The influence of perceived agency and valence of feedback of a social robot on energy use during washing tasks

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Preface

The research that is described in this master thesis was carried out in order to obtain the degree Master of Science at the Eindhoven University of Technology for the department of Industrial Engineering & Innovation Sciences (IE & IS) at the group of Human Technology Interaction (HTI). This HTI group studies the interaction between humans and technology from a psychological perspective. Because the people who use technology are central in this master program, also an emphasis is placed on empirical research. This empirical research is also part of the current master thesis.

The subject of this thesis was found after deliberation with Cees Midden who suggested a study that investigates the persuasive effects of a social actor on energy conservation behavior. This study has drawn my interest because it is becoming increasingly important to use the resources that we currently have as economically as possible.

To be able to conduct this research I first of all want to thank Cees Midden and Jaap Ham for their support and comments during my research. Furthermore I want to thank Jan-Roelof de Pijper and Martin Bosman for their technical support with programming and facilitating the experiment.

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Abstract

Persuasive technology is becoming increasingly important in our everyday lives. This technology can help change peoples' behavior. In the current study such a persuasive technology is used to investigate the change of conservation behavior of users of a simulated washing machine, who received feedback on their energy use from a robotic social actor. Factors that are expected to be important for changing this behavior are the perceived agency of the social actor, the type of feedback and the valence of that feedback. In the experiment, the level of agency of the robotic social actor, the iCat, was manipulated, and also the type of feedback and the valence of the feedback that the participants received varied over conditions. Furthermore implicit and explicit measures were developed to assess the amount of perceived agency of the social actor. Results indicated that a higher level of perceived agency of the social actor seemed to evoke more energy conservation over time. Also this same effect was found for positive feedback of that social actor. Furthermore two of the measures that were developed to measure perceived agency proved to be reliable and could be used in further research that investigates the perceived agency of social actors. Implications of the results are discussed and recommendations for further research are given.

Chapter 1 Introduction

Currently society faces numerous threats with regard to climate change due to human behavior. Polar areas and glaciers are melting, temperatures and sea levels are rising, emissions of CO2 and other greenhouse gasses are growing and natural resources are depleting (Gardner & Stern, 2002). The consequences of these phenomena can be catastrophic in the long run (21st century). Here disturbances like flooding, drought, wildfire, insects, ocean acidification, pollution, fragmentation of natural systems and overexploitation of resources are likely to take place. These disturbances could have very serious consequences for people's everyday life and health (IPCC, 2007).

Because of these problems there is a large need for renewable energy sources that will reduce these effects on climate change. Here the development and implementation of renewable energy sources like wind power, solar power, water power and nuclear power is of great importance. Other possibilities to mitigate climate change are to make systems more efficient and try to conserve more energy.

For the last solution, conserve more energy, it is important that people's behavior will be changed. It is necessary that people will be persuaded to save more energy. These persuasion attempts can be made by people, as well as with help of technology. Also the interaction between these two parties can be of great importance.

Such a persuasion attempt can be made by an electronic device that gives suggestions of how to conserve energy in a domestic environment. This device could for instance be able to monitor lighting, temperature and airflow in several rooms. An intelligent agent, whose intention it is to conserve energy, is also present in this system and gives advise on how to optimally set temperatures and other values to minimize energy usage. The users of the system will feel that the agent is competent when he gives correct information and also shares the same goal of conserving energy. Therefore they will "listen" to this agent, and adapt their behavior according to its advices. In this example it is important how the user perceives the system. If the users regard the agent who is making the suggestions as incompetent, incapable and does not have particular goals, they might ignore its advice.

In the current study the main question that is investigated, is how a combination of perceived capability, intelligence and intentionality (later on conceptualized as perceived agency) of an agent can persuade people to change their conservation behavior. In this introduction first the concept of persuasive technology is explained. Secondly the definition of (perceived) agency is clarified and its relation to persuasive technology is explained. Finally different types of feedback are discussed that could be used for the changing of peoples' conservation behavior.

