . Therefore, it is important to explore robot aspects that could increase the acceptance of robots by elderly people. During this study we looked at the effect of robot-user personality matching on robot acceptance, and explore the mechanisms behind robot personality preferences.

This study takes place in the context of the Florence[1] project (Multi Purpose Mobile Robot for Ambient Assisted Living), which is a European collaboration project (http://www.florence-project.eu/). The Florence project aims to develop and evaluate several care, coaching, and connectedness (help people to keep connected to other people) related functionalities for a social domestic service robot. The functionalities of the robot should support well-being of elderly people and their families and friends, and improve efficiency of care. A robot platform has been developed during the Florence project using current state of the art technology (we will designate this robot the "Florence robot" in this document). The goal of the Florence

1 The project is named after Florence Nightingale (12 May 1820 – 13 August 1910). She became a nurse despite the expectancies of a woman of her status to become just a wife and mother. She believed that it was her tasks from God to become a nurse. She became famous for her pioneering nursing of wounded soldiers during the Crimean War. She was called "The Lady with the Lamp" after her habit of making rounds at night. In 1860 she founded the first secular nursing school of the world. Nightingale is considered to be the founder of modern nursing science. The Florence project partners *"propose to have a robot as mobile facilitator and assistant for the daily life of the elderly; similar to what Florence Nightingale was for her patients who introduced a new way of caring to injured people."*

project was to build a low-cost platform that could be on the market within a relatively short term. This robot platform is used to evaluate applications developed for the robot with potential end-users. Designing the robot in such a way that elderly people will accept it is one of the challenges of the Florence project.

For the purpose of this study we shall focus on a services robot application that has been suggested by the Florence project: an agenda and medication reminder application. Memory of older adults is impaired relative to younger adults (Nichols, Rogers, & Fisk, 2006). Remembering medication or appointments is more difficult for older adults, especially under demanding conditions. Non-adherence to medication regimes could lead to ineffective medication therapies, hospital admission, and even deaths (Buisman & Mosis, 2008). Forgetting medication is one of the main causes of medication non-adherence (Buisman & Mosis, 2008).

To get insight in the problem of medication adherence and in the acceptance of a robot that provides medication reminders, we conducted an interview with ten elderly people who used medication on a daily basis and three care providers (see Appendix A and B for more information about the interviews). Seven of the ten elderly people (65 to 84 years old, M=75.3 years, 3 male and 7 female) interviewed indicated that they forget their medication from time to time. Three interviewees received medication adherence support from care providers. The three care providers also indicated that many elderly people have problems with remembering their medication. We asked the elderly participants whether they would like a robot in their house that would give medication reminders. Four participants indicated that they would prefer a robot above a care provider to help them remember the medication if they needed that kind of help. The other six participants preferred help from care providers, because they found the robot scary, didn't trust the robot, wouldn't like to learn to use the robot, and/or would miss the human contact of a care provider. The results of the interviews underline the importance of improving robot acceptance.

The Computers As Social Actors (CASA) paradigm suggests that humans perceive computers as social actors and that they apply social models to interact with computers (Nass, Steuer, & Tauber, 1994; Reeves & Nass, 1996). Research has shown that people are polite to computers, gender stereotype computers, and exhibit moral obligations towards computers (Nass et al., 1994; Reeves & Nass, 1996). Three competencies of robots and computer agents elicit social response: use of natural language (verbal and non-verbal language generation and understanding), contingent (intelligent) behavior, and their capability to perform social roles (Dryer, 1999). Studies that have compared the response towards robots and toward interactive screen agents show that the robots elicit more social responses and result in more engagement, higher feeling of social presence (Powers, Kiesler, Fussell, & Torrey, 2007).

In this thesis we will use the term 'social robots' to refer to those robots to which people apply social models to interact with them and to understand them because they have an anthropomorphic (human-like) interaction style (Breazeal, 2003; Fong, Nourbakhsh, & Dautenhahn, 2003). “*Anthropomorphism (from the Greek word anthropos for man, and morphe, form/structure), .., is the tendency of people to attribute human characteristics to inanimate objects, animals and others with a view to helping us rationalize their actions.”* (Duffy, 2003 p. 180). Anthropomorphism increases if the robot has a more human-like appearance and interaction style. Breazeal (2003) defined four subclasses of social robots. The subclasses help to distinguish robots that only appear to be social from robots that really have been designed with artificial social intelligence. From robots that only appear social to robots with implemented social models these subclasses are: socially evocative, social interface, socially receptive, and sociable. Breazeal (2003) states that a robot is genuinely socially intelligent if it behaves according to social models during unconstrained interaction in complex social environments. Breazeal (2003) argues that because people use social models to interact with robots, the robots should have some form of social intelligence to meet the users' expectations. Consistency between user's expectations and the robot's behavior increases the usability (Breazeal, 2003; Hendriks, Meerbeek, Boess, Pauws, & Sonneveld, 2010). Breazeal (2003) argued that social intelligence makes robots capable to interact with humans more effectively and efficiently, which will increase their task performance, and their ability to function in complex social situations. Social models are easily understood and allow for natural interaction. As soon as a robot becomes part of a person’s everyday life it needs to adjust its behavior to that individual (Fong et al., 2003). The robot used during this project fits in the 'social interface' subclass of social robots as defined by Breazeal (2003). A social interface robot uses an anthropomorphic style in its interface (e.g. uses speech and facial expressions), but the social model it has is shallow (if any) and the social behavior it displays is hard-coded or reflective.

Related to anthropomorphism and the CASA paradigm is the tendency of people to attribute personalities to machines (Dryer, 1999; Reeves & Nass, 1996). A personality is attributed to a social robot regardless of whether a personality has been designed for the robot or not. Similar to human-human interaction a personality is inferred from appearance and behavior. There are many definitions of personality. In this thesis we use the term personality as it was defined by Dryer (1999): *"A personality is a collection of individual differences, dispositions, and temperaments that are observed to have some consistency across situations and time."*. A personality can be seen as a mental model of others. We need to order the overwhelming information we collect when interacting with others to be able to anticipate on their behavior, and participate in a fluent social interaction (Dryer, 1999; Reeves & Nass, 1996). Although all people are different and the possibilities for a person to behave in a certain situation are infinite, we can predict how a person will behave in a certain situation based on observed behaviors of that person in other situations or on observed behaviors of others in a similar situation that are to some extend like that person. There are many different taxonomies of personality. The Big Five Theory, one of the most frequently used personality taxonomies, states that five continuous dimensions could be used to describe a personality (Meerbeek, Saerbeck, & Bartneck, 2009a). These dimensions or personality traits are: neurotic (anxious to calm), extraversion (outgoing to withdrawn), open (curious to closed minded), agreeable (cooperative to competitive), and conscientious (organized to lax) (Dryer, 1999). In human-human interaction a personality is used to predict and understand the behavior of others. In the same way a perceived robot personality is used to predict and understand the actions of the robot. For a robot without an intentionally designed personality this doesn't make much sense, since the robot's actions are unrelated to the perceived personality. However, robot designers could make use of the tendency of people to attribute a personality to a robot to improve its usability by designing a consistent personality for a robot. A consistent personality helps users to form a good mental model of the robot, which increases usability (Meerbeek, Saerbeck, & Bartneck, 2009b).

Like human personalities, certain robot personalities are generally more liked than others. People prefer a robot with a strong, consistent, agreeable, and extravert personality (Dryer, 1999). Research has shown that implementing these personality characteristics can increase usability and acceptance of a robot. Some researchers have argued that the type of robot personality that is preferred might depend on the task or role of the robot (Dryer, 1999; Hendriks et al., 2010; Meerbeek, Hoonhout, Bingley, & Terken, 2006). To get a first impression of the type of personality that would suit a medication and appointment reminder robot we asked the ten interviewed elderly people to indicate what kind of personality facets they would like for a medication reminder robot. The majority of the interviewees desire a robot that is warm, open, creative, calm, spontaneous, efficient, systematic, cooperative, and polite. These are generally desirable personality facets. Interestingly, the opinions of participants were diverse on facets that are related to extraversion (see mean standard deviation figure 14 appendix A).

Although there are general socially desirable personality traits, a person's own personality influences the type of personality he/she likes (Dryer, 1999; Reeves & Nass, 1996). Research has shown that certain personality matches result in a more satisfying interaction than others (Dryer, 1999). Personality psychology has described two seemingly contradicting social rules for the attraction between personalities: (a) similarity attraction (people are attracted to personalities similar to their own personality), and (b) complementary attraction (people are attracted to personalities complementary to their own personality) (Dryer, 1999; Nass & Yen, 2010; Reeves & Nass, 1996). Both social rules are found to be applicable to interaction with robots and computer agents. Some studies have shown a positive influence on the usability of a robot or computer agent with a similar personality (e.g. robot and user with a similar extraversion level) (Nass & Lee, 2001; Tapus & Matari, 2008; Walters et al., 2007), while other studies have shown a positive effect of a complementary personality (e.g. robot and user score on the opposite side of the extraversion scale) (Isbister & Nass, 2000; Lee et al., 2006). A clear answer on the cause of these seemingly contradicting findings is not yet provided. Therefore, in this study we will not only test the effect of similarity matching on robot acceptance but also explore the mechanism behind robot personality preferences.

Related studies have found a 'halo effect' (in which a positive rating in one dimension results in more positive rating of other dimensions) of personality matching (complementary or similar) (Walters, Syrdal, Dautenhahn, te Boekhorst, & Koay, 2007). Personality matching resulted not only in liking of the robot or computer agent, but also increased the perceived intelligence and trustworthiness (Lee, Peng, Jin, & Yan, 2006; Nass & Lee, 2001). The positive effect of personality matching goes even beyond the evaluation of the computer agent itself (Nass & Lee, 2001). The results of that study show that personality matching influenced the evaluation of the information provided by the computer agent and even the evaluation of the creator of that information. Based on this 'halo effect' we expect user-robot personality matching to positively influence diverse aspects that contribute to the acceptance of a robot.

During this study we will focus on the extraversion dimension of personality for user-robot personality matching for the same three reasons why Lee et al. (2006) focussed on that dimension. Firstly, extraversion is - along with agreeability - the most important factor that influences interpersonal interaction. Secondly, previous studies, that showed an effect of user-robot or user-agent personality matching, matched the personalities on extraversion level. Finally, extraversion is the most accurately observed personality trait (Lee et al., 2006).

Several studies showed that in general people prefer sociable (the most prominent characteristic of extraverted people) and extravert robots or computer agents (Goetz & Kiesler, 2002; Heerink, Kröse, Evers, & Wielinga, 2010; Heerink, Kröse, Wielinga, & Evers, 2009; Looije, Neerincx, & Cnossen, 2009; Meerbeek, Hoonhout, Bingley, & Terken, 2008; Midden & Ham, 2009; Verhaegh, 2004; Walters et al., 2007). These personality characteristics increase the enjoyment of the interaction, intention to use a system, technology acceptance, and social acceptance (Bickmore, Gruber, & Picard, 2005; Heerink et al., 2010; Heerink, Kröse, Wielinga, et al., 2009). Thus, these studies suggest that we should design an extravert personality for the agenda and medication reminder robot to increase the acceptance of the robot. Is this influence of the robot's extraversion level on the user acceptance, like studies that showed that social rules like similarity attraction and complementary attraction are applicable to social robots and computer agents suggest, depended on the extraversion level of the user? Is an extravert person more willing to use an extravert robot and an introvert person an introvert robot? Or visa versa? Since studies on user-robot or user-agent personality matching provide contradicting conclusions about which of the two social rules (similarity attraction or complementary attraction) has the most dominant influence on the interaction, we do not only want to know which social rule can be applied to the interaction with the agenda and medication reminder robot for elderly, but also why a certain personality is preferred by potential users. We therefore conducted two experiments: 1) an experiment to test the influence of user-robot similarity matching on robot acceptance, and 2) an experiment to explore the reasons behind personality preferences.

The next chapter describes studies that are related to this study since they also tested the effect of perceived robot personality or computer agent personality on the interaction with the system. This related work motivates our study direction and our hypotheses. Chapter three describes in detail the aim and set up of the user experiments. Section 3.3 titled *Materials* briefly describes the system that was used during the experiments to control the robot. A more detailed description of the system designed to control the behavior of the robot is described in appendix C. Section 3.3 also shows the face that was used for the robot. We decided to display an interactive face on the robot because several studies showed that an animated character with a face (a robot or an embodied conversational agent) results in more positive evaluation of the system and the information it provides and more compliance compared to a textual interface (Bickmore et al., 2005; Looije, Cnossen, & Neerincx, 2006; Looije et al., 2009; Wiekens, 2011) We have designed the used face especially for the Florence Robot during an earlier research project (Brandon, 2012). The results of the two experiments we conducted with the agenda and medication reminder robot are described in chapter four and discussed in chapter five. Chapter six summarizes the conclusions that could be drawn from the results of our experiments. Finally chapter seven provides suggestions for future research directions.

2. Related Work

This chapter describes studies related to the effect of personality design for robots or computer agents on HCI (Human Computer Interaction) and HRI (Human Robot Interaction). Both experiments with robots and experiments with computer agents are described, since the reaction of people to computer agents and to robots is comparable (Lee et al., 2006). The first section describes studies that empirically tested the effect of a robot's personality or computer agent's personality on usability, acceptance, and performance. The conclusions of these studies are ordered by personality design topics. The second section describes studies that compared the effect of similar user-agent or robot-agent personalities with the effect of complementary personalities. These studies are ordered by the social model (similarity attraction or the complementary principle) they support. Section three discusses how the described related work motivates the current study.

2.1. Effects of robot and computer agent personalities

In the recent decades there have been several research projects that studied the effect of intentionally designed personality for conversational agents and robots on HCI and HRI. Most of these studies found that a designed robot personality could be successfully recognized. Perception of the personality can be successfully influenced by manipulating verbal and non-verbal behavior of the robot or agent. Studies that reported that their participants were unable to recognize the designed personalities used too subtle personalities or made the duration of the interaction with the robot or agent too short (Meerbeek et al., 2008; Robben & Neerincx, 2011; Verhaegh, 2004).

Social abilities. Several studies have compared the effect of social robots or agents with less social robots and agents. These studies use a range of behaviors to indicate the social abilities of the robot or agent. A social robot has a personality with high scores on all five traits of the Big Five Theory. Mainly, a high level of extraversion and agreeability are associated with social abilities. The social abilities of the robot or agent increased the perceived empathy of the robot or agent (Looije et al., 2009), the trustworthiness (Looije et al., 2009), the conversational behavior of the user in reaction to the robot or agent (Heerink et al., 2010; Heerink, Kröse, Wielinga, et al., 2009; Looije et al., 2009), the feeling of comfortability (Heerink et al., 2009) and the persuasiveness (Midden & Ham, 2009). Moreover, there is a positive correlation between social abilities and intention to use a robot, technologic acceptance, and social acceptance of the robot (Bickmore et al., 2005; Heerink, Kröse, Evers, & Wielinga, 2006; Heerink et al., 2010). Some studies combined behaviors that make the robot or agent more human-like or more lively (e.g. blinking) with behaviors that are related to a “social personality” (Heerink et al., 2010; Looije et al., 2009). Due to this combination the cause of the positive effects of the social robots is unclear. Is it the “social personality” or the human-likeness that contributes to the positive effects?

Lee et al. (2006) found that the social responses to robots are mediated by the feeling of social presence during the interaction with the robot. A high feeling of social presence means that the user perceives the robot as a natural social partner during the interaction. They also found that a participant who has the tendency to form para-social relationships (people that form an affective relationship with a media character) feels more social presence during the interaction with the robot and will perceive the robot as more socially attractive. Certain personalities increase the feeling of social presence. Sociability determines social presence.

Empathy. A study that tested the influence of expressed empathy on the evaluation of embodied conversational agents shows that an empathic agent is more liked, more trusted, and perceived to care about the user (Brave, Nass, & Hutchinson, 2005). The users felt more supported by the empathic agent. Therefore, empathy is an effective characteristic for robots or agents with a persuasive or coaching task. The appropriate level of empathy for the agent might depend on the user’s personality and the application domain. An interesting consideration for personality design is that the expression of empathic emotions is associated with submissiveness, which is highly correlated with introversion (Brave et al., 2005). The study of Brave et al. (2005) shows that a computer agent that expressed more empathy was perceived as more submissiveness than a computer agent that expressed less empathy.

Agreeability. Agreeability is generally perceived as a socially desirable personality trait. People who score high on the agreeable factor are friendly and cooperative. Results of studies that tested with more and less friendly robots or computer agents show that friendliness resulted in more compliance, more trust, and a stronger desire to use the robot or agent in the future (Bickmore, Mauer, Crespo, & Brown, 2007; Mahmud et al., 2007). Mahmud et al. (2007) performed a between subject experiment with 30 participants who watched a video of an agent that tried to persuade a person to use less energy. There were two types of agents: a friendly and an unfriendly one. The friendly agent was trusted more, and those participants indicated that they would comply more with the friendlier agent. Bickmore et al. (2007) performed an experiment to see whether the perceived politeness of an interruption by an agent has an effect on the compliance with the agent's suggestion. Their results show that the friendliness of an interruption (they used sounds for the interruption that varied in friendliness) positively correlates with compliance and desire to use the system in the future.

Bartneck, Van Der Hoek, Mubin and Mahmud (2007) performed an experiment to test whether a robot’s perceived intelligence and agreeability contributes to animacy (the perceived level of aliveness) of the robot. Among other measures they took the hesitation of participants to kill the robot by turning it off which was told to destroy the robot's knowledge and personality as an indicator of animacy. Participants hesitated three times as long to turn of an intelligent and agreeable robot than to turn of an unintelligent disagreeable robot. One limitation of this experiment is that the hesitation could be due to the difference in expected costs of the robots. An intelligent, agreeable, and more human-like robot could have been perceived as more expensive, and this perceived cost might have increased the hesitation (Bartneck, Van Der Hoek, Mubin, & Al Mahmud, 2007).

Extraversion. In general people like to interact with extraverted robots and computer agents (Goetz & Kiesler, 2002; Kiesler & Goetz, 2002; Meerbeek et al., 2008; Verhaegh, 2004; Walters et al., 2007). However, the appropriate level of extraversion might depend on the task and role of the robot or the computer agent. A study that asked six potential end-users of a robotic vacuum cleaner to describe the type of personality they would like it to have found in contrast with earlier studies that most (five of six) participants desired an introverted and withdrawn vacuum cleaning robot (Hendriks et al., 2010). This result could be explained by the specific role of the robot: vacuum cleaning. It might be the case that people prefer a less extravert personality for a service robot and a more extravert personality for a robot that has a companion role (e.g. a game companion robot).

Goetz and Kiesler (2002) compared the compliance of users to an extraverted playful robot and a serious concerned robot. The robots encouraged the participants to perform breathing and stretching exercises. The participants rated the interaction with the playful extravert robot more positively, but in contrast with the expectations of the researchers the encouragements of the serious concerned robot resulted in longer exercising, which could mean that their was more compliance to the serious robot. The authors provide five reasons for this finding:

1) a serious robot is consistent with the serious exercising task the robot asked the participants to perform;

2) people don’t expect a robot to be playful;

3) a serious robot seems to take the users task serious and therefore might seem to care about the user's health;

4) a serious robot is more credible and more convincing;

5) a serious robot is more likely expected to disapprove of the user when the user doesn't follow the robot's advice. The higher compliance is thus explained by the ‘seriousness’ of the robot and not the relative introversion of the robot.