1.1 Persuasive technology

The example above is an example of the concept of "persuasive technology" that integrates decisions of use and behavioral coaching mechanisms (Fogg, 2003). IJsselsteijn, de Kort, Midden, Eggen, and van den Hoven (2006) define persuasive technology as a class of technologies that are intentionally designed to change a person's attitude or behavior. This technology is mainly used in the area of human-computer interaction. Praise given by computers and gold stars offered by programs can be regarded as forms of persuasive technology. Fogg (2003) distinguishes three different roles of interactive technologies; as tools, as media, and as social actors. He argues that when interactive technologies are acting as tools, they are intended to make activities easier and more efficient to do (for example calculations). Also they are able to influence and motivate people in specific ways. Furthermore he claims that media interactive technologies can be divided into two categories: symbolic and sensory. Symbolic media use symbols that convey information like text, graphics and icons, whereas sensory media provide sensory information like audio, video and touch sensations. According to him both media can influence people, especially with computer simulations where people are motivated and persuaded by the interactive experiences that are provided by computers. Finally Fogg (2003) argues that when interactive technologies are using social cues, these technologies can be perceived by its users as living entities which could be able to establish relationships. He claims that social actors could be persuasive by providing social support to users, modeling a target behavior or attitude and rewarding people with positive feedback.

This persuasive technology could be used as an energy saving mechanism for household appliances and other electrical systems, or even a full "domotic" system that connects all these different appliances into a network that is controlled by some sort of agent. There are many different kinds and definitions of an agent, for example software agents, intelligent agents and

relational agents. The kind of agent that is intended in the current research, is described by Stuart and Norig (2003) as an agent that is able to observe an environment through sensors and act upon an environment through actuators with its intention to achieve certain goals. The sensors of a human agent would comprise eyes, ears and other organs, whereas hands, legs, mouth and other body parts would be the actuators. For robotic agents camera's and infrared range finders could be sensors and various motors could be actuators. Software agents might receive keystrokes and file contents as sensory inputs and will act on the environment by displaying them on the screen. Also the agents that are intended here are able to perceive their own actions (Stuart & Norig, 2003). One of the roles of such an agent could be, to try to persuade users to conserve energy. However it is still relatively unknown how this agent should behave and be represented to get optimal results regarding its persuasive character.

Especially the last role of interactive technology described by Fogg (2002), the role of social actor, is interesting when trying to persuade users to conserve energy in a household environment with help of an agent. Here the agent could be regarded as a social actor that tries to bond with its users and tries to persuade users to for example conserve energy. Recent research of Ham, Midden and Tak (2008) investigated the persuasive effects on behavioral change of social feedback that was provided by an embodied agent. In a lab setting participants had to do washing tasks on a simulated washing machine where they were able to conserve energy. The experiment tested the effect of (positive and negative) social feedback, which was given by an embodied agent, and compared it with more often given factual feedback. The results showed that participants who received social feedback conserved more energy than participants who received factual feedback. Also a conservation effect was found which demonstrated that participants conserved more energy after they had received negative feedback. This research showed that a social actor, in this case an embodied agent, is able to persuade users to conserve energy. It changed the washing behavior of people who received feedback of their energy usage of the embodied agent.

A social actor approach could be important because it, as shown above, could change people's attitude and behavior. When systems or agents are perceived to be social actors, they will be able to use the principles of social influence to motivate and persuade users. Social influence is not possible without a social actor. Therefore, when trying to persuade people by means of a social actor it is important that the actor (or agent) is perceived to be social. Fogg (2003) proposes five primary types of social cues which cause people to make inferences about social presence in

computing products. These five types of social cues are: *physical cues* like a face, body and movement; *psychological cues* like personality, feelings and empathy; *language cues* like interactive language and language recognition; *social dynamic cues* like praise, turn taking and reciprocity; *social roles cues* like an opponent, teammate and guide.

As Fogg (2003) has shown, an agent can be represented socially in many ways; in texts, on computers, as avatar (graphical representation) or as embodied robot. There is al lot of research done in the field of human-computer interaction and human-robot interaction on how humans perceive computers and robots. Mostly these studies are about appearances of the agent, emotions and about attitudes towards these machines. Nass, Steuer, Tauber and Reeder (1993) provided the first experimental evidence that users attributed social properties towards minimal computer-based agents, even though the users themselves believed that these attributions were inappropriate. Here the minimal computer-based agents comprised a computer evaluation of a computerized tutoring session where voices, amount of computers and praise or criticism were varied. This new experimental paradigm which was proposed by Nass, Steuer and Tauber (1994) was called "Computers are Social Actors (CASA)". Fogg and Nass (1997) also found that flattery from computers produces the same effects as the general effects of flattery from humans. This study also made use of a very simplistic computer-based agent; a completely text based interaction.

Furthermore, studies in human-computer interaction show that when virtual humans look realistic, humans would treat them as normal social beings and are prepared to interact with them (Zhang, Yu, & Smith, 2006). However, a study of Nowak and Biocca (2003) which, among other things, investigated the influence of anthropomorphism on social presence, found that participants who interacted with low anthropomorphic images reported more social presence than participants who interacted with high anthropomorphic images. Anthropomorphism can be described as the attribution of human characteristics, human form or human behavior to non-human creatures, objects or phenomena, such as robots, computers, and animals (Bartneck, Croft, & Kulic, 2008). This result was explained by higher expectations regarding the interaction with high anthropomorphic images. When these higher expectations are not met, it leads to reduced feelings of social presence.

Also studies in human-robot interaction find that humans are best in interacting with entities that look and act human. This because our brains have evolved together with our bodies and faces,

and have been trained by experience to understand human feelings and intentions (MacDorman & Ishiguro, 2006). When robots are looking more humanlike they seem more familiar, however small deviations from real human norms will cause them to look repulsive. This phenomenon causes a "valley" in the graph that depicts familiarity as a function of human likeness. This valley is called the Uncanny valley (Mori, 1970; MacDorman & Ishiguro, 2006; MacDorman, 2006; Bartneck, Reichenbach, & Carpenter, 2008; Minato, Shimada, Itakura, Lee, & Ishiguro, 2005).

1.2 Agency

As can be seen in the text above it is important for persuasive social agents that they are human-like, or have human-like properties. Besides the appearance of the social agent, one of these human-like properties that could be of significant importance is how much agency is ascribed to this social agent. The term agency is somewhat abstract and needs some clarification.

The term agency is widely used and has multiple interpretations. According to Kashima and colleagues (2005) agentic social beings are seen as being goal directed, and act upon the pursuit of these goals. Also they are responsible and may potentially be praised or blamed for their actions. Agentic social beings that demonstrate activities towards a common goal are seen to be entitative as well. Kashima and colleagues (2005) conceptualize perceived agency as the extent to which a social being is attributed mental states such as beliefs, desires, and intentions.

Morris, Menon, and Ames (2001) suggest that people hold implicit theories of agency (ITA), according to which an entity can act intentionally and autonomously. For example these entities could be individuals, groups and supernatural beings. They also suggest that a being that possesses agency presupposes it to have internal states, which comes with the capacity to believe, want and intend.

Wooldridge and Jennings (1995) distinguish two general usages of the term agents. They differentiate between a weak notion of agency and a stronger notion of agency. The weak notion, which is the most general way to denote hardware or a software-based computer system, is characterized by autonomy, social ability, reactivity and pro-activeness. Autonomy refers to the ability of the agent to operate without the direct intervention of humans or others. Also the agent has some kind of control over its actions and internal state. Social ability means that agents are

able to interact with other agents via a certain language (these other agents could also be humans). Reactivity stands for that the agent is able to perceive its environment and adapt its behavior to changes that occur in that environment. Pro-activity intends that agents not simply act upon their environment, but they can also display goal-directed behavior.

The stronger notion that is particularly held by researchers working in Artificial Intelligence (AI) characterize an agent, in addition with the properties that are mentioned in the weaker notion, as a concept that is more usually applied to humans. Here concepts like knowledge, beliefs, intentions and obligation are used. Some AI researchers have even gone further and investigated emotional agents. Bates (1994) investigated the requirements for believable characters, and found that appropriately timed and clearly expressed emotions are essential for the believability of the agent. Besides this, the appearance of reactivity, goals and social competence are factors that influence the believability of an interactive character. Human-like attributes could also be given to agents by representing them visually, by for instance using animated faces or cartoon-like icons (Maes, 1994).