Meerbeek et al. (2008) designed a personality for a TV program adviser robot, implemented on the iCat (a cat-like robot developed for research by Philips). They implemented one extraverted agreeable personality and one introverted formal personality. During a first experiment their results showed that the participants could successfully recognize the personalities. Participants gave the extraverted robot higher scores on intelligence, although both robots had the same level of intelligence. The personality of the introverted robot was made less extreme for a second experiment. The robot was perceived as shy and depressed during the first experiment, which was undesirable according to the researchers. Participants didn’t recognize the personalities during the second experiment. The researchers wanted to know the level of control preferred for a TV program recommendation robot and whether a certain level of control would match a certain personality. Participants preferred the extravert agreeable robot. The recommendations of the extraverted robot were more appreciated and the participants were more willing to use the extravert robot in the future. The results show that a high level of user control is a better match with a more introvert robot and a low level of user control with an extraverted personality. Thus, the personality design could also be used to influence the perceived level of user control. By making the personality more or less extravert the perceived level of control could be influenced.

In 2004, Verhaegh performed an experiment with children playing a game with a robotic iCat game companion. Each child experienced three types of game companions: 1) Katy, an extravert and agreeable yellow iCat, Phoebe, an olive green iCat with a normalized personality (scores in the middle of the personality construct scales), and Felice, a static image on a computer screen of the yellow iCat. The results of the experiment show that children did seem to recognize the design personalities for the iCat. However, the differences between the perceived personalities were not significant. Most children preferred Katy, the extravert robot game companion.

Consistency. People prefer to interact with others who have consistent personalities (Dryer, 1999). It is common knowledge in HCI that an interface should be internally (all items within the interface have consistency in their appearance and behavior) and externally consistent (consistent with users expectations). The rule of consistency is widely applied in character design for movies, animations, games, etc. Isbister and Nass (2000) performed an experiment with 40 participants that played a game on a computer with an embodied screen-agent that provided suggestions. The personality of the agent was expressed through its body-language and text (displayed in a text balloon on the screen). Some participants experienced an agent that displayed the same personality in text and body language, while other participants experienced an agent of which the body language was inconsistent with the personality inferred from the text. The agent with a consistent personality was perceived more enjoyable, more useful for interaction, and a more useful character. Moreover, participants liked and trusted information provided by an agent with a consistent personality more, although the information provided was constant over the conditions. The influence of consistency on the evaluation of the agent and the information the agent provided was stronger than the found positive effect of agent-user personality matching (Isbister & Nass, 2000).

A year later, Nass performed an experiment together with Lee that tested the effect of personality consistency between voice and text of a TTS-system (text to speech system) (C Nass & Lee, 2001). The results show again that consistency of the personality inferred from the voice and the personality inferred from the spoken text increased the liking of the voice, the credibility of the writer of the text, and the liking of the writer.

Personality Strength. Dryer (1999 p. 282) describes a study that showed that the strength of a personality has an influence of the liking of a character. "*It may be better to be extreme on the socially undesirable end of a dimension than to be in the middle".*

Summary. The above described studies indicate that a deliberately designed robot or computer agent personality will be recognized by the users and influence the evaluation of the system. In general it is a good idea to design a sociable, empathic, agreeable, extravert, strong and consistent personality. However, the most appropriate personality for a system depends on the task and role of the system. For example, if perceived empathy of a system is important (e.g. for coaching system) it might be better to design an introvert personality, because empathy is associated with submissiveness. The study of Goetz and Kiesler (2002) showed more compliance with an introvert serious robot exercise coach than with a extravert playful robot. A robot with service oriented tasks like vacuum cleaning might also require a more introverted character. Social presence has a mediating function in the effect of a designed personality. People that have the tendency to form para-social relationships with media characters will feel more social presence during the interaction with a computer agent or social robot. Table 11 in appendix F shows an overview of the effects of personality characteristics as described in the studies reported in this section.

2.2. Robot-user or computer agent-user personality matching

In human-human communication it has been shown that certain combinations of personalities lead to a more enjoyable and effective interaction. In the introduction we described the social rules "similarity attraction" and "principle of complementarity". Some studies (Nass & Lee, 2001; Tapus & Matari, 2008; Walters et al., 2007) showed that the similarity-attraction rule was applicable to the interaction with a computer agent or robot and other studies have found the complementarity principle to play a role ((Isbister & Nass, 2000; Lee et al., 2006).

Similarity attraction. Nass and Lee (2001) performed an experiment to test the effect of user-system personality matching. They used a TTS (text to speech system) for a website that provides book reviews (C Nass & K M Lee, 2001). Participants (40 students) heard either an introvert voice or an extravert voice giving a book review. The volume level, fundamental frequency, frequency range and speech rate of the voices were manipulated. The TTS with a personality similar to the participant positively influenced the evaluation of the voice, the review, and the writer of the review. The similar personality voice was liked more and perceived as more credible. The quality of the review was evaluated higher and more persuasive when presented by a voice with a similar personality. The personality of the writer of the review was inferred from the perceived personality of the TTS system that read the review. A similar personality voice that reads the review increased the trustworthiness and attractiveness of the review writer.

Walters et al. (2007) performed an experiment with three robots with different appearances: mechanical appearance, robot appearance, and humanoid appearance. The 79 participants (students) were shown video recordings of each type of robot. Each video recording shows the same scenario in which a domestic robot tries to draw the attention of an person to signal him that there is someone at the door. The person doesn't hear the door bell because he is listening to loud music. The robots don’t only differ in their appearances, but also use different methods to draw the attention of the user. Overall the participants preferred the humanoid appearance with a human-like method to draw the attention. Surprisingly, participants that scored low on extraversion and emotional stability preferred the mechanical appearance and the more mechanical way to draw the attention. According to Walters et al. this result relates to the stress that introverts and individuals that score low on emotional stability experience during social interactions. A mechanical looking robot suggests less social interaction than a humanoid. After the interaction with the robots the participants were also asked to score the personality of the robots. The robot with the mechanical appearance was rated low on extraversion and emotional stability. This suggests that the difference in appearance preference related to the user's personality can be explained with the similarity attraction rule.

Tapus and Mataric (2008) have evaluated the effect of matching the personality of a social health coach robot to the personality of the user. The robot was used for post stroke rehabilitation therapy. Twelve participants were told to perform several rehabilitation exercises as long as they liked. Either an extravert robot with a challenge-based encouragement style or an introvert robot with a nurturing-based encouragement style supported the exercises. They used activity level and sociability as cues of personality. Extravert people are according to Eysenck more sociable, more energetic and more active than introvert people (Tapus & Matari, 2008). Introvert participants liked the extravert and introvert robot equally. In contrast, extravert participants preferred the extravert robot. The results showed that personality similarity matching resulted in longer, and more enjoyable exercise sessions. This result shows that similarity matching not only improves the satisfaction of the interaction and the perceived value of information provided by the system, but also increases the persuasive power of the system. It also suggests that extravert people are more influenced by similarity attraction.

The complementary principle. In section 2.1. under *"consistency"* we described a study of Isbister and Nass (2000) in which participants interacted with an embodied computer agent that provided suggestions during a game play. This experiment was not only designed to compare the effect of an agent with a consistent personality with an agent with an inconsistent personality, but it also tested whether similarity attraction had a positive influence on the evaluation of the agent. The personality of the game companion agent was modified through both verbal and non-verbal cues (gestures and body pose). The agent with a complementary personality to the participant was liked more and perceived as more enjoyable to interact with.

Lee et al. (2006) have conducted a similar experiment with two types of personalities (extravert and introvert) implemented in an AIBO dog (a dog-like robot from Sony). The personalities where manipulated by verbal (loudness of speech, mean fundamental frequency, frequency range, and speech rate) and non-verbal (facial expressions, moving angle, moving speed, autonomous movement) behavior. Similar to the findings of Isbister and Nass participants (students) evaluated the AIBO dogs with a complementary personality as more intelligent, more socially attractive, and more enjoyable. Participants also felt more socially present during the complementary personality condition. Social presence was found to function as a mediating factor between personality matching and the perceived enjoyment, perceived intelligence, and attractiveness of the robot. The feeling of social presence was stronger when participants interacted with an AIBO dog with a complementary personality.

Isbister and Nass (2000) and Lee et al. (2006) explain their seemingly contradicting results with earlier studies that found that similarity attraction was of more influence on the evaluation of robots and computer agents, by the fact that they used embodied characters in their experiments. According to the researchers the embodiment triggers a more human-like reaction. Complementary attraction is found to play an important role in human-human interaction satisfaction. This explanation is questionable since Walters et al. (2007) and Tapus and Matari (2008) found that similarity-attraction positively influences the satisfaction of the interaction with robots (thus embodied). It might be that in case of embodied characters both similarity attraction and complementary attraction play a role and that in case of disembodied characters only similarity attraction plays a role.

Summary. Social rules like similarity attraction and complementary attraction from human interaction are applicable to human-robot and human-computer agent interaction. Matching the personality of the robot or computer-agent with the personality of an user could increase liking, credibility, persuasiveness, trustworthiness, enjoyability, perceived intelligence, social attractiveness, and social presence. The results of Tapus and Mataric suggest that extraverted people are more sensitive for personality matching then introverted people. Which of the two social rules is the most appropriate for a medication and agenda reminder robot is unclear. Isbister and Nass (2000) and Lee et al. (2006) suggest it depends on the embodiment of the system. Table 12 and 13 in appendix F provides an overview of studies that looked at the effect of user-system personality matching.

2.3. Implications of related work on this study

The above described studies provide knowledge that could help us to design a robot personality. In general robots and agents with social abilities and with a strong, consistent, extravert and agreeable personality have the most positive effect on HCI and HRI. However, the type of personality that is the most effective might depend on the role and task of the robot, the characteristics of the target users and on the personality of the user. The related studies show that social rules like similarity attraction and complementary attraction are applicable to the interaction with robots and computer agents. However, the studies differ on which of these rules is the most applicable. Which social rule is the most applicable for a social domestic medication reminder robot is unclear. Whether adapting social rules like similarity attraction could improve the acceptance of a social domestic service robot for elderly is an open issue. This thesis describes an experiment that tests the influence of robot-user personality matching on acceptance.

Another gap in the related work are the mechanisms behind the personality preferences. Why are people attracted to people (and robots) with similar or complementary personalities? Are the reasons why introverted people are attracted to introverted people equal to the reasons why extraverted people are attracted to extraverted people? With this study we wanted to explore the reasons behind their attraction to a robot personality.

3. User Experiments

The aim of this study was to test the effect of robot-user personality matching on the acceptance of a social assistive robot by elderly and to explore reasons for personality preferences. Related studies showed contradicting findings on which social rule, similarity attraction or complementary attraction, has the biggest impact on the interaction. In his most recent book Nass (2010) argued that similarity attraction has a stronger influence than complementary attraction on the interaction with computer agents. We therefore expected that robot-user similarity matching to have a positive effect on the acceptance of a robot. To test this expectation we designed two personalities for the Florence Robot; an extravert personality and an introvert personality. We conducted two experiments in which the 22 elderly participants experienced the agenda and medication reminders provided by the Florence Robot with an extravert or introvert personality. The aim of the first experiment was to test the following hypotheses:

(h1) *A designed personality will be successfully recognized by elderly users, and*

(h2) *User-robot similarity matching on extraversion improves the acceptance of a domestic assistive social robot that provides agenda and medication reminders by elderly.*

The goal of the second experiment was to explore the mechanisms behind robot personality preferences.

It was impossible to place the robot in the homes of elderly participants and let participants use the robot as a medication and agenda reminder for a few weeks due to the status of the Florence robot, the status of the agenda and medication reminder application and time constraints of this study. Instead, elderly people experienced the robot in a home-like laboratory room of the Experience Lab of Philips Research in Eindhoven, the Netherlands. We used WOZ (Wizard of Oz) experiments. A WOZ experiment is an experiment in which participants believe that they are interacting with a fully automatic system, while the actions of the system are fully or in part controlled by a person. In our experiments the experiment leader controlled the behavior of the robot from a different room.

3.1. Participants

A few weeks before the actual experiments, 48 elderly people (aged 60 years or older) filled in a questionnaire. The questionnaire contained a validated Dutch version of the 44 items Big Five Inventory test, some questions about personal information (e.g. age, gender, computer usage) and questions about their general need and interest regarding a medication and agenda reminder device. We used the BFI-44 because it is a validated and frequently used personality test. The BFI-44 consist of 44 statements (for each construct six or seven items) to with the participant can indicate his or her level of agreement on a five point Likert scale (1= totally disagree, 5= totally agree).

Most people recruited were found on a list of people that participated in other experiments of Philips. There were several exclusion criteria. Participants should be aged 60 years or older, speak Dutch fluently, should have no visual or hearing problems that make it difficult for them to hear or see the robot, and have no mental or cognitive disabilities that make it difficult for them to complete the tasks of the experiment. People were told that the goal of the experiment was to test a medication and agenda reminder device. They were not informed that the used device would be a robot. This information was not revealed to avoid getting a selection of people that had an affinity with robots. From the 48 potential participants, a group of 24 people with the most extreme and consistent scores (standard deviation of the score of items on the extraversion construct) on extraversion-level calculated from the BFI-44 test results were selected for the experiments. Participants weren't told that and why they were given a personality test and what criteria were used to select participants. Selected participants were classified as either extravert or introvert. Twelve selected participants were classified as introvert and twelve were classified as extravert.

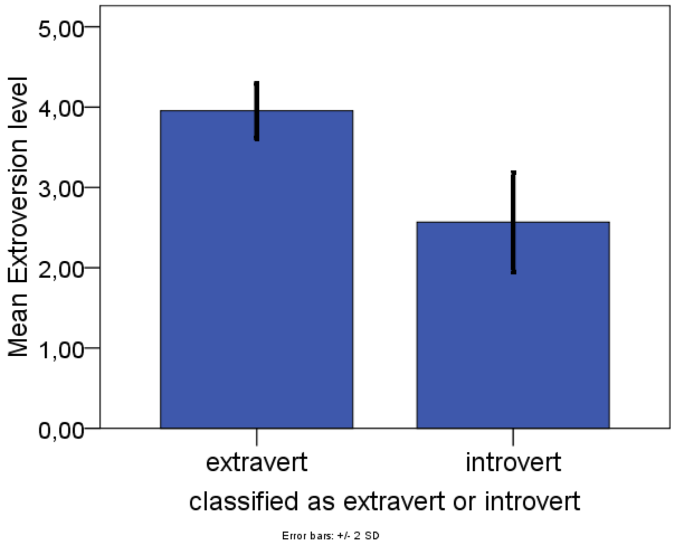


*Figure 1: mean and standard deviation (errorbars: +/- 2*SD) extraversion level participants classified as extravert and participants classified as introvert*

Two participants of the selected twenty-four participants with the most extreme extraversion level, couldn't participate because they had serious health problems at the time of the experiment. Thus, the experiments were conducted with 22 participants (aged 63 to 87 years, 11 male and 11 female). The data of one participant for the second experiment was not used for analysis because there where no video recordings of this participant. Thus, for the second experiment we analyzed the data of 21 participants. Figure 1 shows a significant ($p < .01$) difference between the mean extraversion level of the group of people classified as extravert (N=11, 6 female 5 male, age: M=67.73 years SD=3.197) that had a mean extraversion level of 3.95 (SD=0.20) on a five point scale and the group classified as introvert (N=11, 5 female 6 male, age: M=74.45 years SD=8.407) that had a mean extraversion level of 2.57 (SD=0.31).

Half of the extravert and introvert participants experienced an introvert robot during the first experiment and the other half an extravert robot. Thus, half of the participants experienced a similar robot personality and the other half a complementary robot personality. We tried to match the participants in the similar (SIM) group and complementary (COM) group on age (SIM: M=71.36 years, SD=6.889 and COM: M=70.82 years SD=7.627) and gender. (SIM: 5 female, 6 male and COM: 6 female, 5 male). We also tried to match the participants in the extravert robot (EXT ROB) group and the introvert robot (INT ROB) group on age (EXT ROB: M=69.4 years, SD=8.369 and INT ROB age: M=72.5 years, SD=5.839) and gender (EXT ROB: 6

female, 4 male and EXT ROB: 5 female, 7 male).

3.2. Experiment design

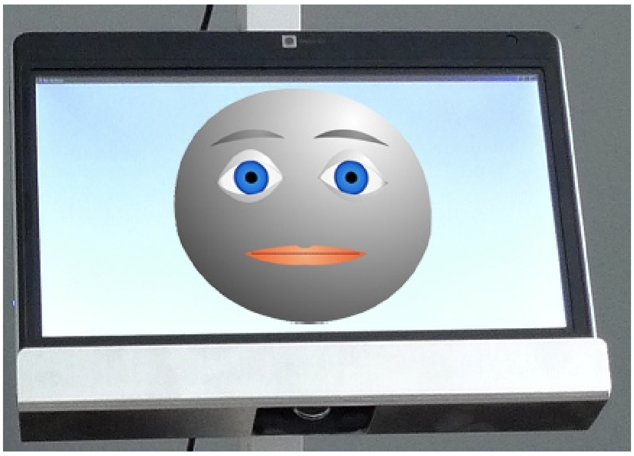
Experiment 1. The first important decision for the first experiment design was between a "within-subject design" or "between-subject design". Both methods have their pros and cons. During a "within-user design" participants will experience both types of robots in sequence, first an introvert robot and then an extravert robot or vice versa. The main advantage of this method is that twice as many participants experience each robot personality. This increases the strength of the results, which is especially desirable when the project's limitations only allow to test with a small number of participants. However, an important drawback of these type of experiments is the risk of order effects influencing the results. Apart from the order effects like getting tired (more likely during experiments with elderly people), getting bored or getting used to the robot, we expected an extra order effect in relation to the order of the personalities. It can be expected that people will not perceive personalities displayed by the same robot, with a similar face and a similar voice as belonging to two separate entities. On the contrary, participants might perceive the two designed personalities displayed after each other by one robot as a personality change of one entity. Personality change towards the personalities of the user has a positive influence on the evaluation of a robot (Nass & Yen, 2010) . Therefore, the perceived personality change is expected to influence the measures for acceptance. Giving each personality a different appearance of the face or a different voice could enforce the perception of two separate entities with different personalities. Unfortunately, additional variance between the conditions might cast a shadow on the results. Another drawback of a "within-user design" is a longer duration of the experiment, because participants have to interact with both types of robots twice and fill in a post-condition questionnaire twice. Experiments and especially experiments with elderly people shouldn't last too long. Yet another disadvantage of a "within user design" is that participants will be more aware of the differences between the conditions. As a result of this awareness people will experience the robot differently (e.g. they will pay more attention to differences). This awareness also increases the risk of getting socially desirable answers.

Given these pros and cons of both methods we decided to use a "between user design" for the first experiment. A 2 (introvert participant vs. extravert participant) by 2 (similar robot personality vs. complementary robot personality) has been conducted. During the experiment participants experienced one type of the robot personality and filled in a perceived robot personality questionnaire and a robot acceptance questionnaire afterwards.

Experiment 2. The second experiment was conducted after the first experiment with the same participants. The goal of this experiment was to get insight in the mechanisms behind robot personality preferences. This experiment had an explorative nature. A semi-structured interviewing technique was used to collect qualitative data about reasons behind robot personality preferences. The participants were shown the two robot personalities providing a medication reminder in sequences. The order of the robot personalities was interchanged between participants. Subsequently, the participants were asked to indicate and deliberate their preference for the first or second manner to provide an reminder. The participants weren't told that the difference in the ways to provide a reminder was related to the extraversion level of the robot.

3.3. Material

The Florence Robot. The Florence robot is shown in Figure 2b. The Florence robot consists of a Wany Pekee mobile robot platform base. The Wany Pekee robot has an embedded PC on which Linux is running as the operating system and all the robot specific (e.g. navigation) software is running. The Wany Pekee robot base has an embedded infrared telemeter module that can be used for navigation (e.g. can be used to create a map of the room and to detect obstacles). The base has two steering wheels. The robot can move forward, backward, and rotate 360 degree in horizontal direction. On top of this base the Florence robot has a pillar with a touch-PC holder and a touch-PC in the holder. A Kinect-sensor bar is placed on top of the pillar. The Kinect-sensor can be used for user localization, user detection, navigation, object recognition, etc. During the experiments the touch tablet displayed the face of the robot. Figure 2a shows the face of the Florence Robot. We designed this face especially for the robot during an earlier project (Brandon, 2012a). The touch input and the Kinect-sensor bar were not used during this project.