An agent also may exist in intelligent, virtual environments, where intelligence is understood as the capacity of an environment or agent to autonomously interact to modifications in the interaction with a user or with its environment. This form of intelligence is more or less referring to autonomy (Diesbach & Midgley, 2007). Maes (1995) defines autonomous agents as "computational systems that inhabit some complex, dynamic environment, sense and act autonomously in this environment, and by doing so realize a set of goals or tasks for which they are designed".

After reviewing some definitions of agents and agency, the term agency in the current research will be similar to the stronger notion of agency that is proposed by Wooldridge and Jennings (1995). Thus the term agency will, in a social actor context, comprise that the actor (agent) has certain knowledge of things, beliefs, goals, intentions and obligations. Also it should be able to act autonomously without the direct intervention of humans and should have some sort of emotional states. In short, the term agency comprehends the properties that a social actor has towards its users. The users perceive this social actor to have a certain amount of agency, which in fact is the perceived agency of the social actor.

1.2.1 Perceived agency

Currently not much research is available on perceived agency towards social agents. However there is some research where perceived agency is discussed. Barrett and Johnson (2003) investigated the role of control in attributing intentional agency to inanimate objects. Participants in this study had to place ball bearings in divots of a puzzle board under which electromagnets were hidden. These magnets were turned on, either by the participants themselves (in Control), or by the experimenter (no Control). In the "in Control" condition this was done by flipping a switch when a light came on, whereas in the "no Control" condition the magnets were activated by the experimenter without the notion of the participants. The magnets caused the ball bearings to move from the holes in which they were placed and also collided with each other. The participants had to explain out loud what happened. Results indicated that participants that were in the no Control condition used more relational expressions and language that normally only used for animals and persons. Thus participants that were in the no Control condition attributed more intentional agency (by using relational expressions and humanlike language) than when they were in Control of the electromagnet. This could mean that when people cannot, in this case, see the cause of movement of objects because of lack of control, they will attribute more agency towards these objects.

Perceived agency was also measured by Epley, Akalis, Waytz, and Cacioppo (2008). They found that participants who are, and feel lonely ascribe more agency to gadgets, gods and pets. This was measured in three studies were participants had to fill in different rating scales. In the first study participants had to fill in an anthropomorphic mental-state rating about a couple of gadgets that were presented. These ratings were about metal states like intentions, free will and consciousness. In the second study participants were asked in which extend they believed in god, the devil, miracles, etc. In the third study the participants had to assign traits which best described pets. Also they had to describe ambiguous figures. In all studies also questions were asked about loneliness and social connections of the participant. These studies showed that people ascribed agency towards non-human objects, especially when feeling lonely.

Other recent research of Bartneck and colleagues (2008) developed a questionnaire that measures the anthropomorphism, animacy, likeability, perceived intelligence and perceived safety of robots. These measured concepts are closely related, and party corresponding with the concepts of perceived agency. Eventually Bartneck and colleagues (2008) came up with five

questionnaires that measured the abovementioned concepts with help of a semantic differential scale. In this scale the participants indicated their position between two bipolar words that are presented. Examples of words that are used for the concept of anthropomorphism are: fake versus natural, machinelike versus humanlike, unconscious versus conscious and artificial versus lifelike. The questionnaires were used in several studies and proved to be reliable with high internal consistency reliabilities of the individual concepts (all Cronbach Alpha's above 0.7). Since this questionnaire proved to be reliable for the abovementioned concepts, (parts of) it could also be used for investigating the perceived agency of other social actors.

Besides measuring the amount of perceived agency of social actors it would be interesting to discover what the role of this perceived agency of a social actor is on the behavior of users, and also how this can be used to establish energy conservation. A very recent study that was mentioned earlier of Ham and colleagues (2008) manipulated the level of agency of a social robot that was used to give feedback on washing tasks. The agency level was manipulated by introducing the robot either as Victor (high agency), a very sophisticated robot that has a little mind of its own with the intention to conserve energy, or as an advanced electronic device (low agency) that could give feedback on the amount of electricity that was used. Victor was able give 12 different speech reactions whereas the electronic device only was able to give 2 different speech reactions. In contrast to the expectations that the high agency robot should lead to a greater conservation of energy, this effect could not be demonstrated. The main reason for the absence of this effect is that the agency manipulation was to a large extent only verbal. This verbal manipulation might have been overruled by the surprise effect that the interaction with the iCat could have elicited by the participants.

Because of the limited amount of research done on the influence of the perceived agency of a social actor on the persuasion of users, it is interesting to investigate these effects. Furthermore it would be interesting to develop a measure that is able to measure the amount of agency of a social actor that is perceived by its users.

1.3 Feedback

Besides the amount of (perceived) agency of the social actor, the way of providing feedback could be of great importance for changing people's energy conservation behavior as well. Recent

reviews of intervention studies aimed at household energy conservation (Abrahamse, Steg, Vlek, & Rothengatter, 2005; Midden, Kaiser, & McCalley, 2007) found that the interventions that were used had a varying degree of success. In general, information tends to increase knowledge levels, but not necessarily results in changes in behavior or energy savings. Feedback has proven that it has the ability to change behavior, especially when provided frequently and specific. Also rewards have shown to be resulting in energy conservation; however these effects are not long lasting. New technological solutions (i.e. computers that can provide feedback) have enabled two-way interaction between user and system which allows for possible improvements for feedback efficacy. This is because energy use is always the outcome of a user and an electricity consuming device. Not much research is done on these interactive devices in the domain of energy conservation behavior. However McCalley and Midden (2002; 2006) have demonstrated that in several studies an energy conservation of 18% was achieved by using an energy meter on an interface of a virtual washing machine. Here the participants were presented factual feedback that entailed an amount of kWh that was used by the settings of the washing machine, like water temperature, spinning speed and duration of the washing cycle. These results look promising in regard conservation of energy with help of interactive feedback.

Next to this type of factual feedback it would be interesting to investigate the role of "social feedback" provided by a social agent. In several research domains like child education, health behavior and social interaction as a mechanism for behavioral change, social reinforcements have been widely applied (Bandura & Mcdonald, 1963; Wright, 1968). Here positive and negative social incentives have proved to be both effective. However the question remains whether these social reinforcements could also be effective when provided by a system.

As mentioned earlier Nass and colleagues (1993) showed that people treat computers as social actors, and show similar behavior towards computer systems as to humans. Also Fogg and Nass (1997) found that praise from computers is extremely powerful, and that it makes people feel better about themselves, their performance, the interaction and about the computer. Since these results are similar to flattery studies from humans, this finding gives extra support to the Computers Are Social Actors (CASA) paradigm. These findings support the suggestion that social reinforcements made by social actors (in this case a computer) are able to influence users.

The study of Ham and colleagues (2008) compared factual kWh feedback of a simulated washing machine with social feedback that was given by an embodied agent. Results showed that social

feedback provided by an embodied agent led to more energy conservation than factual feedback provided by an energy meter, thus a behavioral change. This was quite remarkable since factual feedback was earlier regarded as one of the most successful types of feedback for encouraging energy conservation (Midden et al., 2007). Besides the difference between factual feedback and social feedback, Ham and colleagues (2008) also investigated the effects of feedback valence on energy conservation. The feedback was presented by the social actor within each trial interactively, so users were able to change their machine settings after each feedback moment. Results showed that negative feedback of the embodied agent caused more energy conservation behavior in comparison with positive feedback. This finding is in contrast with results found where praise of systems led to better evaluations of the system, themselves and their performance. Thus it is not obvious that people will change their actual behavior after such praise of computers.

The finding that negative social feedback had a greater effect is also in line with a review of more general feedback studies done by Baumeister, Bratlavsky, Finkenauer, and Vohs (2001). They suggest that "bad" feedback has a greater impact and power than "good" feedback. Also they found that people tend to make greater efforts to minimize "bad" feedback than to maximize "good" feedback.