(a)

(b)

Figure 2: Florence Robot. (a) Tablet-PC with robot face, (b) Wany Pekee PC base with stand,Tablet PC, and Kinect sensor.

The System to Control the Behavior of the Robot. To control the behavior of the robot we designed a system that consists of five components: 1) a (WOZ) Wizard of Oz application with a graphical user interface to send BML (Behavior Modeling Language), 2) a modified and extended Elckerlyc BML realizer, 3) a Loquendo TTS System (text to speech), 4) an interactive animated face, and 5) a remote control robot application to move the robot. Figure 3 shows these components and how they are connected. The system controls speech output, interactive face animation, and robot movements. The WOZ application provides an interface to control the behavior of the robot (speech and facial expressions). When a button in the WOZ interface is pressed, a description of the robot's behavior in BML is sent to the Elckerlyc BML realizer. The Elckerlyc BML realizer (http://elckerlyc.ewi.utwente.nl/) translates behavior described in BML to a language that the behavior realizers (Loquendo and the interactive face) understand. Elckerlyc is also responsible for the timing of the behavior realization. Elckerlyc is a freely available BML realizer developed by the University of Twente.

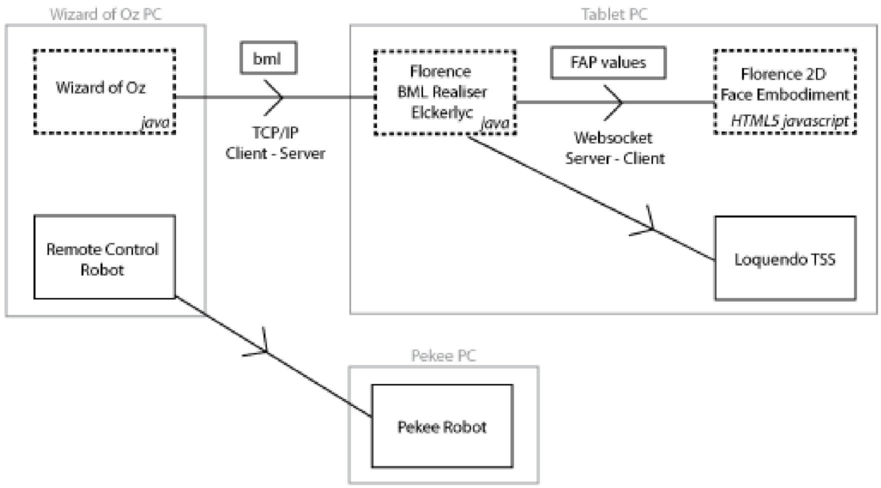


Figure 3: Architecture system to control Florence robot speech, facial animation, and movements

We used Loquendo TTS-system because of its high quality voices and the support of SSML (synthetic speech language) that allows influencing speech characteristics like speech rate, speech volume, and speech frequency range which were used to modify the personality of the robot. We use the Dutch voice called "Willem" of Loquendo during the experiments.

Since we designed our own robot face during this project we also implemented our own interactive face application. The interactive face is implemented using javascript and html5 canvas and uses the MPEG4 facial animation format. The MPEG4 face animation format defines FAPs (Facial Animation Parameters). Other applications can send values for the FAPs to the interactive face. Based on these FAP values the interactive face is animated through translation of FPs (feature points) in the face. The FP translation is calculated from the FAP values. For each FAP the MPEG4 facial animation format defines which feature point is translated if its value changes and in which direction. FAPUs (facial animation parameter units) are distances between FPs in a neutral face (for example the distance between the eyes) these FAPUs are used to normalized the FAP values for faces with different proportions. Thus, Elckerlyc translates an abstract description of a facial behavior in BML received from the WOZ application to FAP values and sends these

FAP values to the interactive face.

With the remote control robot application the experiment leader drove the robot during the experiments using the arrow keys on the keyboard.

For a more detailed description of the system and the components that were designed or modified for this project (Wizard of Oz application , Elckerlyc BML realizer, interactive animated face) see Appendix C.

3.4. Procedure

Selected participants were invited to the experience lab of Philips research in Eindhoven, the Netherlands. Figure 4 shows the order of the tasks performed during the session.

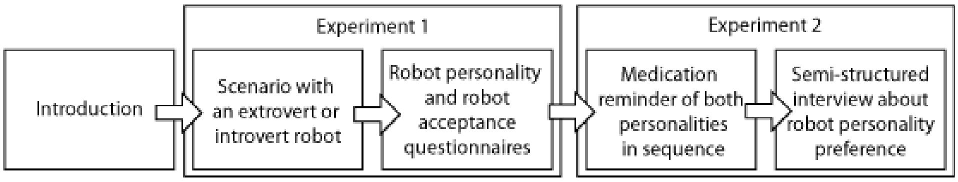


Figure 4: The order of the tasks performed during the sessions with elderly participants in the Experience lab..

Introduction. After signing a consent form the participant was introduced to the robot, the home-like laboratory room and the control room. The participant was informed about the cameras and microphones present in the home-like laboratory room. The researcher told the participant that the test would be recorded for analyzing data purposes. The participant was informed about the capabilities of the robot (e.g. robot can drive, robot can speak, robot can’t understand human speech). The purpose of the Florence project (designing a robot for elderly user with care related and entertainment related applications) was explained and two examples of applications for the robot beside providing agenda and medication reminders were given (robotic telepresence, and fall handling). The participant wasn't told that the robot was controlled by the experiment leader from another room.

First experiment. After this introduction an explanation of what was expected from the participant during the first experiment was given. During the first experiment the participant played a scenario with the robot in which the robot provided three reminders to the user. The participant was asked to pretend that the home-like laboratory room was his or her home. The participant was left alone in the home-like laboratory room during the scenario with the robot. The researcher could see the participant during the scenario and could, if needed, give instructions to the participant via an intercom.

A Wizard of Oz system was used to control the robot (see chapter 4). When the participant entered the room the robot turned towards the participant and greeted him. The participant was instructed to sit on the couch after entering the room. The robot followed the user towards the couch and stood still at about 6.5 feet (1.98 m) distance from the user (its standby position). The robot turned towards the television. The participants could watch a movie on the television or read a book. During the scenario the robot drove three times from his standby position to the participant to provide a reminder: first a medication reminder, secondly a reminder that someone from the thrombosis services would come to the participants home to measure his or her blood status, and thirdly a reminder of an appointment with the doctor. No actions from the participant were required after the reminders, except for the last reminder. The participant was instructed to leave the room after the last reminder. The robot greeted the participant when he or she left the room. After a reminder the robot drove back to its standby position. Pauses of one minute were kept between the reminders. The duration of this scenario was 5 minutes.

After this scenario the participant was asked to fill in a questionnaire to measure the acceptance of the robot and another questionnaire to measure the personality he or she attributed to the robot.

Second Experiment. Subsequently, the participant was asked to take place on a chair in front of the robot. The participant was instructed that he would be shown two types of reminders and that he would be asked about his preference afterwards. The participant was shown a medication reminder given by the extravert robot followed by a medication reminder given by the introvert robot or visa versa. The robot didn't move. It only used speech and facial expressions. The robot behavior was again controlled by the researcher from the control room using the wizard of oz application. Afterwards the participant was asked to indicate and deliberate his or her preference for the first or second way (introvert or extravert way) of providing a medication reminder using a semi-structured interviewing method. The first two questions were: “Which of the two manners you saw to provide an medication reminder would you prefer?” “Why would you prefer that manner?”

3.5. Manipulation

The personality of the robot was created by manipulating spoken text, speech characteristics, amplitude of facial expressions, and the distance the robot keeps from the user while giving a reminder (Proxemics). Figure 5 shows how the different robot personalities behaved during the scenario.

Figure 5: The texts spoken by the extravert robot and introvert robot during the scenario in the first experiment.

	Introvert robot	Extravert robot
The robot greets the user when he/she enters his/her home.		
	Robot: *"Hello."*	Robot: *"Hello sir. Welcome home."*
The robot provides the user a medication reminder.		
	Robot: *"Madam. Madam, I believe it's time for your medicine. I hope that you don't mind that I have asked Annie, the home care lady to place the medication on the table."*	Robot: *"Sir, I have to disturb you. It's time you know. Yes, you got it. It's time again for you medication. Take your medication quickly, so you can continue watching the movie. I have asked Annie, the home care lady to place the medication on the table. So, you don't have to go far. Good thinking of me, don't you think so?"*

The robot provides the user an appointment reminder.		
	Robot: "Madam. Madam, I believe that somebody of the thrombosis service is coming by any moment to measure your blood coagulability."	Robot: "Sir, I'm sorry but I have to disturb you again. Somebody of the thrombosis service is coming by shortly to measure your blood coagulability."
The robot provides the user an appointment reminder.		
	Robot: *"Madam. Madam, I believe that you got an appointment with the doctor in half an hour. So, maybe it's time for you to leave."*	Robot: *"I have to disturb you again. You got an appointment with the doctor in half an hour. So, it's time for you to leave, sir."*

The robot greets the user when he/she is leaving his/her home.		
	Robot: *"Goodbye."*	Robot: *"Goodbye sir. See you soon"*

Text. Extravert people use relatively more words and use strong assertive language expressed in the form of confident assertions ("I have to disturb you again", "*So, it's time for you to leave, sir.*"). However, introvert people use relatively less words and use weaker language expressed in the form of suggestion ("*So, maybe it's time for you to leave.", "Madam, I believe it's time for your medicine.*"). This knowledge found in (Isbister & Nass, 2000; Nass & Lee, 2001) was used to modify the phrases that the robot spoke in each condition. Although the phrases are different they provide the same factual information.

Facial Expressions. Extraversion has been modified in related studies by the expressiveness of the face of the robot or agent. To enforce the perception of a extravert personality the agent or robot displayed more facial emotional expressions with a bigger amplitude (Meerbeek et al., 2008; Verhaegh, 2004) . Because we wanted the introvert and extravert robot to be perceived equally friendly, both robot personalities showed the same friendly smile (see figure 6) at the same moment for same duration. Figure 7 shows a joy smile, this type of smile was only displayed by the extravert robot.

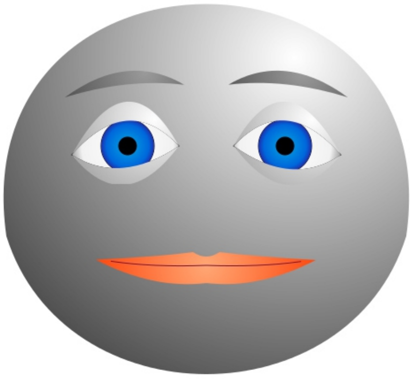


Figure 6: Friendly smile (extravert and introvert robot)

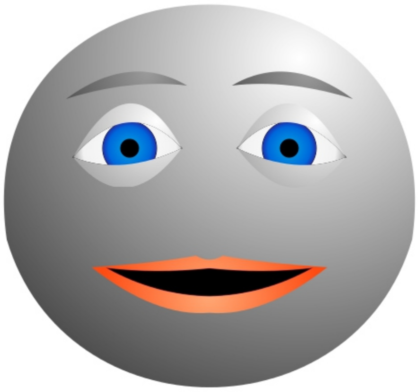


Figure 7: Joy smile (only extravert robot)

Voice characteristics. For both robot personalities we decided to use a Dutch male TTS voice of Loquendo (Willem). Extravert people talk faster, louder, higher fundamental frequency, and more frequency range (more variation in frequency) than introvert people (Nass & Lee, 2001). Therefore, we modified the voice in such a way that the extravert robot talks 2 time louder, 40 times faster and used 20 Hz more variation in pitch/frequency than the introvert robot. The fundamental frequency was kept constant over the conditions.

Proxemics. Edward T. Hall studied the non-verbal communication of humans through use of space (Hall, 1966 in Tapus and Matari, 2008). Hall coined the term proxemics defined as *"the interrelated observations and theories of man's use of space as a specialized elaboration of culture"*. According to Hall the physical distance between people is related to their social distance. Hall has defined four zones of interpersonal distance:

- intimate: up to 1.5 feet (.45 m),
- personal: between 1.5 and 4 feet (.45 and 1.3 m),
- social: between 4 and 12 feet (1.2 and 3.6 m), and
- public: between 12 and 25 feet (3.6 and 7.5 m).

According to Hall the distance that a person keeps to others also depends on the person's personality.

Extravert people keep less distance from interlocutors then introvert people. Similar to the study of Tapus and Matari (2008) we used the distance that the robot keeps from the user when it provides a reminder as an aspect to influence the perceived personality. The personal distance and social distance are the most appropriate for the reminder giving task. The introvert robot kept a distance of 4-5 feet (1.2-1.5 m) and the extravert robot kept a distance of 2-3 feet (.6-.9 m).

3.6. Measurements

There were two aspects we wanted to measure during the first experiment: a) perceived robot personality, and b) acceptance of the robot. After the participants experienced one of the two types of robot personalities their acceptance of the robot and the personality they attributed to the robot were measured using questionnaires.

Perceived Robot Personality. The Big Five Inventory (BFI) test was used to measure the personality that participants attributed to the robot (Benet-Martínez & John, 1998; John, Donahue, & Kentle, 1991; John, Naumann, & Soto, 2008). The BFI test is originally designed as a self-assessment test, but is also frequently used as an instrument to measure the personality that others attribute to a person. We made some small changes in the BFI questionnaire to make it suitable to measure the personality that participants attribute to a robot instead of a person. The BFI has been used by related studies to measure the attributed robot personality. A short version of the BFI test with sixteen items was used to reduce the time needed for this measurement. Since, we were mainly interested in the extraversion level attributed to the robot, this 16-items BFI consisted of all eight items for the extraversion construct of the validated 44-items BFI and the eight items for other constructs of the validated 10-items BFI (Rammstedt & John, 2007). The 44-item BFI is more reliable than the 10-item BFI. The order of the 16 items was made such that each extraversion item was followed by an item of another construct. The used 16-item BFI can be found in appendix D.

Robot acceptance. Acceptance can be defined as “the demonstrated willingness within a user group to employ technology for the tasks it is designed to support” (A. Dillon, 2001 in Heerink, 2009). In 2009 Heerink, Kröse, Evers, and Wielinga described a method to measure acceptance and the underlying constructs of acceptance of social robots (Heerink, Kröse, Evers, & Wielinga, 2009; Heerink et al., 2010).The method they described is based on an often-used acceptance model called UTAUT (Unified Theory of Acceptance and Use of Technology) (Venkatesh, Morris, Davis, & Davis, 2003). Venkatesh et al. (2003) formulated the UTAUT model that intergrades elements of eight earlier prominent acceptance models. Heerink et al. (2009) argue that the UTAUT model needs some additional constructs to be suitable for testing the acceptance of social robots, such that it contains constructs both for technological acceptance and for social acceptance. For the acceptance of a social robot not only aspects like Ease of Use or Perceived Usefulness are important, but also aspects in relation to the acceptance of the robot as a social actor. The model described by Heerink et al. (2010) is called the Almere Model and consists of the following constructs: Anxiety, Attitude, Facilitating Conditions, Intention to Use, Perceived Adaptability, Perceived Enjoyment, Perceived Ease of Use, Perceived Sociability, Perceived Usefulness, Social Influence, Social Presence, Trust, and Use. Heerink et al. (2009, 2010) developed an questionnaire for the Almere model. The questionnaire to measure the acceptance constructs of the Almere Model consists of 2 to 5 statements per construct for which the order is randomized. All constructs of the questionnaire were found reliable in experiments of Heerink et al. (2010).We used a Dutch version of this questionnaire and removed the items for the following constructs: Facilitating Conditions, Social Influence, and Usage, since they are not applicable to our experiment. Appendix E shows the constructs used and the items for each construct. Table 1 shows the used abbreviations and definitions of the constructs we used to measure the acceptance of the robot.

Code	Construct	Definition
ANX	Anxiety	Evoking anxious or emotional reactions when it comes to using the system
ATT	Attitude	Positive or negative feelings about the appliance of the technology
PAD	Perceived Adaptability	The perceived ability of the system to adapt to the needs of the user
PENJ	Perceived Enjoyment	Feelings of joy/pleasure associated with the use of the system
PEOU	Perceived Ease of Use	The degree to which one believes that using the system would be free of effort
PS	Perceived Sociability	The perceived ability of the system to perform sociable behavior
PU	Perceived Usefulness	The degree to which a person believes that the system would be assistive
SP	Social Presence	The experience of sensing a social entity when interacting with the system
TR	Trust	The belief that the system performs with personal integrity and reliability

Table 1: Abbreviation for used acceptance constructs and their definitions (Heerink et al., 2010).

4. Results

This chapter describes the results and analysis of results of the experiments. During a role play three reminders were given by an introvert or an extravert robot. Next, the participants were given a 14 items-BFI questionnaire to test the personality that participants attributed to the robot and a 34 items Almere robot acceptance questionnaire. The results of the tests are described in section 5.1. and 5.2, respectively. After filling in the questionnaires the participants were given a medication reminder as provided by an introvert robot and subsequently a medication reminder as provided by an extravert robot. The order of the personalities was interchanged to balance order effects. Afterwards, the participants were asked to indicate which of the two reminders (introverted or extraverted) they would prefer and to deliberate their answer during a semi-structured interview. Section 5.3. describes the results of this interview about the participants' robot personality preference.

4.1. Robot Big Five Inventory (BFI) Test

After interacting with an extraverted robot or an introverted robot the participants were given a short version of a modified BFI test to measure the perceived robot personality. The questionnaire used consisted of 14 statements about the robot (e.g. “I see the robot as a robot that is talkative”). The participants could indicate their agreement with the statements using a five point Likert scale (1= totally disagree, and 5 = totally agree). We expected higher extraversion level scores for the extravert robot than for the introvert robot. Therefore, we focussed on the extraversion construct of the test. The extraversion construct had eight items. The reliability of the extraversion construct is analyzed by calculating the Cronbach's alpha value. An alpha of .646 is found for the perceived robot extraversion level. A statistical rule of thumb is that alpha scores above .7 are acceptable. The reliability of the extraversion level score could be improved by removing item 6 of the BFI for the extraversion construct. Removing item 6 results in an alpha score of .732 which is acceptable.

Using an independent samples t-test we compared the mean scores of the extraversion level of the participants who interacted with the extravert robot with scores of the extraversion level of the participants who interacted with the introvert robot. Table 2 shows the means and standard deviations of the perceived extraversion level for the two robot personalities. As expected the mean extraversion level of the extravert robot is higher than the extraversion level of the introvert robot. However, differences between the mean scores are not significant. We had expected to find a higher mean extraversion level for the extravert robot.

Table 2: Independent samples t-test to compare robot extraversion level of extravert robot and introvert robot

	N	Mean	Std. Dev.	t	Sig. (2-tailed)
Extravert robot	10	2.9857	.42298	1.584	.129
Introvert robot	12	2,6071	.64789		

4.2. Almere model acceptance measure

A Dutch questionnaire of the Almere model was used to test the acceptance of the robot. The questionnaire used consisted of 34 statements with a five point Likert scale for the participants to indicate their agreement with the statement (1= totally disagree, and 5 = totally agree).This questionnaire was given to the participants after they experienced the introvert or the extravert robot.

Reliability. The first step in the analysis of the results was testing the reliability of the acceptance constructs of the measurement. Table 3 shows the Cronbach's alpha values for each construct. Most constructs have an acceptable alpha value (>= .7). Only the alpha value for perceived ease of use is unacceptable. However, removing both item PEOU4 and item PEOU5 resulted in a Cronbach's alpha value of .782 with is acceptable. Therefore, PEOU4 and PEOU5 are removed form the results.

Table 3: Cronbach's alpha values for acceptance constructs of the Almere acceptance measurement.

Construct	N of Items	Cronbach's alpha
ANX	4	.8
PAD	3	.74
PEOU	5	.32
PU	3	.82
TR	2	.74
ATT	3	.74
PENJ	5	.7
PS	4	.75
SP	5	.76
PEOU without item 4 and item 5	3	.78

General acceptance. Figure 8 show the means of the scores for acceptance constructs of all participants (extravert participants and introvert participants). The attitude towards a domestic assistant robot that provides agenda and medication reminders is in general positive. Participants believed that such a robot is useful and would be easy to use. They would in general trust and follow the advice that the robot gives. The participants were not afraid of the robot. However, the perceived sociability and social presence mean scores are low. This indicates that the general social acceptance (accepting the robot as a social actor) is low. The participants in general don’t perceive the robot as a real personage and they don't think that the robot is acting in a social way.

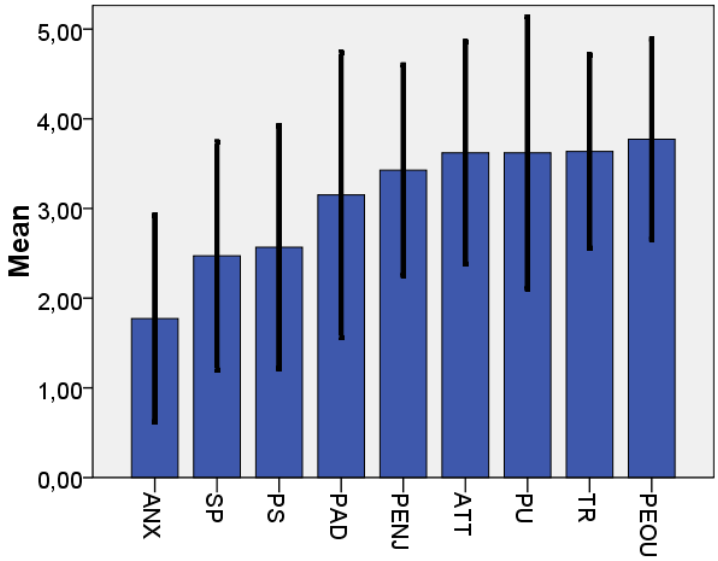


Figure 8: Means and standard deviations of scores Almere model robot acceptances constructs for all (introvert and extravert) participants

Acceptance & personality matching. Our main hypothesis was: h1) *User-robot similarity matching on extraversion improves the acceptance of a domestic assistive social robot that provides agenda and medication reminders by elderly.*

To test this hypothesis we compared the means for the acceptance constructs of the participants that experienced a robot with a similar personality to their own personality (similar group) with the mean scores of the of participants that interacted with a complementary robot personality (complementary group). An independent-samples t-test was used to compare the means for the acceptance constructs of the similar group with those of the complementary group. Table 4 shows the mean scores, standard deviations, and 2-tailed significance value of the difference between the groups. The Levene's Test for Equality of Variances for the samples supports the equal variance assumption for each construct. All acceptance constructs scores were higher for the similarity condition, except for perceived ease of use. However, none of the differences were significant with a confidence level of 95%. Surprisingly, participants that interacted with a similar robot were more afraid of the robot than the participants that interacted with a complementary robot. The difference in anxiety is marginally significant ($p = .063$).

Table 4: Independent samples t-test to compare means of acceptance constructs between similar group and complementary group.

Construct	Similar (SIM) / Complementary (COM)	Mean	Std. Dev.	t	Sig. (2-tailed)
ANX	SIM	2.0000	.6423	1.971	.063 †
	COM	1.5455	.4156		
ATT	SIM	3.7273	.4427	.796	.436
	COM	3.5152	.7654		
PAD	SIM	3.2424	.8040	.527	.604
	COM	3.0606	.8140		
PENJ	SIM	3.4909	.4036	.500	.623
	COM	3.3636	.7420		
PEOU	SIM	3.6970	.5045	-.628	.537
	COM	3.8485	.6212		
PS	SIM	2.5682	.5711	.000	1.000
	COM	2.5682	.7992		
PU	SIM	3.6667	.7149	.275	.786
	COM	3.5758	.8312		
SP	SIM	2.6727	.4839	1.525	.143
	COM	2.2727	.7226		
TR	SIM	3.6818	.6030	.388	.702
	COM	3.5909	.4908		

Note: † p<.1.

Acceptance & participant personality. Comparing the mean scores on the acceptance constructs of extravert and introvert participants shows no significant differences. Thus, the acceptance of the robot is not significantly different for extravert or introvert participants.

Acceptance & robot personality. Comparing the mean scores on the acceptance constructs of the two types of robot personalities shows three significant differences. The results of an independent sample t-test are shown in table 5. The Levene's Test for Equality of Variances shows that equal variance can be assumed between samples for each construct except Trust. For Trust we therefore show in table 5 the significance value that doesn't need the equal variance assumption. Firstly, the perceived sociability is significantly higher for the extravert robot ($p<.01$). Secondly, the mean score for perceived enjoyment was significantly higher during the interaction with the extravert robot ($p<.05$). Finally, the social presence was marginal significantly higher in the condition where participants interacted with an extravert robot ($p=.05$).

Table 5:Independent samples t-test to compare means of acceptance constructs between extravert robot group and introvert robot group.

Construct	Extravert Robot (EXT ROB) / Introvert Robot (INT ROB)	N	Mean	Std. Dev.	t	Sig.
ANX	EXT ROB	10	1.6500	.33747	-.907	.375
	INT ROB	12	1.8750	.71906		
ATT	EXT ROB	10	3.7333	.49191	.767	.452
	INT ROB	12	3.5278	.71715		
PAD	EXT ROB	10	3.4333	.72094	1.570	.132
	INT ROB	12	2.9167	.80560		
PENJ	EXT ROB	10	3.7600	.42999	2.796	.011 *
	INT ROB	12	3.1500	.56649		
PEOU	EXT ROB	10	3.8000	.35832	.205	.840
	INT ROB	12	3.7500	.69812		
PS	EXT ROB	10	2.9750	.72077	3.029	.007 **
	INT ROB	12	2.2292	.40534		
PU	EXT ROB	10	3.7667	.70361	.815	.425
	INT ROB	12	3.5000	.40534		
SP	EXT ROB	10	2.7600	.67198	2.090	.050 †
	INT ROB	12	2.2333	.51050		
TR	EXT ROB	10	3.6500	.42999	.106	.911 #
	INT ROB	12	3.1500	.56649		

*Note: † p<.1, * p<.05, ** p<.01, # equal variance not assumed*

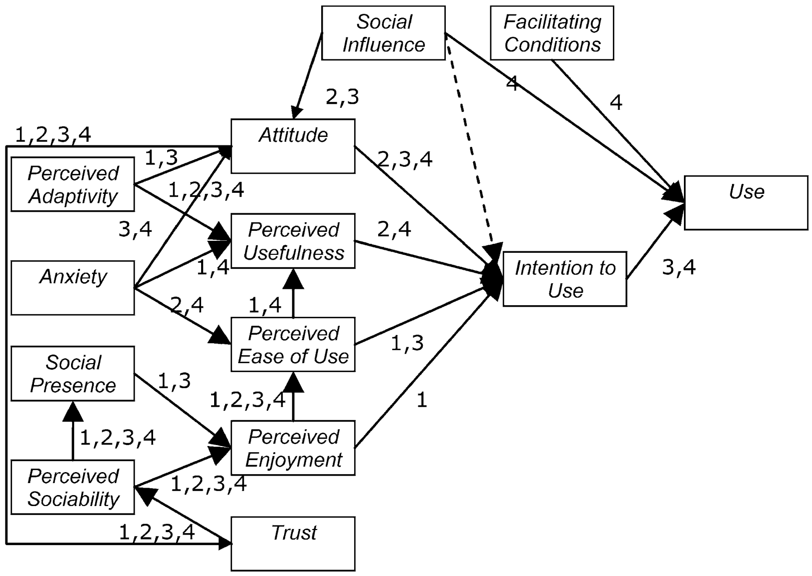


Figure 9: The Almere model described in (Heerink et al., 2010). Heerink et al. (2010) describe 4 experiments with robots where this model was used to test the robot acceptance. The numbers refer to the experiments that confirmed the interrelations by regression scores. Dotted line: not confirmed by any regression analysis.

Almere model hypotheses. The Almere model (see Figure 9) describes how each construct of the model can be used to predict technology usage (acceptance). We tested if the same kind of relationship (path estimates) between constructs could be found for the data that we collected. To test this we used linear regression analysis.

Table 6 shows the results of a regression analyses between acceptance constructs for which a path is drawn in Figure 9. Four paths of the Almere model are found to be significant ($p<.05$) and three paths marginally significant in our experiment. Anxiety could be used to predict perceived ease of use ($p<.005$). Perceived ease of use could be used to predict perceived usefulness ($p<.005$). Perceived sociability could be used to predict the feeling of social presence during the interaction with the robot ($p<.05$). Social presence could be used to predict perceived enjoyment ($p<.05$). Perceived sociability could be used to predict perceived enjoyment ($p=.063$). Perceived adaptability and anxiety could be used to predict attitude.

Table 6: Regression analysis of Almere model acceptance constructs

Independent variable	Dependent variable	Beta	t	Sig.	R^2
PAD	ATT	.378	1.958	.065†	.225
ANX		-.361	-1.870	.077†	
PAD	PU	.221	1.395	.180	.483
ANX		-.025	-.133	.896	
PEOU		.672	3.495	.003***	
ANX	PEOU	-.680	-3.377	.003***	.312
PENJ		-.239	-1.189	.249	
SP	PENJ	.413	2.131	.049*	.429
PS		.383	1.977	.063†	
PS	SP	.525	2.761	.012*	.240
TR	PS	.185	.843	.409	-.014
ATT	TR	.233	1.074	.296	.007

*Note: † p<.1. * p<.05. ** p<.01. ***p<.005.*

4.3. Preferred robot personality & reasons for preferences

After experiencing one type (introvert or extravert) of personality for the robot and filling in the questionnaires the participants were shown a medication reminder of both robot personalities in sequence. The order of robot personalities was interchanged. Afterwards, participants were asked: “You have seen two ways in which the robot can provide a reminder, which way would you prefer?” The participants were asked to deliberate their preference for either an extravert or an introvert robot. The participants weren't told what the differences between the robots was. In line with our main hypothesis, we expected participants to prefer a robot personality similar to their own personality. Below we first describe which personality was the most preferred and the relation between the participants own personality and the personality he or she preferred. Subsequently, we investigated the effect of the robot personality that the participants experienced during the first experiment and their indicated robot personality preference during the second experiment. And finally we summarize the reasons that the participants provide for their personality preference. There were two differences between participants that influences their robot personality preference: 1) the role that the participants believe the robot should have: (a) companion or (b) service oriented machine, and 2) the appreciation of expressed self confidence. Moreover, we found that our robot personalities influenced the feeling of privacy and safety.

Preference & personality matching. Table 7 shows a contingency table with participants personality and robot personality preference as variables. Since, something went wrong with the video recordings of one participant we could not check his preference. Therefore, we removed the data of this person from the preference data. Thus, results from twenty-one participants were used. Fifteen of the twenty-one participants preferred the introvert robot. Fourteen of the twenty-one participants preferred the medication reminder of the similar personality. The extravert participants choose almost as often for the introvert robot (6 participants) as for the extravert robot (5 participants). In contrast, most introvert participants preferred the introvert robot (9 of 10). To calculate the probability of the frequency distribution shown in table 7 assuming the null-hypothesis that the probability that a person prefers a similar personality is equal to the probability that a person prefers a complementary personality we used both a Pearson Chi-Square test and a Fisher’s exact test. The probability to get the distribution shown in table 7 assuming the null-hypothesis is .072 (using the Pearson Chi-square test). Thus, the null hypothesis can not be rejected with a 95% confidence level.

Table 7: Participants robot personality preference versus participants personality. Chi-Square test and Fisher's exact test are used to calculate the probability of the distribution

Robot Personality Preference	Participant Personality		
	Extravert Participant	Introvert Participant	χ^2
Extravert Robot	5	1	.072 †
Introvert Robot	6	9	

Note: † p<.1.

Preference & earlier experienced robot personality. During the experiments participants first experienced one type of robot personality and then both types of robot personalities. The between subject experiment could have influenced the second experiment. Table 8 shows a contingency table of the participant's robot personality preference versus the experienced robot during the first test. Sixteen of the twenty-one participants made a choice in favor of the robot personality they experienced during the first experiment. A Chi-square test was used to check the chance of this distribution assuming no influence of the earlier experienced robot personality. The results show that significantly more ($p<.05$) participants indicated that they preferred the robot they experienced during the first experiment than the robot personality they didn't experienced.

Table 8: Participants robot personality preference versus experienced robot personality during first experiment. Chi-Square test and Fisher's exact test are used to calculate the probability of the distribution

Robot Personality Preference	Robot Personality Experiment 1		
	Extravert Robot	Introvert Robot	χ^2
Extravert Robot	5	1	.018 *
Introvert Robot	4	11	

*Note: *p<.05.*

Role robot: Companion or Machine. The reasons provided for the robot preferences show that participants thought differently about the role that the robot should have. Some participants said that they would like the robot to be a companion which could provide an enjoyable interaction. These participants therefore preferred the extravert robot since they perceived the extravert robot as more sociable, human-like, talkative, and friendly (1 introvert and 4 extravert participants). On the contrary, to the opinion of five other participants (3 introvert and 2 extravert) the robot should behave like a machine and not like a human or a companion. Some remarks that illustrate this opinion are: *"It should stay a robot"*, *"It's not going to be my friend"* and *"I see the robot like a machine"*. These participants chose the introvert robot, since the behavior of that robot was perceived less human-like and less extravert. Some of these participants found even the introvert robot too human-like, they would prefer the robot to provide a reminder with a pulsing light (1 participant) or providing a shorter more to the point message without formalities. According to one participant the robot shouldn't be made too human-like because of the risk that elderly people confuse the robot with a real human being. Two extravert participants perceived the extravert robot as patronizing and childish. They felt the social behavior of the robot insulting. *"I'm not miserable and lonely"* was a remark of one participant.

Self confidence. The reactions indicated that there were strong differences between opinions on what kind of behavior is socially desirable. Some introvert participants (3) judged the self confidence of the extravert robot as very undesirable. The extravert robot said: “*Good thinking of me, don't you think so?”*. On the contrary, some extravert people (3) judged the insecurity of the introvert robot as undesirable. The introvert robot said: “*I hope that you don't mind that I* ...”. The participants found it difficult to explain why these behaviors were undesirable. Two participants (1 extravert and 1 introvert) found the messages that the robot provides less compulsory due to the remark “*I hope that you don't mind that I ..”.*

Privacy and Safety. One participant said that the introvert robot gave her a feeling of more privacy and safety. The extravert robot triggers the feeling that the robot is watching you. The extravert robot said: “*Take your medication quickly, so you can continue watching the movie”*. This indicated that the extravert robot could see the participant watching the television.

5. Discussion

Here we discuss the results of our experiments. Firstly, we describe some general limitations of the method used that effected all results. Secondly,we summarize our main findings and provide per finding an explanation of how we interpreted the finding (which conclusion can be drawn) and discuss what kind of limitations of the used method could have influenced the results.

5.1. The used method

Do the participants represent the target group? The participants were not completely representative for the target group for two reasons. Firstly, most participants were recruited via a list from Philips of people that had participated in earlier experiments of Philips. Some of them had participated in an experiment with a robot. Therefore, these participants are expected to have a relatively positive attitude towards technology and robots. Secondly, the participants were relatively young and mentally and physically healthy. We needed participants who were willing to come to the Experience Lab of Philips. For people with health issues that was too difficult. Still, there were at least five participants who had problems with walking. Most participants indicated that they didn't need support yet to remember their medication and appointments.

Are the used measures reliable? We used a version of BFI with sixteen items in which we have combined items of the 10-items BFI with items of the 44-items BFI. We found an acceptable Cronbach's alpha after removing one item for the extraversion construct. However, this measure has never been completely validated as a measurement for perceived robot personalities. For a complete validation of a measurement a great number of measurements have to be performed with the test. A completely validated test for perceived robot personalities is not yet available.

The Almere model questionnaire has not been completely validated either. However, the constructs test has been found reliable for several studies (Heerink et al., 2010). Whether the Dutch and the English versions of the questionnaire are equally reliable is not clear. We found for all constructs acceptable Cronbach's alpha values, except for Perceived Ease Of Use. Two items of the Perceived Ease Of Use seem to have led to misinterpretations. Removing items PEOU4 and PEOU5 led to an acceptable Cronbach alpha value. The statement of PEOU4 is: “I think I can use the robot when there is someone around to help me.” and the statement PEOU5 is: “I think I can use the robot when I have a good manual.” We recall from the experiments that several participants had problems with the interpretation of these statements. From the questions that people asked about these statements and inconsistency of the results of these items compared to other items of the same construct, we expect that some people misunderstood the statements. These participants interpreted these statement such that fully agreement with them means that the robot was not easy to use. They might have thought: *“I find the robot easy to use. Thus, I don’t need any help of someone else or a manual to use it. So, I disagree with this statement.”* The word *“when”* in these statements could be interpreted as *“only when”*. In statements PEOU4 and PEOU5 it is also ambiguous what kind of support people receive from the person that is around to help (help with medication use or with using the robot) or the manual. We recommend for future studies to consider reformulation of these items. For example, PEOU 4 could be: *“I think I cannot use the robot, even when there is someone available to assist me with that use.”* and PEOU 5 could be: *“I think I cannot use the robot, even when I have a good manual that describes how to use the robot.”*.

5.2. Robot personality recognition

The 14-items BFI test for the perceived robot personality results show that, as predicted, the participants gave the extravert robot higher extraversion scores than the introvert robot. However, this difference was not significant. The extravert robot was perceived less extravert than expected. The used acceptance questionnaire has a Perceived Sociability construct. The Perceived Sociability was significantly higher for the extravert robot than for the introvert robot. Sociability most clearly indicates a person’s level of extraversion (Tapus & Mataric, 2008). Eysenck used sociability as one of the adjectives to describe extraverted people (Eysenck, 1953, in Tapus & Mataric, 2007). Thus, the hypothesis that participants would be able to recognize the designed robot personalities can be supported by this result.

5.3. General acceptance robot

The mean scores of the acceptance constructs of all participant were analyzed. The attitude towards a domestic assistant robot that provides agenda and medication reminders was in general positive. Participants thought that such a robot would be useful and would be easy to use. The participants indicated that they would trust and follow the advices of the robot. The participants were not afraid of the robot. However, perceived sociability and social presence mean scores were low, meaning that the participants in general didn't perceive the robot as a real personage and that they didn't think that the robot was acting in a social way. Thus, the technological acceptance of a social robot is positive but the social acceptance is negative. We should however bear in mind that the participants didn't completely represent the population of the target group since they were selected on their extreme scores on extraversion level.