These differences in type and valence of feedback are interesting for further research. Especially the differences between factual feedback and social feedback are interesting since not much research is done on this topic. Furthermore, as research of Ham and colleagues (2008) has shown, social feedback seems to lead to more energy conservation than, the as one of the most successful regarded feedback types, factual feedback. This result could be promising for the future application of social feedback of a social actor in the domain of energy conservation.

Besides this it is also interesting to investigate the influence of differences in valence of feedback of a social agent, because the current literature has not treated this subject intensively yet. Also there are opposing results on this matter.

Chapter 2 Research outline

In the previous chapter an overview is presented that discussed the need for conservation of energy by the usage of persuasive technology. Here a social actor approach was suggested that makes use of a smart agent that is embedded into a (domotic) system. Such an agent could differ in amount of (perceived) agency and can provide different types of feedback. This chapter will provide the goal, the research question and the hypotheses of the current study.

2.1 Goal

The main goal of this study is to find out whether the level of perceived agency of a social actor influences the conservation behavior of users of a simulated washing machine. Also the influence of the valence of the feedback of the social actor on conservation behavior will be investigated.

Furthermore this study tries to replicate the results of the earlier mentioned work of Ham and colleagues (2008), which investigated the differences between type and valance of feedback provided by a social actor during washing tasks. They found that social feedback led to more energy conservation that factual feedback. This effect was the strongest for users who had received negative feedback from the social actor.

Besides this, another goal of this study is to try to develop several measures that will be able to assess the amount of perceived agency of a social actor. These measures of perceived agency might be used in the future when other research is done on the influence of perceived agency of social agents and actors.

2.2 Research question

The research question of the current study is: *What is the influence of perceived agency and valence of feedback of a social robot on energy use during washing tasks?* In the next paragraph the hypotheses that are derived from the research question, and will be tested, are presented.

2.3 Hypotheses

From the presented research question and literature the following hypotheses are derived:

H1 Users will consume less energy when feedback is given by a social actor (social feedback), compared with when this feedback is given by an energy meter (factual feedback). This assumption is made since Ham and colleagues (2008) found that social feedback led to more energy conservation than factual feedback.

H2 Users will consume less energy when feedback is given by a high agency social actor, compared with a low agency social actor. When this social actor has a higher level of agency, people ascribe more knowledge, intentions and goals towards it and they regard it as more competent. Because of these attributions it is plausible that people will change their behavior more when feedback is given by a high agency social actor.

H3 Users will consume less energy when negative feedback is given as compared to when positive feedback is given. This is assumed since results of the study of Ham and colleagues (2008) showed that negative feedback led to more energy conservation. Also this is in line with findings of Baumeister and colleagues (2001) who suggest that "bad" feedback had a greater impact and power than "good" feedback.

Chapter 3 Method

In this chapter is described how the actual research was performed and how the research question was operationalized. First, the design of the experiment is explained, and the participants who participated are characterized. Secondly the materials that were used during the experiment are described, and the experimental procedure is explained. Finally the different dependent measures are presented.

3.1 Participants and design

Eighty-four participants conducted the experiment and were assigned randomly to the experimental conditions that were carried out between subjects. Fifty-eight of them were males, twenty-six were female. All participants were adults and native Dutch speakers. Of the participants 81% were between the age of 18 and 25, whereas the other remaining 19% were between the age of 26 and 40. The experiment consisted of a 2 (agency: low agency social feedback vs. high agency social feedback) x 2 (feedback valence: positive feedback vs. negative feedback) design + a factual feedback (control) condition. The duration of the experiment was approximately 30 minutes for which the participants received 5 Euros (± 3,35 $ at the time the experiment was conducted).

3.2 Materials and procedure

The experiment consisted of a simulated washing machine and, in the social feedback conditions, an iCat (which in this study is used as an embodied social actor), was placed next to the laptop on which the simulated washing machine was displayed. The display of the simulated washing that was shown on the laptop is depicted in *figure 3.1*. This simulated washing machine is based on an advanced washing machine (Miele Novotronic Super XS935) that has a similar display. On this display several functions like temperature, washing program, spin dryer speed and extra functions can be chosen.