5.4. User-robot personality matching

The main hypothesis of this study was that participants will be accepting a robot with a similar extraversion level as the participant more than a robot with a complementary personality. Comparing the mean scores for the acceptance constructs of the Almere acceptance model of the participants that experienced a robot personality similar to their own personality and the participants that experienced a robot personality complementary to their own personality shows no significant differences. Opposite to our expectation, the anxiety for the robot was marginally significantly higher when participants interacted with a similar robot personality than when people interacted with a complementary robot. This finding doesn't match with the theory that introvert people would not be attracted to extravert robots or computer agents because they find the social behavior that is required during the interaction with extravert robots or computer agents stressful (Walters et al., 2007). We expected the participants to perceive a similar robot less anxious because they are more familiar with their behavior. These were two aspects about the extravert robot that could have increased the anxiety for that robot. Firstly, the extravert robot kept less distance from the participant when it provided a reminder. Since, the Florence robot staggered when it stopped driving the participants might have been more afraid that the robot would fall on them in the extravert robot condition. Secondly, the extravert robot said things that indicated that the robot would be able to see what the participant is doing which might have enforce the anxiety for the robot. But, these aspects don't explain the found differences in anxiety of complementarity group versus the similarity group, unless extravert people are more sensitive to these aspects. We can imagine two reasons for our result. Firstly, introvert people might in general find social interactions stressful, but they might find it less stressful when the other person is taking a leading role in the interaction and when the other person is at ease in the interaction. Secondly, extravert people might like to have a leading role in the interaction and might find it stressful when the robot is taking to much initiative. Meerbeek et al. (2008) found that a submissive robot enforces the feeling of user control over the system.

The indicated preference of participants after seeing a medication reminder from both robot personalities in sequence shows a different pattern relative to the applicability of the social rules. Participants preferred a similar robot personality more often than a complementary personality. Extravert participants preferred a similar personality almost as often as a complementary personality. Interestingly however, almost all introvert participants preferred an introvert robot personality. These patterns in relation to the indicated preference were marginally significant. However, the test and method used to get an idea of the participants' preferences regarding the extraversion level of the robot personality are somewhat questionable. Firstly, as already suggested by Nass (2010), the tendency of people to react socially (use social models) to computers and robots is an unconscious process which is difficult to be measured through a direct question as we did. For example, Nass performed an experiment of which results indicated that participants were polite to computers (Nass & Yen, 2010). However, when participants were asked after the experiment if they would be polite to a computer they all denied. In the same way our participants might have reacted more negatively towards the more social (more extravert) robot during the direct questioning than their actual responses have been.

Secondly, the personality that participants said they preferred has been significantly influenced by the personality they already had experienced during the scenario they played with the robot during the first experiment. Sixteen of the twenty-one participants have chosen the robot personality they already experienced during the scenario. This might be due to the tendency of people to give socially desirable answers or due to the effect of recognition. The findings on the relation between the indicated preference and the reason of preference should therefore not be interpreted as new facts, but rather as a source for new hypotheses that need further exploration.

Moreover, the difference between the introvert and extravert participants could also be influenced by age differences between the groups. The mean age of the introvert participants was higher than the age of the extravert participants. Since robot acceptance has been found by previous studies to be age related this might explain the differences found between introvert and extravert participants.

5.5. Reasons for personality preferences

Although the indicated robot preference seemed to have been influenced by the robot personality they experienced during the first experiment, the reasons for preferences seemed genuine to us. There were two main differences between individuals that influenced their robot personality preferences. Firstly, the role the participants believe that the robot should have influenced their preference. Some participants believed that the robot shouldn't act like a human with emotions and thought. The robot should just provide the message clear and short without acting sociable or friendly. These participants preferred the introvert robot, since they perceived that robot as more machine-like. Thus, similar to the study of Walters et al. (2007) that found that people attribute a more introvert personality to robots with a more machine-like appearance and a more extravert personality to a robot with a anthropomorphic appearance, we found a relationship between the perceived role or function (machine or companion) of the robot and the personality of the robot. “It should stay a robot” was a remark that was often expressed during the interviews. On the other hand there were also participants that would like the robot to have a companion role. These participants preferred the extravert robot.

Secondly, the appreciation of expressed self-confidence influenced the robot personality preference. This seems to be related to similarity attraction. Some extravert participants didn't seem to understand the expressed insecurity of the introvert robot and some introvert people didn't seem to understand the expressed self-confidence of the extravert robot.

5.6. Acceptance and robot personality

Comparing the mean Almere acceptance constructs scores for people who experienced an extravert robot with people that experienced an introvert robot shows some significant differences. The perceived sociability, social presence, and the perceived enjoyment were significantly higher for the extravert robot. These results are in line with other studies that found that extravert robots had a positive effect on the experience of the interaction with robot (Goetz & Kiesler, 2002; Kiesler & Goetz, 2002; Meerbeek et al., 2008; Verhaegh, 2004; Walters, Syrdal, Dautenhahn, te Boekhorst, & Koay, 2007).

Contrarily, participants indicated that they preferred the introvert robot more often after seeing both personalities. As explained under above discussion this difference might be due to unreliability of the used method to get insight in a person's real preference.

5.7. Acceptance model

The regression analysis of the acceptance construct means for all participants shows that some of the paths of the Almere model were confirmed. Four paths of the Almere model are found to be significant and three paths marginally significant in our experiment. Figure 10 shows the interrelations between constructs that were confirmed by our experiment results. Sociability seems to have a positive effect on the acceptance of the robot as a social actor and the enjoyment of the interaction. Perceived Enjoyment can according to the Almere model influence Intention to Use. The importance of our finding that anxiety marginally significantly decreases when participants interact with a robot with a complementary personality is underlined by the influence that anxiety seems to have on Perceived ease of use and attitude. Perceived Ease of Use and Attitude are according to the Almere model factors that influence Intention to Use which in turn influences actual Use. However, no significant differences on Perceived Ease of Use and Attitude were found between the complementary versus similar condition.

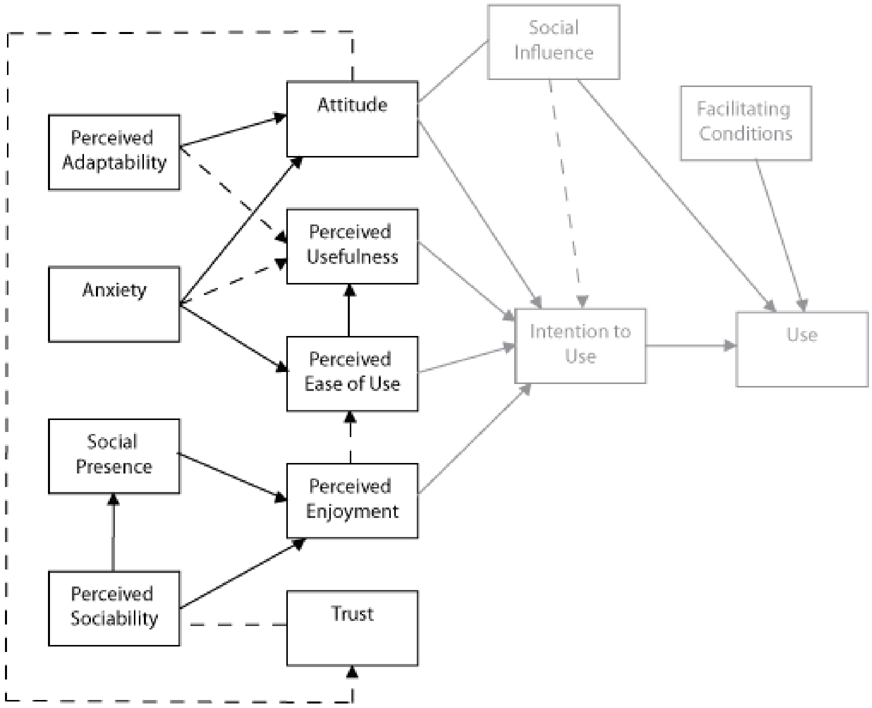


Figure 10: Almere model interrelations confirmed by regression scores for our experiment. Black dotted lines: not confirmed by our regression analysis. Gray: constructs not used in our experiment.

6. Conclusions

Like in related studies the robot personalities were successfully recognized. The perceived sociability, the most prominent characteristic of extraverted people, of the extravert robot was significantly higher. In general our participants found the robot useful, perceived it easy to use, trusted the robot, were not afraid of the robot and indicated that they will follow it's advices. However, on average participants didn't accept the robot as a social actor. The real reaction towards the robot might have been more social then they answered to the questions of the questionnaire we used to measure social acceptance. People are often not aware of their social reaction towards machines and if they are they might be embarrassed of that reaction. Many of our participants talked to the robot or reacted with non-verbal signals (e.g. smiled towards the robot) during the experiments. In extravert robot condition the perceived sociability, the feeling of social presence, and the perceived enjoyment were higher. These factors were also found to be positively correlated. Perceived sociability increase the feeling of social presence and both perceived sociability and social presence determine perceived enjoyment.

Our main hypotheses that the acceptance of a robot with a similar personality as the user will be higher than of a robot with a complementary personality was not supported by the results of our first experiment. On the contrary we found that people were more afraid of a robot with a similar personality. Anxiety is according to the Almere model an determining factor for intention to use a robot. Our experiment results showed that participants that found the robot less anxious had a more positive attitude towards using the robot and were more optimistic about the perceived ease of use. The results of the second experiment in which participants saw a medication reminder of an introvert robot followed by a medication reminder of a extravert robot or visa versa showed a different pattern. Participants were asked to indicate and deliberate which personality they preferred. Extravert participants preferred the extravert robot almost as often as the introvert robot. On the contrary almost all introvert participants preferred the introvert robot. However, the results of the second experiment have been effected by the robot participants experienced during the first experiment. Participants preferred the robot they had experienced during the first experiment. Though, the explanations that participants provided for there preferences seemed genuine to us. The explanation of the participants seem to indicate that there is a difference between introvert people and extravert people in the type of role they wish for the robot. Some introvert people argued that the robot should act like a machine. Extravert users were more open towards a more social companion like role of the robot. Moreover there was a difference between extravert and introvert participants in the appreciation of expressed self-confidence. Introvert people did not like the robot to express self-confidence. On the contrary extravert people did not liked the expressed insecureness of the introvert robot. The participants couldn't explain why this behavior was according to them undesirable. They indicated they didn't understand that the expressed self-confidence or insecureness.

Thus, this study suggests (with more or less confidence) that:

1) designing a medication reminder robot with a extravert personality could increase the social acceptance of a robot and the enjoyment of the interaction,

2) complementary matching could decrease anxiety,

3) similarity attraction is more applicable to introvert people

4) people seem to prefer a robot with a similar extraversion level,

5) similar extraversion level is preferred because a similar robot seems to take a role (machine-like vs. companion-like) the user wishes for the robot

6) similar extraversion level is preferred because a similar robot expresses an for the user appropriate self-confidence level.

7. Future Work

First of all this study reports some interesting trends that should be studied more thoroughly. Long term studies are needed to test the effect of personality design on acceptance of social robots by elderly.

This study and related studies suggest that the perceived personality of a social robot has a significant effect on usability, performance, and the acceptance of the robot. But, as this and other studies also show, these is not one type of personality that works for all people. Social rules like similarity attraction or complementary attraction could be used to predict a persons preferred robot personality. But, which social rule is the most dominant is still unclear. We analyzed reasons our participants provided for personality preference. From this analysis we suggest that the role people desire for the robot influenced the participants personality preference. People that would like the robot to have a social companion-like role prefer an extravert robot and people that desired the robot to act like a machine prefer an introvert robot. This trend we found should be studied more exhaustively. It would also be interesting to compare the preferred robot personalities for several application domains (e.g. robotic game companion, health coach robot, and service robot like a vacuum cleaning robot). A different application would suggest a different robot role and therefore require a different personality. There could also be a correlation between robot role and the applicability of the social rules. For example, an extravert person prefers an introvert service robot but an extravert game companion robot. Or visa versa.

This study and previous studies mainly focused on one personality trait, namely extraversion. Future work should focus on agreeability and agreeability in combination with extraversion. Agreeability plays a very dominant role in the satisfaction of human-human interaction. Although most of our participants indicated they preferred a friendly robot, some of our participants found the robot they experienced during the experiments too friendly and too polite. For example, one participant said that he would like a robot that provides more compulsory messages. According to him the robot should say: “John, you must take your medication.” or “John, did you take your medication?” and if he doesn't take the medication after the first reminder: “I believe you didn't take you medication. I did you warn you, didn't I?”

We believe that many aspects besides ones own personality determines peoples preferences regarding the personality of a robot. For example, the personality of a persons role model in their early youth or the personality of one's partner. It would be interesting for future studies to create and evaluate more complex and more accurate models to predict a persons personality preference.

Changes in personality could also have a significant effect on the usability, performance, and acceptance. Nass (2011) found that a computer agent that start the interaction with a personality that is complementary to the personality of the user and then slowly changes it's personality in a similar personality, is preferred above a personality that is similar to the user from the start of the interaction. Whether changing a robots personality towards the personality of the user has an effect on the acceptance of social robots would also be an interesting subject for further exploration.

Since current models to predict a persons robot personality preference are not accurate enough we advice robot designers to design multiple personalities for the robot and let the user choose between these personalities. Many of our participants indicated that they would like to be able to choose between different faces, voices, and manners to provide a message. Because consistency of a personality is very important we wouldn't suggest to design a robot that gives the user the possibility to choose a face separately from a voice. We suggest to design different characters with strong and consistent personalities and a face and voice consistent with the character. The effect of such a feature on HRI and HCI would be according to us a very interesting subject for future studies.

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Appendix A: Orientation Interview Potential Users

In a early stage of the study we asked ten elderly people (65 - 84 years old, mean age = 75.3 , three men and seven women) that used medication on a daily basis during a semi-structured interview about their medicine usage, their medication adherence related problems, their needs and wishes in relation to a medication adherence coaching robot, their general attitude towards such a robot, the type of face they would like for the robot , and the type of personality they would like the robot to have. Seven of the participants were living in senior homes (houses with one floor and sometimes other facilities for elderly people) three participants were living in eldercare homes. These interviews helped us to determine the focus of the study (type of robot application) and to make design decisions in relation to the face of the robot and the personality of the robot. This appendix provides an overview of the results of these interviews. The results in relation to the face design are reported in an earlier paper of us so we will not repeat those findings here (see Brandon, 2012a).

A.1. Medication Use and Medication Adherence Related Problems

Medication use. The interviewees used medications on a daily basis, on average 8.7 pills per day. The amount of medicine support the participants received from formal and informal care providers varied. Most participants (9 of 10) got their medicines delivered at home by a pharmacy. Three participants receive their pills in the normal fabric packages, two participants receive medication blisters (pills sealed per intake moment, see figure 11), and four participants received a pre-filled weekly pill boxes (see figure 12). Only one participant went to the drug store to pick up his medicines. This participant also used a weekly pill box that his wife filled for him.

Figure 11: medication blister

Figure 12: Medication weekly pill box

Remembering medication. Two participants were given the medication by a care provider, meaning that the care provider handed over the medication or prepared a dose by placing it on a regular place (e.g. on a saucer at the dining table) for later use. One of the interviewees, an older woman that lives in a eldercare home said that she tried to do as much as she can independently. She tried to remember her medication. In her case the care providers only checked after the intake moments whether she has taken her pills ("Didn't you forget to take your medication?"). Seven participants didn't received help from care providers with remembering their medication. None of the participants used technology (e.g. alarms) to remind them. Though, seven out of ten interviewees indicated that they sometimes forget to take their medication. One participant, an older woman said that she had experienced negative consequences of forgetting her medication (very intense pain). One participant said that she sometimes takes by accident more pills then she needs, because she has forgotten that she has already taken her medicine.

Deliberate non-adherence . Five participants indicated that they some times deliberately don't use a medication that was prescribed by a doctor. Reasons for deliberate non-adherence were: negative (side) effects, unpleasant to use, believing that using the medication is unhealthy, not fully understanding why they needed them, and experimenting to see whether they still need the medication. An older woman said that she has recently said to her daughter that she wanted to stop using a certain medication. Her daughter reminded her that she had stopped once before with that medication and that it had negative consequences. Therefore she didn't stop using that medication.

Motivation and literacy. The participants only use medications that are prescribed by a doctor. Most interviewees believe that it is very important to follow up the medicine regiments of the doctor. Three participants indicated that they had no idea what kind of medication they were using and had never read the leaflet. Most participants had read the leaflet and knew vaguely what kind of medications they were using and why they needed them. Most interviewees indicated that they used their medication because the doctor told them so. Four participants indicated that they used the medication because they believed that they needed it and because it made them feel better.

A.2. Needs and wishes medication adherence robot coach

Acceptance of medication reminder robot. The elderly woman that indicated that she experienced negative consequences of forgetting her medication was the only participant that indicated that she would be interested in a robot that provides medication reminders. This participant had to take her pills every two hours. She said that she was constantly looking at the clock to she whether it was time for her pills. This resulted in al lot of stress. Therefore, she liked to have a devices that takes over this responsibility. Three participants said that they don't need a reminder jet, but that they would like to have a robot medication reminder when they forget their pills more often. Two of them even prefer the robot above a care provider to remind them, because then they wouldn't have to account for a care provider's visit (the time of their visit varies). All other participants (six) were not interested in a robot medication reminder, because they : 1) preferred help from a care provider (human contact), 2) found the robot scary, 3) didn't trust computers, and 4) didn't want to learn to use the robot.

How should the robot provide a medication reminder? Although, not all participants were interested in a robot medication reminder robot they were asked to imagine that they needed it and that there was no other option. Subsequently, they were asked about how they would like to be reminded. Would prefer a beeper or a voice? Three participants liked to be reminded by a beeper. One of them said that she didn't like the unnatural voices of robots. Another participant said that he might get angry at a robot with a voice when he is in a bad mood. A robot with a beeper would not trigger an emotional response. Two participants would prefer a voice preceded by a beeper. Two participants prefer a voice. One of them said that there is already a lot of technology in her home that makes a beeping sound. Another thought that it would be more personal. The participants were asked whether they would prefer to be reminded only if they forget their medication or to be reminded everyday at the same time. Five participants preferred the first option and liked to stay as independent as possible. Most participants (6 of 10) said that their medication is more important then other things and don’t want the robot to wait when they are involved in an activity. Only one participant said that he would like the robot to wait with a reminder if he is involved in an activity (e.g. having a visitor or ready a book). In case they don’t react to the robots medication reminder the first time all participants wanted the robot to repeat the reminder.

Should the robot provide information about medication? Three participants were interested in a robot that provides them information about their medication. One woman said that she had difficulties with understanding the language of the leaflets. None of the participants wanted the robot to provide information about medication intake method (e.g. with water).

Should the robot support medication planning? None of the participants wanted help from the robot with planning their medication intake moments.

Should the robot greet the user when he is leaving or coming home? Most participants indicated that that a robot doesn't have to greet them. Some of interviewees reacted as if it a ridiculous feature; they laughed or reacted offended. Participants also indicated that they didn’t know whether they would like it or not because they had no experience with it.

Should the robot give a compliment when you remember you medication without help? Two participants would like it if the robot gives them a compliment. The other participants wouldn’t like to get a compliment, because they found that childish or not useful.

Should the robot look around and move a little in his standby modus? Most participants (six) didn’t want that, because it would scare them. The other participants didn’t mind.

Additional functionalities suggested:

- Provide agenda reminders
- Remind the user to order new medications

- Remind the user before he is leaving the house to take the medication before leaving or to take his medication with him.

- Remind the user before he is going to bed to take his medication. For example when the user needs to take his medication around 23:00, but he is going to bed earlier. In that case the robot should not give a reminder at 23:00 when the user is sleeping but before the user falls asleep.

- Checking whether the medication is working

- Checking how things are going when the user is ill.

- Warn a care provider in case the user doesn’t react to the reminder.

General acceptance of domestic service robot. In general most participants weren't enthusiastic about having a robot in their home, because they 1) found it scary, 2) didn't trust computers and robots, 3) found the robot too big, and 4) were scared it would replace human contact. Mainly this last point was mention often. The potential end users had the feeling that they would be left alone with a robot in the future and there would be even less human contact.

A.3. Desirable Personality Aspects

The participants were asked to order several cards with personality facets on them on an A2 paper. On this A2 paper there were three fields: desired, undesired, and neutral. This method is described in (Meerbeek & Saerbeck, n.d.; Meerbeek et al., 2009b). Each facets was related to one of the big five dimensions: neurotic (anxious to calm), extraversion (outgoing to withdrawn), open (curious to closed minded), agreeable (cooperative to competitive), and conscientious (organized to lax). We added the facets “warm” and “cold” which are not directly related to one of the big five dimensions. Figure 13 shows the mean desirability of each personality facet and figure 14 shows the mean desirability and standard deviation of the desirability of the personality traits. All participants indicated that cold, moody, and bold were undesired. Closed, superficial, easily discouraged, careless, distant, and withdrawn were undesired according to most participants. The majority of the participants desired a robot that is warm, open, calm, spontaneous, efficient, systematic, cooperative, and polite. The participants opinions varied the most for the desirable level of extraversion and open to new experiences of the robot.

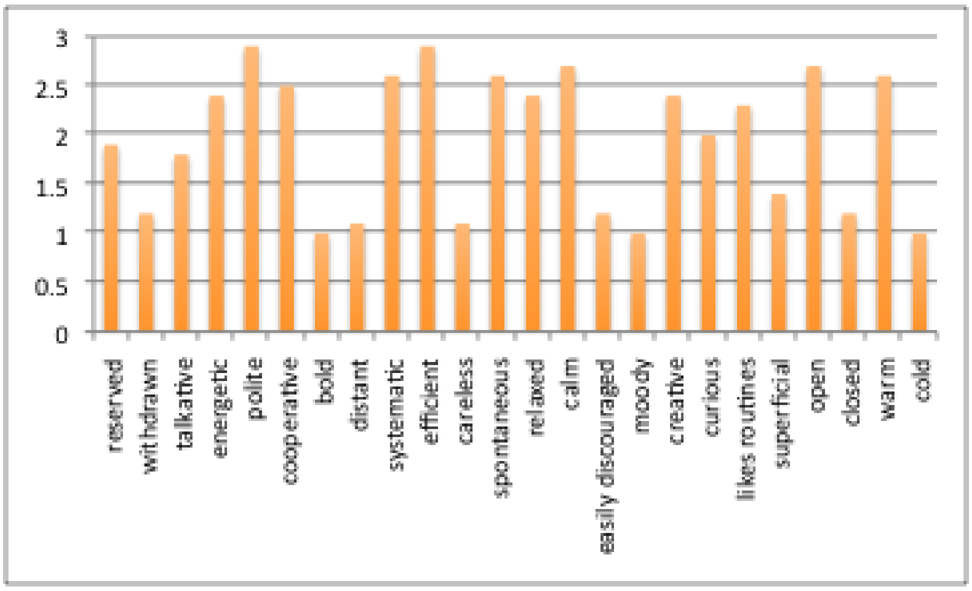
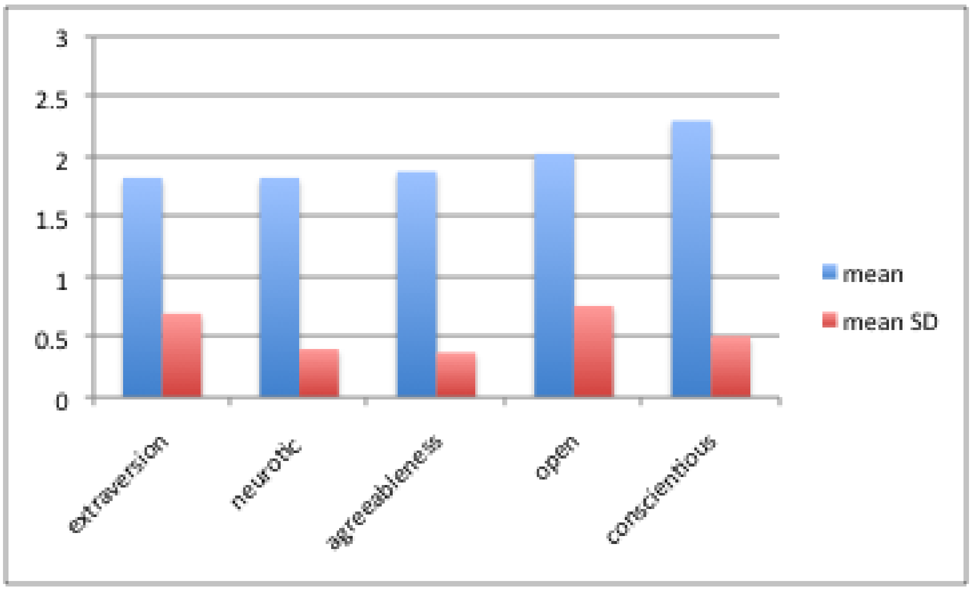


Figure 13: mean values for each personality facet.

Note: 1 = undesirable, 2 = neutral, 3 = desirable



Note: 1 = undesireble, 2 = neutral, 3 = desirable
Figure 14: mean values and standard deviations for personality traits

Appendix B: Orientation Interview with Care Providers

Three care providers were interviewed to elicit their experience with helping elderly people to adhere to their medicine regiments. They were asked about what kind of medication adherence related problems they observe during their jobs, what the causes are of these problems, and what kind of medication related help they provide. Two of the interviewed care providers work at an eldercare home and one with an organization that provides help to elderly people at their homes (in Dutch: thuiszorg). Below a summary of the important remarks in relation to this research project.

The biggest problem in relation to medication adherence is forgetting to use medication. The cause of this problem is cognitive decline due to aging and dementia. If the care providers discover this problem, or if the client or his relatives inform the care provider about this problem, the care provider and the client will talk about the best solution. This solution depends on the client's wishes and capabilities. The care providers believed that it was important to stimulate independency and listen to the client specific wishes. In some cases the care providers would only control from now and then whether the client has taken his medication following the regiments. In other cases the care provider always checks whether or not the patient has taken his medication. For some clients the care providers prepares the medication by putting the medication for one intake moment some were the patients wants them (e.g. on a saucer at the dining table). In other cases the care providers remind the elderly person of their medication. If the patient forgets his medication despite the care provider has reminded him or her multiple times, the care provider will hand over the medication and will not leave before the client has actually taken the medication in their mouth and swallowed it. Patients with dementia for example sometimes put their medication in their mouth but then for some reason (they don't like the taste) get the pill out of their mouth and put it somewhere (e.g. a plant pot).

Using more medicines than prescribed was also according the care providers a problem that frequently occurs. Mentioned causes were cognitive decline and dementia. When the care providers notice this (for example if the medication box is empty too soon) they have a conversation about this with the client. Most of the time the clients don't remember taking more pills than necessary. As a solution the pills are put in a medication locker in the room of the client that only the care providers can open to hand over the medication.

All patients of the eldercare home receive filled weekly pillboxes of the pharmacists. These boxes are bought to the residents on Tuesday morning after the residents have taken their pills for that morning. This is some times confusing for the residents because in the new pillbox the pills in the section Tuesday morning are for the next week. This regular results in patients taking their Tuesday morning medication twice.

According to the care providers most patients don't know what medication they are using or why the need it. They trust the doctor for his decision. Now and then the care providers gets questions like "Why do I need all this medication?". If the care provider knows answer she will try to explain this to the client. But the care providers often don't have a clue. In such cases the care provider tells to the client that she doesn't know what the medications are for and that she will look it up for the client (Using Internet, calling the drug store, or calling the doctor).

Most clients use the same medication over years. Additional medication is added when needed, like antibiotics. Sometimes these additional temporal medications are added to the weekly pillboxes. In those cases, the pharmacy will get the pillboxes from the elderly people refill them and bring them back. But medications are also often provided apart from the weekly boxes. Many elderly people use pills to make their blood thinner, to prevent thromboses. The dose of these pills is adjusted to the patient's blood status. This is measured regularly.

Clients don't often refuse to use their medication. Sometimes they don't want to use certain medication that is very unpleasant to use. In such cases the care provider explains why the clients needs that medication and also shows sympathy. The client is never forced to use a medication. If he or she decides to not use the medication, his or her freedom of that choice is respected. But if the care provider knows that not using the medication can result in serious problems the care provider will first try to convince the client and if that doesn't work he/she will contact the doctor.

All care providers underline the importance of certain communication manners while providing medication support. Here is a list of how a care provider should and shouldn't act, according to the interviewees.

A person that provides medication support

- should always be friendly;
- should ask open questions like: "Don't you forget to take your medication?";
- should be clear;
- shouldn't be patronizing;
- should coach;
- shouldn't give compliments;
- should use humor;
- should show respect; and
- should show sympathy.

Appendix C: System Design

This appendix describes the system used to control the behavior of the robot in detail. We first describe the SAIBA Framework (for more information about this framework see (Kopp et al., n.d.) which explains the conceptual basis for the used Elckerlyc BML realizer. Next we describe the architecture of the Elckerlyc BML Realizer (for more information about Elckerlyc see Reidsma & Welbergen, 2011; Reidsma, Welbergen, Paul, Laar, & Nijholt, 2010; H. Welbergen, Reidsma, Ruttkay, & Zwiers, 2010). Subsequently, we describe the MPEG4 animation standard used by our system to animate the interactive face of the robot (for more information about the MPEG4 standard for face animation see (Ostermann, 1998; Raouzaiou, Tsapatsoulis, Karpouzis, & Kollias, 2002; Reidsma et al., 2010). Section C.4. Describes the system components used to control the robot behavior and how these components are connected. The following sections describes the components that have been developed or extended for the current study: 1) Florence BML Realizer Elckerlyc, 2) Florence Wizzard of Oz, and 3) Florence 2D MPEG4 javascript Face. One should notice that we tried to build a system that allows modifications and extensions, so that it is useful for future projects of the Florence Project.

C.1. SAIBA Framework - BML

A group of embodied conversation agent (ECA) researchers have together designed a framework SIABA (Situation Agent Intention Behavior Animation), to design interactive virtual humans. This framework should make it easier for ECA researchers to pool their resources, and thus avoid duplication of work. The SAIBA framework has defined three sequential processing phases that take place in an ECA: 1) planning of communicative intent, 2) planning of multi-model realization of the intent, and 3) realization of planned behaviors. Dividing the process into phases makes ECA-systems more modular.

In the first phase, planning communicative intent, plans of what the ECA wants to do in a certain situation are made. For example, the Florence robot intends to give the user a medication reminder. This intent planner doesn't need to know how this intent will be translated in behavior. The behavior planner translates the intent in behavior. For example, in case of a reminder the robot will walk towards the user and say something like *"it's time for your medication"*. This intent realizer planner doesn't need to know how this behavior is realized (e.g. what kind of TTS-system is used, how the robot navigates to the user, if and what kind of animated face is used). The behavior realizer is responsible for translating the planned behavior into actions of different component of the robot. To support the modularity of these components, languages are designed to bridge the gaps between the phases. This make it easier for ECA researchers to reuse components developed by others. Figure 15 shows the SAIBA framework. Between the intent planning and the planning of realization of intent an Function Markup Language (FML) describes the intent on an abstract level without describing the type of behavior. The Behavior Markup Language (BML) is an XML based language that can be used to control the behavior of a virtual human. This is done at such an abstraction level that it is independent of the behavior realization. We decided to use the SAIBA framework for the design of the system to support modularity and avoid duplication of work. The system described here will focus on the behavior realization phase. BML will be used as input for the behavior realization. Below an example of BML expression is given.

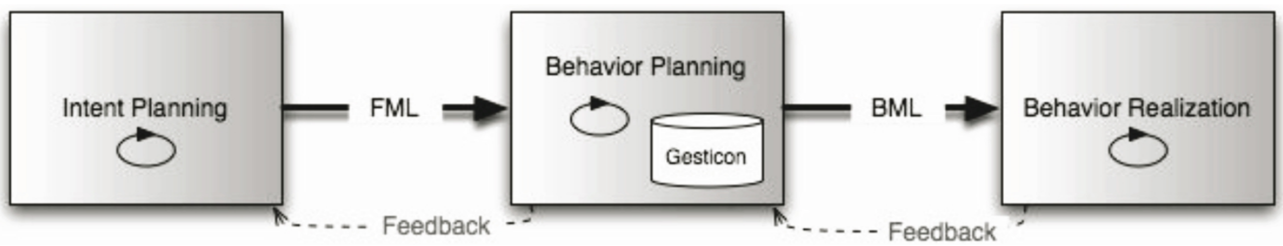


Figure 15: SAIBA framework for multimodal generation, figure from (Kopp et al., n.d.) .

```
<bml id="bml1">
   <speech id="speech1" start="1">
      <text>Hello.</text>
   </speech>
   <face id=”f1” start=”speech1:end” end=”speech1:end + 2” type=”LEXICAL-
IZED” lexeme=”friendly_smile” amount=”1”>
</bml>
```

This piece of BML tells an embodiment to say *“hello”* and smile afterwards. BML describes what kind of behavior (facial expressions, gestures, speech, etc) have to occur, and when (timing).

For the behavior realizer component, so-called BML realizers are designed. These BML realizers take BML as input and translate this to specific commands to virtual human components. For example, the piece of BML given above is translated in such a way that a TTS engine and a face engine can be controlled. For the design of the system we decided to use the Elckerlyc BML Realizer.

C.2. Elckerlyc BML Realizer

Elckerlyc is selected as BML-realizer. In comparison with other BML-realizers Elckerlyc provides better support of continuous interaction and of integration of new modalities and embodiments. Elckerlyc can be implemented as a component in an application independent of the OS or programming language that was used for the application. Here we will provide a short description of the working of Elckerlyc.

The global architecture of Elckerlyc is shown in Figure 16. This architecture should support configuration, extension, adaptation of the system to match the application specific requirements. Elckerlyc is the last stage of the SAIBA framework; the behavior realization stage. Elckerlyc receives a BML string of the Behavoir Planner and controls the realization of the behavior on the application specific embodiment of a human-like agent. A BML Realizer Port is used to send BML form the Behavior Planner to Elckerlyc and to send feedback back to the Behavior planner. This BML Realizer Port is designed in such a way that different types of connections can be implemented (TCP/IP, ActiveMQ).

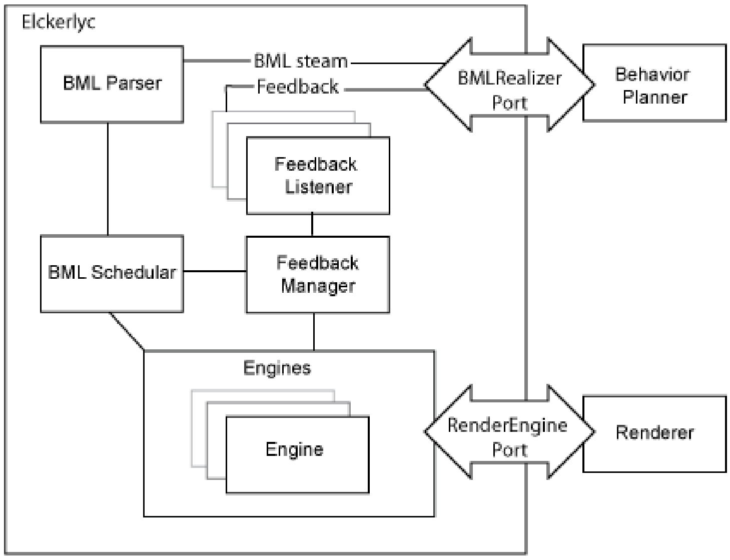


Figure 16: Elckerlyc's architecture

The behavior realization is split into two parts: Scheduling and Playing. The scheduler is responsible for the synchronization of behavior that has to be realized by different engines. The scheduler determines which piece of the BML string should be handled by which Engine. For example, the part between the nodes <face></face> should be handled by the Face Engine. The playing part is handled by the engines.

The Engines implement the Engine interface. All Engines are entities of the DefaultEngine class that implements the Engine interface. Figure 17 shows the Engine interface structure. Each engine consists of: 1) a Planner, 2) a Binding, 3) a PlanManager, 4) a Player, and 5) a PlanPlayer. The Planner uses a Binding to map the abstract BML behaviors to Plan Units. A Plan Unit describes the specific information that the Renderer needs to produce the specific behavior. The Binding uses an XML file that describes how BML behaviors are bound to plan units, parameters in the BML are bound to parameters in the plan units. An engine executes a sequence of one type of behavior Plan Units. For example, the Animation Engine executes MotionUnits and TimedMotionUnits that provide information about VJoints rotation. The Face Engine executes FaceUnits that provide information that the Face Renderer can use to displace certain points (2D) or vertexes (3D) in the face. New Engines could be added to control application specific behavior. For the Florence project an engine could be added to control the robot’s movements. This is however not yet implemented during this project, due to time constraints.

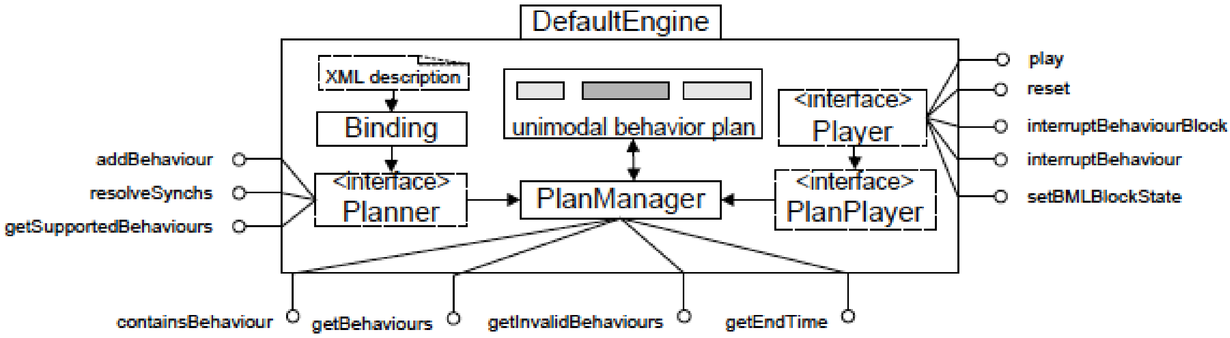
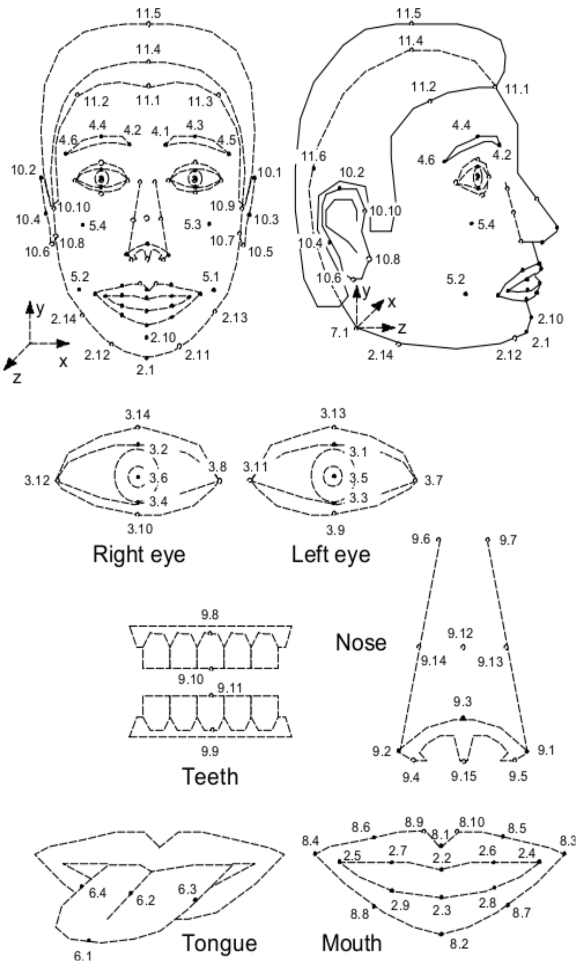


Figure 17: Elckerlyc's default engine setup from (Reidsma & Welbergen, 2011)

C.3. MPEG4 Facial Animation Standard

An interactive animated face needs to be designed that can be controlled using Elckerlyc. Chapter 3 describes the designed face for the Florence robot. The MPEG4 standard for facial animation is used to implement the Florence interactive face. Elckerlyc already has components to support MPEG4 facial animation. The alternative for 2D faces that Elckerlyc supports are keyframe animations. When using keyframe animation BML expressions can be described by sequences of pictures. This method requires drawings per keyframe which is expected to be time consuming. Moreover, keyframe animation is less flexible than the procedural animation of MPEG4. Using the MPEG4 standard, new expressions or combinations of expressions could be established more easily. It is also more easy to change the visual appearance of the face. For 3D faces Elckerlyc supports the use of morph targets. I decided to implement a 2D face. For later versions of the face design it would perhaps be interesting to experiment with a 3D face, for example using the new Three javascript API.