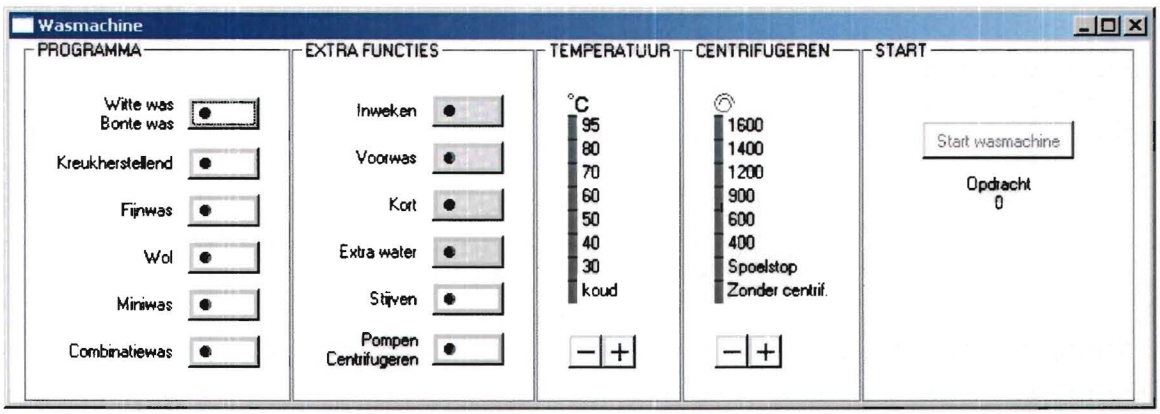

Figure 3.1. The washing machine panel with which participants had to fulfill the washing tasks. This panel was showed on the laptop screen.

The iCat, which is developed by Philips (see www.research.philips.com/robotics) for experimental purposes, is an animated robot that has a head and a body that resembles a cat. The iCat is able to display social expressions by moving his eye-brows, eye-lashes, lips and by playing speech files. Besides this, the iCat has also lights in his ears and paws that can change in color, proximity sensors and a camera in its nose.

In the factual feedback condition, where the iCat was not present, an energy meter was added to the display of the simulated washing machine. Here a bar with lights could indicate how much energy (in kWh) was used during the washing tasks which the participants had to accomplish. This extra energy meter was not shown in the social feedback conditions where the iCat was present.

In the experiment the screen of the laptop, on which the participant had to complete the washing tasks, was split in two sections; a top section where the simulated washing machine was displayed, and a bottom section where the instructions and the washing tasks were shown.

The experiment started with a general introduction after which the participants were informed about the task that they had to accomplish: adjust the controls of the simulated washing machine to the washing tasks that are presented, and try to do these washes the same way as you would do at home. After this two goals were presented to the participants. The first goal was that the participants had to do the wash as good as possible, without shrinking or damaging the (virtual) laundry. The second goal was to use as little energy as possible. Some examples of how to

minimize energy use (i.e. wash on a lower temperature) were given as well as the comment that feedback about their actual energy use would be provided during the experiment.

In the factual feedback condition the instructions showed the energy meter and explained on which way feedback would be given by this meter during the washing trials. In the low agency social feedback conditions (positive and negative), the participants were told that they would receive feedback about their energy consumption from a special feedback device (the iCat). The iCat could be activated by pushing one of the buttons on a control panel that was placed in front of the iCat. When the "start" button of the washing program was clicked on the washing machine display, a feedback code (one of four colors) appeared on the display of the laptop. This code had to be entered manually on the control panel after which the iCat would give feedback to the participants, either positive (in the positive condition) or negative (in the negative condition). Furthermore the participants were told that the iCat could show three types of feedback: facial expressions, lights in his ears and verbal expressions. Dependent of the settings, the iCat could show one or more of these expressions. The energy use of the washing machine was divided into six levels (three positive and three negative). The more extreme the result, for example level 1 in the positive condition, the more expressions the iCat displayed: green lights in ears, smiling face and a positive speech utterance. When this value became less extreme (i.e. level 3) the iCat adapted his way of expressing by only showing a smiling face and illuminated ears. If the participant would have a negative result regarding energy use in the positive feedback condition (levels 4 to 6), the iCat closed his eyes to indicate that he had nothing positive to mention. In the instructions was also mentioned that (in this case) the iCat only gives positive feedback, and when the iCat has nothing positives to say it will close its eyes. In the negative conditions this was exactly the same however now a high energy level (6) resulted in the most extreme expression of the iCat (red lights in ears, sad face and a negative speech utterance).