The MPEG4 standard describes 84 feature points (FPs) located in the face. These feature points can be used to analyze facial actions, or to automatically recognize facial expressions. They could also be used to create expressions with 2D or 3D computer faces. Figure 18 shows the position of these FPs in a neutral face.



Note: only the FP shown as filled black circles are affected by FAPs
Figure 18: Feature points in neutral face from (Ostermann, 1998)

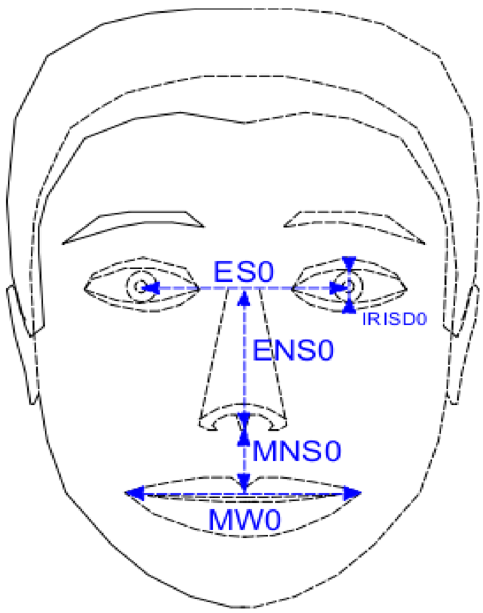


Figure 19: Face animation parameter units (FAPUs) from (Ostermann, 1998).

The MPEG4 standard uses these FPs to animate a face. Not every FP in the face can move (in picture 22 the FP shown as black points can move, the FP shown as unfilled black circles can't move). For each FP that can move the MPEG4 standard describes an FAP (Facial Animation Parameter). An FAP describe how an FP can move. Each FAP has a number, a name, a linked FP, a direction (left, right, up, down, forward, backward), a boolean value indicating whether or not the FP can be displaced in both directions, and a FAPU (face animation parameter unit). FAPUs are fractions of distances between key points in a neutral face. For example, the distance between the pupil centers in a neutral face divided by 1024 is a FAPU. Figure 19 shows these FAPUs as described in the MPEG4 standard. These FAPUs are used to calculate the displacement of an FP given an FAP. The idea behind the MPEG4 standard is that by using this FAPU values a certain FAP value will result in a similar facial expression on different faces. The same FAP values can be used for a face with different size and morphology and result in more or less the same expression. FAP values can be sent to an MPEG4 face and are translated in facial movements. Thus, for this project we implemented a MPEG4 2D face in javascript. Elckerlyc sends FAP values to this face and the face transforms according to the FAP values.

C.4. System Components and Architecture

Figure 20 shows the components of the system. We have developed a simple application, which we refer to as Wizard of Oz that produces BML code and sends it to the BML Realizer. This application offers a graphical interface that was used during the experiments to control the BML that was being send to the Florence BML Realizer. The users didn't know that the robot was controlled by a person, they believe that the robot functioned automatically. Hence the name Wizard of Oz. The Florence BML Realizer Elckerlyc is the freely available Elckerlyc as described in section C.2. with some extensions and modifications to control the Florence Face. The Florence 2D Face Embodiment creates the interactive animated face. Florence 2D Face Embodiment is implemented in javascript and uses the MPEG4 standard described in section C.3. Florence BML Realizer Elckerlyc translates face behaviors described in BML to FAP values and sends these FAP values to the Florence 2D MPEG4 Face. The Florence 2D MPEG4 Face updates the locations of the FPs using the FAP values and redraws the face. As TTS-system we used Loquendo TTS. Loquendo TTS has high quality voices for diverse languages. The Dutch voice Willem was used during the experiments. SAPI 5 (Speech Application Programming Interface), the speech API of Microsoft, is used by Elckerlyc and Loquendo. Loquendo TTS supports the use of SSML (Speech Synthesis Markup Language). SSML is an XML-based markup language used for speech synthesis which provides elements to control speech aspects like pronunciation, volume, pitch, rate, etc. Control of speech characteristics is one of the system requirements. Speech characteristics are used to manipulate the robot's personality. SSML is used to let the robot use different type of voice characteristics for the introvert and extravert robot. SSML can be encapsulated in BML. Elckerlyc already supported the use of SSML. The control of the robot movement (e.g. driving to the user) is done with a separate interface: Remote Control Robot. This application was already designed for testing purposes during the Florence project.

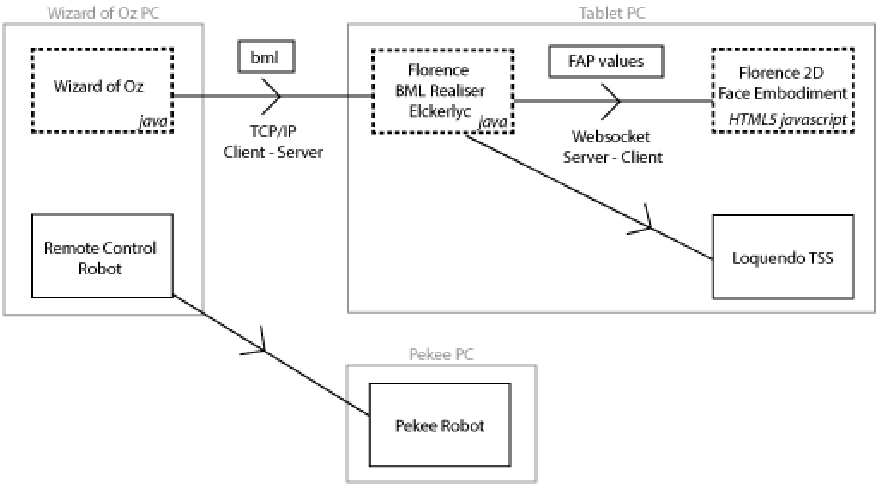


Figure 20: System architecture

During the experiment the participant were left alone with the Florence robot in the home-like room of the Experience Lab of Philips. We controlled the robot from the control room using the remote control robot application. The Remote Control Robot application provides an interface to control the movement of the robot with the arrow keys on the keyboard. In the home-like room of the Experience Lab there were several cameras installed. The video streams were displayed on screen in the control room. The video streams were useful as feedback for the remote control of the robot. The Wizard of Oz interface had several buttons to send BML strings to the Florence BML Realizer Elckerlyc. A TCP/IP connection was used to send BML from the BML Florence Wizard of Oz to the Florence BML Realizer Elckerlyc. The Florence BML Realizer Elckerlyc creates a server and the Florence Wizard of Oz a client. Between the Florence BML Realizer and the Florence MPEG4 2D javascript face there was a web socket connection. A WebSocket connection provides full-duplex communication over a single TCP socket. This technology can be implemented in browsers and webservers but also by any other client or server application. Websockets can therefore facilitate the communication between a java application and web application. The Florence BML Realizer creates a websocket server in java. The javascript websocket client of the javascript face connects to the server. In this way, the FAP values can be sent as a string of 68 FAP values separated by white-spaces. Both the Florence BML Realizer and the Florence MPEG4 2D run on the Tablet PC of the robot.

We decided to use a Wizard of Oz system for the agenda and medication reminder functionality, since the design of a fully automatic robot that would execute the behavior we had in mind for the agenda and medication reminder would consume too much time to program. Nevertheless, the architecture and some components could be used in the final robot version of the Florence Robot. In that case the Wizard of Oz interfaces are removed and replaced with, for example, a Behavior Planner and an Intent Planner as suggested by the SAIBA framework.

The next sections will explain the implementation of the components developed or extended during this project: 1) Florence BML Realizer Elckerlyc, 2) Florence Wizzard of Oz, and 3) Florence 2D MPEG4 javascript Face.

C.5. Florence BML Realizer Elckerlyc

Section C.2. presents the Elckerlyc BML Realizer. Elckerlyc is designed in a way that it can be implemented in new applications. The Florence robot face will use the MPEG4 standard. Although, Elckerlyc already has implemented components that support the use of MPEG4 faces some changes and extensions were needed to control the Florence face. This section will explain the changes that were needed. The core of Elckerlyc remained unchanged.

Elckerlyc uses an XML file to load the application specific embodiments, engines, and GUIs. For the Florence face the florencefaceloader.xml is used (see below). The xml file consist of different loader nodes, to load: guiembodiment, florencefaceembodiment, blinkengine, face engine, and speech engine. Each of these elements has its own loader that constructs the responding classes using the sub-notes and parameters of the loader notes.

florencefaceloader.xml:

```
<ElckerlycVirtualHuman>
  <BMLRealizer loader="hmi.environment.vhloader.ElckerlycRealizerLoader">
  </BMLRealizer>
  <Loader id="guiembodiment" loader="hmi.environment.vhloader.impl.FlorenceGUI">
     <BmlUI/>
     <FeedbackUI/>
     <ServerUI/>
     <KillButton/>
  </Loader>
```

```
        <Loader id="florencefaceembodiment" loader="hmi.environment.vhloader.impl.FlorenceFaceEmbodiment">
            <FlorenceFaceHost port="8887"/>
        </Loader>
        <Loader id="blinkengine" loader="hmi.emitterengine.vhloader.EmitterEngineLoader">
            <EmitterInfo class="hmi.blinkemitter.BlinkEmitterInfo"/>
        </Loader>
        <Loader id="faceengine" loader="hmi.environment.vhloader.impl.FaceEngineLoader" requiredloaders="florencefaceembodiment,guiembodiment">
            <FaceBinding basedir="" resources="Humanoids/florence/facebinding/" filename="facebinding.xml"/>
            <FaceUI/>
        </Loader>
        <Loader id="speechengine" loader="hmi.environment.vhloader.impl.SpeechEngineLoader" requiredloaders="faceengine,guiembodiment">
            <? include file="sapi5speechengine_mpeg4.xml" ?>
            <SpeechUI/>
        </Loader>
    </ElckerlycVirtualHuman>
```

The speech engine loader includes the sapi5speechengine_mpeg4.xml file that describes the settings of the speech engine:

```
    <SpeechBinding basedir="" resources="Humanoids/shared/speechbinding/" filename="disneyspeechbinding.xml"/>
    <MPEG4VisemeBinding resources="Humanoids/florence/facebinding/" filename="disneyvisemebinding_mpeg4.xml"/>
    <Voice voicetype="SAPI5" voicename="Willem" factory="WAV_TTS"/>
```

Figure 21 shows the global structure of the Florence BML Realizer Elckerlyc. The elements with dashed lines are added or modified for the use of the Florence MPEG4 face.

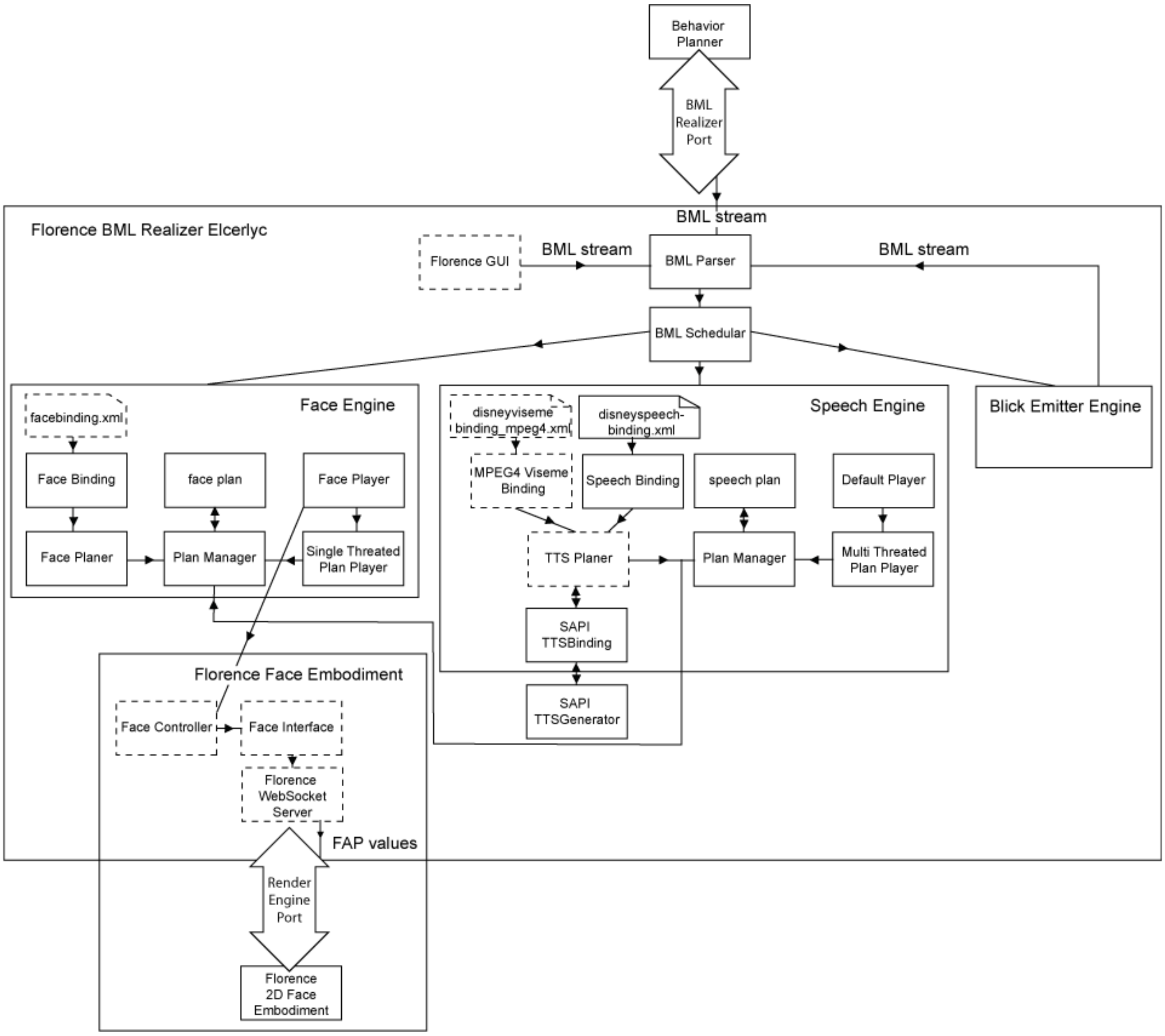


Figure 21: Florence Elckerlyc BML Realizer architecture

Each engine translates BML to behavior specific units that are executed by the player. The Face Engine plays a sequence of FaceUnits. The FlorenceFaceController provides the Face Unit access to the FlorenceFaceEmbodiment. The Player plays a sequence of FaceUnits (FACSFU) by calling the function play() of these FaceUnits. The FaceUnits have a reference to the FlorenceFaceController. They will set the new MPEG4 configuration of the FaceUnit on the FlorenceFaceController. The FlorenceFaceControler has a FlorenceFaceInterface. The FlorenceFaceInterface is responsible for sending the FAP values to the Florence MPEG4 2D Face. The FlorenceFaceInterface extends a Thread and sends 12 times per second the FAP values using the FlorenceWebSocketServer. The FlorenceWebSocketServer is used for the communication between the Florence MPEG4 2D Face and the Florence BML Realizer Elckerlyc.

There are different types of Face Units for different types of faces. For MPEG4 faces Elckerlyc offers Face Units that maintain AUs (action unit) values and convert them to MPEG4 FAP values. The class that is used for this is called FACSFU, which implements the FaceUnit interface. Facial Action Coding System (FACS) is a system to describe human facial expressions. FACS describes which AUs (Action Units) are involved in an expression and the extend to which the AU is involved. AUs are based on facial muscle movements. For each muscle or group of muscles of which the contraction results in a change of the visual appearance of a face there is an AU. FACS was initially developed by P. Ekman, W. v. Friesen, and R. J. Davidson to analyze faces. The taxonomy has also facilitated automatic facial expression recognition and facial expression synthesis. Elckerlyc has a class to convert AUs to FAPs. This is done by the FACConverter that uses a text file to map AUs to FACs. This text file is called facs_to_mpeg4.txt. The file describes for 64 AUs which of the 68 FAPs are involved. Using the original mapping resulted in unnatural facial expressions when using our face. Therefore, we changed the facs_to_mpeg4.txt file manually. We did this by setting the FAP values on the Florence face such that the expression of the face matched the AU description and pictures on http://www.cs.cmu.edu/afs/cs/project/face/www/facs.htm.

Using BML facial actions can be controlled in three ways:

1) by directly setting a value for an AU,

2) by setting an expression, and

3) by sending speech.

The following BML is an example of setting an AU directly.

```
<bml id='bml1'>
   <face id='f1' start= '0' end='2' type='FACS' au= '1' side='right' amount='1'>
</bml>
```

As mentioned, there are 64 AUs. The number after “au=” tells Elckerlyc which AU the face should display. The timing and duration can be set using the start and end attributes. The amount attribute which describes the extent of the action of a certain AU can vary from 0 to 1.

The following BML is an example of setting a predefined facial expression using BML.

```
<bml id='bml1'>
   <face id='f1' start= '0' end='2' type='LEXICALIZED' lexeme= 'joy' side='right'
amount='1'>
</bml>
```

The facebinding.xml file is used by the Face Binding and Face Planner to map BML to Face Units. The binding that is desired depends on the type of face. For the MPEG4 face a new facebinding.xml file had to be created which describes predefined facial expressions in AU values (FAC configuration). Here is an example of such a mapping of BML to a facial expression description in the facebinding.xml:

```
</bml>
   <FaceUnitSpec type="face">
      <constraints>
         <constraint name="type" value="LEXICALIZED"/>
         <constraint name="lexeme" value="joy"/>
      </constraints>
      <parametermap>
         <parameter src="amount" dst="intensity"/>
      </parametermap>
      <parameterdefaults>
         <parameterdefault name="intensity" value="1"/>
      </parameterdefaults>
      <FaceUnit type="FACS" filename="Humanoids/shared/faceexpressions/FLjoy.xml"/>
   </FaceUnitSpec>
</bml>
```

The FLjoy.xml file describes FACS configuration of the expression:

```
<FACSConfiguration>
   <AU number="7" side="LEFT" value="1.0"/>
   <AU number="12" side="LEFT" value="1.0"/>
   <AU number="13" side="LEFT" value="1.0"/>
   <AU number="27" side="NONE" value="0.36"/>
   <AU number="28" side="NONE" value="0.0"/>
   <AU number="1" side="RIGHT" value="0.0"/>
   <AU number="7" side="RIGHT" value="1.0"/>
   <AU number="12" side="RIGHT" value="1.0"/>
   <AU number="13" side="RIGHT" value="1.0"/>
   <AU number="20" side="RIGHT" value="0.0"/>
</FACSConfiguration>
```

Only those facial expressions that are used during the test are implemented this way. Without too much effort new expressions can be added. We used the FACSconverter tool of Elckerlyc to save the FAC configuration of an expression. This is a graphical interface with sliders for each AU.

The Speech Engine uses the Face Engine to set visemes on the face. Visemes are the visual aspects that come along with speech. The smallest elements of speech are phonemes. Different mouth openings are used to produce a phoneme. A viseme is the visual appearance that came along with a phoneme. Elckerlyc supports two types viseme sets: disney and IKP. The disney viseme set defines 21 visemes and the IKP viseme set consists of 15 visemes. Elckerlyc determines which viseme has to be displayed when a text is spoken. The current version of Elckerlyc didn't support the mapping of visemes to MPEG4 FAP values; it only had a mapping from the visemes to face units that use morph targets to deform a face (MorphVisemeBinding). We added the MPEG4VisemeBinding that uses the disneyvisemebinding_mpeg4.xml file to map visemes the MPEG4 FAP values. The disneyvisemebinding_mpeg4.xml file describes per disneyviseme the corresponding AU values. We used the FACsConverter tool that comes with Elckerlyc to save the FACSconfigurations for each viseme. Below is an example of a viseme described as a facsconfiguration in disneyvisemebinding_mpeg4.xml:

```
<Mapping viseme="2" name="aa">
   <FACSConfiguration>
      <AU number="22" side="NONE" value="0.0"/>
      <AU number="23" side="NONE" value="0.0"/>
      <AU number="25" side="NONE" value="0.0"/>
      <AU number="26" side="NONE" value="1.0"/>
      <AU number="27" side="NONE" value="0.0"/>
   </FACSConfiguration>
</Mapping>
```

The mapping of IKPvisemes to MPEG4 values is not implemented during this project.

C.6. Florence Wizard of Oz

The Florence Wizard of Oz application should provide an interface to send BML to Florence BMLRealizer Elckerlyc. With the Elckerlyc software comes a demo that can send BML to the Realizer using a TCP/IP connection. We used this demo (TCPAdapterDemo) as a starting point. The interface of the Florence Wizard of Oz is shown in Figure 22 The Florence Wizard of Oz creates a client that connects to the server of the

Florence BLM Realizer Elckerlyc. The ip-adress of the server can be set in the Wizard of Oz interface. The Florence Wizard of Oz application consists of three classes: 1) the FlorenceWOZ, 2) the FlorenceWOZGUI, and 3) the FlorenceWOZBMLCreator. The FlorenceWOZBMLCreator sends semi hard coded BML strings. We call it semi-hard coded because some aspects of the send BML are based on variables. Using the FlorenceWOZ interface these variables can be set. Namely, the user's gender, the robot's language, and the robot's personality (introvert or extravert) can be set in the interface. These variables are used during the creation of BML. The user's gender is used to make a matching reference to the user. The personality influences the type of text that is spoken by the robot and how it is spoken (e.g. volume, speech frequency range, and speech rate). The language variable influences the language of the texts in BML.

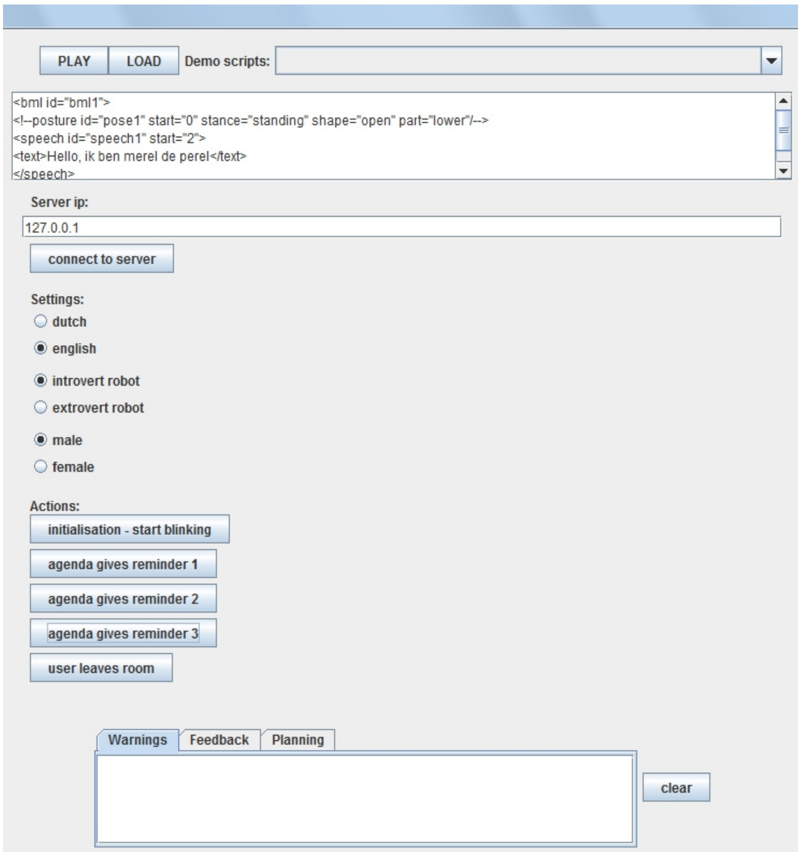


Figure 22: WOZ application graphical user interface

C.7. Florence 2D Face Embodiment

Section C.3. describes the MPEG4 standard. We used this standard for the implementation of the face for the Florence robot. An MPEG4 face takes FAP values as input and calculates the face deformation based on the FAP values. The MPEG4 standard is used more often for 3D faces than for 2D faces. In 3D MPEG4 faces FAP values are translated to vertex displacements. Only a few vertexes of 3D faces are represented by FPs (Feature Points) for which the displacement can be calculated via a linear function from the FAP values. For the displacement of all the other vertexes around the FP different kinds of algorithms exist. For the purpose of this study, we decided to design a 2D face. The deformation of the face is based on the FP only. This requires a more simple formula to calculate FP displacements based on FAP values.

The displacement of the FP that belongs to an FAP is calculated using the following formula:

*FP displacement = FAPU * FAP*

where

FP displacement = the position of the FP after the displacement minus FP position in a neutral face

FAPU = Face Animation Parameter Unit for the FAP (see section .. for more information on FAPUs)

FAP = Facial Animation Parameter

As explained in section C.3. the FAPU variables are used to adjust the FAP values to the size and form of the face. Thus, the same FAP values should result in similar facial deformations on different faces. However, if you design a face of which the morphological characteristics deviate from a standard face, additional adjustments might be needed.

For the implementation of the face we used a structure that divides tasks similar to the MVC-model (Model View Controller model). The face model is responsible for maintaining the FP positions and FAP values. The face model calculates new FP positions if new FAP values are set. The face view is responsible for drawing the face. The view uses the face model to get the FP positions. This view draws the robot-like face for the Florence robot. If a new kind of face will be designed for the robot with a totally different appearance only a new face view class has to be implemented. Figure 23 shows the components.

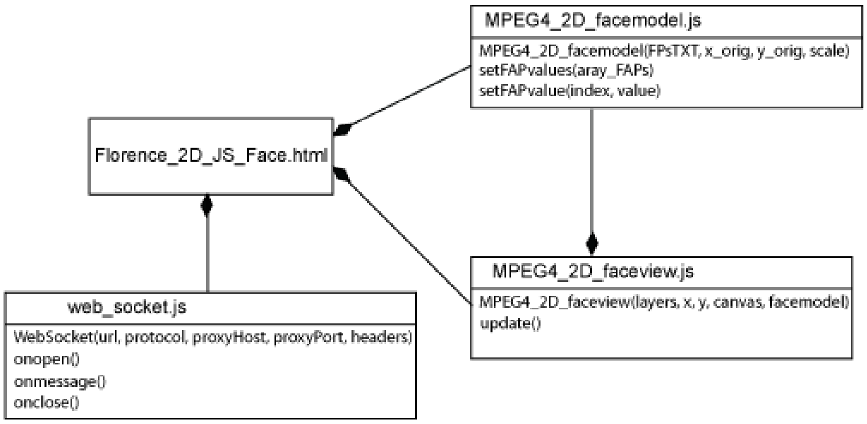


Figure 23: structure of the Florence 2D Face Embodiement

The Florence_2D_JS_Face.html has the role of the controller. Florence_2D_JS_Face.html creates a MPEG4_2D_facemodel and a MPEG4_2D_faceview. The MPEG4_2D_facemodel doesn't need to know anything about the graphics of the face. MPEG4_2D_faceview gets a link to the model. The MPEG4_2D_facemodel constructor can take the FP position in the neural face as a parameter. These FP positions are read from an external text file (e.g. fp_values_florence_face.txt). The Florence_2D_JS_Face.html creates a websocket client. When the "connect" button is pressed in GUI the websocket client will try to connect to a websocket server. The websocket server is expected to send 68 FAP values separated by white spaces. These 68 values represent the 68 FAPs of the MPEG4 standard. The position of the numbers in the string matches the numbers of the FAPS of the MPEG4 standard. Thus, the first FAP in the string is FAP number 1. The first two FAP values that describe high level animation are not used. The Florence_2D_JS_Face.html will call the setFAPvalues() method of the MPEG4_2d_facemodel.js with the FAPs as an array of integers as parameter. The .setFAPvalues() of the MPEG4_2D_facemodel will set new positions for the FPs. Subsequently the Florence_2D_JS_Face.html will call the update() function of the MPEG4_2D_faceview. The MPEG4_2D_faceview will use the updated FP positions in the MPEG4_2D_facemodel to redraw the face.

The designed face only has eyes, a mouth, and eyebrows. The face therefore has less FP than a standard face: 38 instead of 84. Figure 24 shows the 38 FP of the face. As already explained in section .. not all FPs are used to transform the face. The animation of the faces is based on the position of the FP. The HTML5 canvas API is used to draw the face in the code. The face consist of layers. On each layer an element of the face is drawn (e.g. mouth, eyebrows, head, eye white, eye lids, irises, pupils).

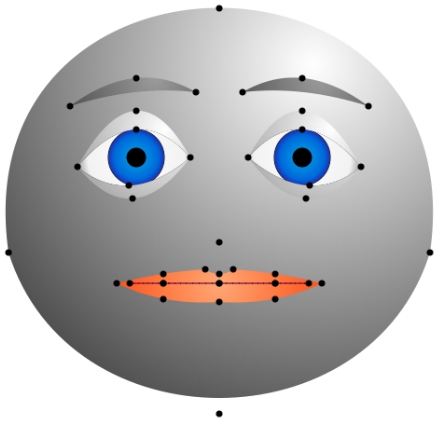


Figure 24: Florence robot face with FP shown by black circles

The face is redrawn when the update() function of the MPEG4_2D_faceview is called. Only those parts of the face of which the FP are given a new position will be redrawn. For web-animation a frame rate of 12 frames per second is often used. So, the faces has to be redrawn twelve times per second. Updating only those parts of the face that are changed requires less CPU capacity. The frame rate of the system is determined by the FaceInterface of the Florence BML Realizer Elckerlyc.

Appendix D: Questionnaire 1 – 16 items BFI for Perceived Robot Personality

Table 9 shows the statements of the questionnaire we used to test the personality that participants attributed to the robot they experienced. This questionnaire is a combination of all the eight items for Extraversion in the 44 items BFI (REF) and the 8 items for the other constructs of the 10 items BFI (REF). We used a Dutch validate version of the BFI (REF). The order of the items was made such that the extraversion items are interchanged with other construct items. The participants could indicate their agreement with each statement on a 5 point Likert scale. Some changes were made to make the test suitable to test the personality of the robot instead of the persons own personality.

Construct	Num.	Statement English	Statement Dutch
		I see the robot as a robot that ...	Ik zie de robot als een robot die ...
Extraversion	1	... Is talkative.	... Spraakzaam is.
	2	... Is reserved.	... Terughoudend is.
	3	... Is full of energy.	... Vol energie is.
	4	... Generates a lot of enthusiasm.	... Veel enthousiasme opwerkt.
	5	... Tends to be quiet.	... Doorgaans stil is.
	6	... Has an assertive personality.	... Voor zichzelf opkomt.
	7	... Is sometimes shy, inhibited.	... Soms verlegen, geremd is.
	8	... Is outgoing, sociable.	... Hartelijk is, houdt van gezelligheid.
Agreeableness	1	... Tends to find fault with others.	... Geneigd is kritiek te hebben op anderen.
	2	... Is generally trusting.	... Mensen over het algemeen vertrouwt.
Neuroticism	1	... Gets nervous easily.	... Gemakkelijk zenuwachtig wordt.
	2	... Is relaxed, handles stress well.	... Ontspannen is, goed met stress kan omgaan.
Openness to new experience	1	... Has few artistic interests.	... Weinig interesse voor kunst heeft.
	2	... Has an active imagination.	... Een levendige fantasie heeft.
Conscientiousness	1	... Tends to be lazy.	... Geneigd is lui te zijn.
	2	... Does a thorough job.	... Grondig te werk gaat.

Table 9: Modified and selected BFI statements used in a questionnaire to measure the perceived robot personality.

Appendix E: Questionnaire 2 – Almere Model Robot Acceptance

We used the Almere robot acceptance questionnaire as described in (Heerink, Kröse, Evers, et al., 2009; Heerink et al., 2010). We removed some construct of the original questionnaire because they were not useful for our type of test where participants can only interact with a prototype robot for a very short duration (5 minutes). We used Dutch translation that has been developed by the creators of the original questionnaire. The order of the statements was randomized. Participants could indicate their agreement with each statement on a 5 point Likert scale. Table 10 shows the statements of the questionnaire we used to test the robot acceptance.

Code	Num.	Statement English	Statement Dutch
ANX	1	If I should use the robot, I would be afraid to make mistakes with it	Als ik de robot zou gebruiken, zou ik bang zijn er fouten mee te maken.
	2	If I should use the robot, I would be afraid to break something	Als ik de robot zou gebruiken, zou ik bang zijn iets stuk te maken.
	3	I find the robot scary	Ik vind de robot eng.
	4	I find the robot intimidating	Ik vind de robot intimiderend.
ATT	1	I think it's a good idea to use the robot	Ik vind het een goed idee de robot te gebruiken.
	2	The robot would make my life more interesting	de robot kan mijn dagelijks leven interessanter maken.
	3	It's good to make use of the robot	Ik vind het fijn om de robot te kunnen gebruiken.
PAD	1	I think the robot can be adaptive to what I need	Ik denk dat de robot zich aanpast aan wat ik nodig heb.
	2	I think the robot will only do what I need at that particular moment	Ik heb het idee dat de robot alleen dat voor me doet waar ik op dat moment behoefte aan heb.
	3	I think the robot will help me when I consider it to be necessary	De robot zal me pas helpen als ik dat nodig vind.
PENJ	1	I enjoy the robot talking to me	Ik vind het leuk als de robot tegen me praat.
	2	I enjoy doing things with the robot	Ik vind het leuk om met de robot dingen te doen.
	3	I find the robot enjoyable	Ik vind de robot plezierig.
	4	I find the robot fascinating	Ik vind de robot boeiend.
	5	I find the robot boring	Ik vind de robot saai.
PEOU	1	I think I will know quickly how to use the robot	Ik denk dat ik snel doorheb hoe ik met de robot moet omgaan.
	2	I find the robot easy to use	Ik vind de robot gemakkelijk in het gebruik.
	3	I think I can use the robot without any help	Ik denk dat ik met de robot kan omgaan zonder hulp.
	4	I think I can use the robot when there is someone around to help me	Ik denk dat ik met de robot kan omgaan als er iemand in de buurt is om te helpen.
	5	I think I can use the robot when I have a good manual.	Ik denk dat ik met de robot kan omgaan als ik een goede handleiding heb.
PS	1	I consider the robot a pleasant conversational partner	Ik vind de robot een prettige conversatiepartner.
	2	I find the robot pleasant to interact with	Ik vind de robot prettig in de omgang.
	3	I feel the robot understands me.	Ik heb het gevoel dat de robot begrip voor me heeft.
	4	I think the robot is nice	Ik vind de robot aardig.
PU	1	I think the robot is useful to me	Ik vind dat de robot nuttig is voor mij.
	2	It would be convenient for me to have the	Ik zou het handig vinden om de robot te

		robot	hebben.
	3	I think the robot can help me with many things	Ik vind dat de robot me met veel dingen kan helpen.
SP	1	When interacting with the robot I felt like I'm talking to a real person	Toen ik met de robot bezig was voelde het toen alsof ik met een echt personage in gesprek was.
	2	It sometimes felt as if the robot was really looking at me	Ik had af en toe het gevoel of de robot echt naar me keek.
	3	I can imagine the robot to be a living creature	Ik kan de robot zien als een levend wezen.
	4	I often think the robot is not a real person.	Ik denk er vaak aan dat de robot geen echt personage is.
	5	Sometimes the robot seems to have real feelings	Ik vind dat de robot soms echt gevoel lijkt te hebben.
TR	1	I would trust the robot if it gave me advice.	Ik zou de robot vertrouwen als ze me advies gaf.
	2	I would follow the advice the robot gives me.	Ik zou een advies van de robot ook opvolgen.

Table 10: Statements of Almere-model questionnaire (Heerink et al., 2010).

Appendix F: Overview Described Related Work

This appendix shows three tables that provide an overview of the related work described in this thesis.

	Social ability	Empathy	Agreeability	Extraversion	Personality Strength	Consistency	Seriousness
	+						
	+	+	+			+	
	+						
	+						
	+		+	- [1]			+
	+		+	+			
	+						
	+						
		+		+ [2]	+		+
		+					
		+					
			+				
				+			
				+			+
				-			
							+
							+

Table 11: Effects of personality characteristics of computer agents and robots. [1]An serious introvert robot was more persuasive then an extravert playful robot. [2] Depends on the task and role of the robot.

Ref.	Type of System	Conditions	Modifications	Role / task	Effects
Nass & Lee, 2001	TTS (Text to Speech System)	- extravert voice - introvert voice	- paralinguistic cues (volume, speech rate, fundamental frequency, frequency range)	Providing book reviews	similarity matching positively correlated with: - evaluation of the voice (liking and credibility) - evaluation of the review (persuasiveness) - evaluation of the writer of the review (trustworthiness and attractiveness)
Walters et al., 2007	Robots	- mechanical appearance and attention-seeking style - robot appearance and attention-seeking style - humanoid appearance and Attention-seeking style	- Appearance - Attention-seeking style	Draws the users attention to signal that there is someone at the door.	- participants with low extraversion and emotional stability scores prefer mechanical appearance and attention-seeking style - robot with mechanical appearance and attention-seeking style was perceived introvert and emotional unstable
Tapus & Mataric, 2008	Robot	- extravert robot with challenge-based encouragement	- activity level - sociability - Proxemics - vocal content	Health coaching robot supports	- introvert participants liked both robots equally - extravert participants preferred extravert robot

	- introvert robot with nurturing-based encouragement	(strong aggressive language vs. Gentle supportive language) - paralinguistic cues (volume, speech rate)	physical exercising	- similarity matching resulted in longer and more enjoyable exercising

Table 12: Summary of studies that showed that similarity attraction was applicable to the interaction with a computer agent or a robot

Ref.	Type of System	Conditions	Modifications	Role / task	Effects
Isbister & Nass, 2000	Embodied computer agent	- extraverted in both verbal and non-verbal behavior - introverted in both verbal and non-verbal behavior; - extraverted in verbal but introverted in non-verbal behavior; - introverted in verbal but extraverted in non-verbal behavior	- verbal content (strong friendly language and confident assertions vs. Weaker language and questions and suggestions) - non-verbal (body pose)	Agent provided suggestion during a game	Complementary matching positively correlated with: - liking - enjoyability
Lee et al., 2006	AIBO robot dog	- extravert dog - introvert dog	- paralinguistic cues (volume, fundamental frequency, frequency range, speech rate) - non-verbal (facial	Playing with dog.	Complementary matching positively correlated with: - perceived intelligence - social attractiveness - enjoyability - social presence Social presence was a

	expression, moving angle, moving speed, autonomous movements)	mediating factor.

Table 13: Summary of studies that showed that complementary attraction was applicable to the interaction with a computer agent or a robot.