After the introduction, the participants could practice the type of feedback they would get during the actual experiment by pushing the buttons on the control panel to get acquainted with the type of feedback. In this practice session they did not receive feedback of the "real" iCat, but instead of an animated iCat that was presented on the laptop screen. In *figure 3.2* a picture of the experimental setup of the low agency social feedback conditions is presented. As mentioned above, the feedback during the experiment could be either positive, or negative depending on the condition.

Figure 3.2. The experimental setup of the low agency social feedback conditions. In the picture the iCat, control panel of the iCat and the laptop with washing machine panel as well as instruction screen can be seen.

In the high agency social feedback conditions (positive and negative) the iCat was introduced as Femke, a modern and intelligent robot who has an own will. Femke informed the participants about their energy use during the washing tasks. In comparison with the low agency social feedback conditions, the participants of the high agency conditions did not need to push a button on a control panel in front of the iCat (the panel was not present in these conditions), instead they received feedback automatically of Femke when they pressed the start button of the washing machine on the display of the laptop. Another difference between the low and high agency conditions was that in the low agency conditions the iCat used only one speech utterance to indicate an extreme result (e.g. "horrible" versus "great") whereas in the high agency condition the iCat randomly chose from either 5 positive, or 5 negative speech utterances. Besides this, there were no differences in procedure between the low agency social feedback conditions and the high agency social feedback conditions. For the different washing machine displays that were used in the different conditions see appendix A.

Before the actual experiment (15 washing trials) started the participants had to perform one practice washing trial after which the two main goals, wash as good as possible without damaging the clothes, and minimize the energy consumption during the washing tasks were repeated. After this the participants could begin with the 15 washing trials. Each trial consisted of an instruction of a specific type of wash that was randomly chosen from a list of thirty common types of washes. An example of such a wash is: "wash a load of white cotton bath towels". During these washing trials the participants could alter the settings of the washing machine display (as showed

in *fig. 3.1*) until they felt comfortable with the settings. Then they had to click on the "start washing machine" button to start the machine and receive feedback of either, the energy meter, low agency iCat or high agency iCat. This procedure was repeated until all fifteen washing tasks were completed.

When all washing tasks were finished the participants had to first complete an "agency" questionnaire that was followed by questions about their washing behavior as well as several demographical questions. Then the participants received a pen and paper task on which they first had to describe how the iCat (or energy meter) had helped them with completing the task. The final assignment was a drawing task were the participants had to place certain figures (under which an iCat/energy meter) in a, for them, freely chosen order.

3.3 Dependent Measures

The first dependent variable was the amount of energy that the participants used during the 15 washing tasks. Here the energy consumption is calculated by subtracting the energy usage of a participant on a single washing task (e.g. wash a load of white cotton bath towels) from the average energy consumption of that specific task for all participants.

After the washing tasks the "agency questionnaire" was presented to the participants. For this a bipolar semantic differential was used (Osgood, Suci, & Tannenbaum, 1957). Here seventeen different items that contained terms that incorporate an evaluation regarding perceived agency of the iCat or energy meter were presented. Some of these terms were taken from the questionnaire of Bartneck and colleagues (2008). The items had to be evaluated with help of a 7-point Likert scale. Examples of these terms are: "stupid" versus "smart", "useless" versus "useful" and "incapable" versus "capable". For all seventeen sets of agency terms see appendix B. The terms were positioned on a way that the term that was placed right had the most agency, thus how higher the total score, the more perceived agency the participants assigned to that condition. The 17 items for this measure proved to be reliable since a Cronbach's alpha of .876 was found.

Consequently participants' washing behavior during the experiment and at home was assessed with 5 questions like: "I was setting the controls during the washing tasks lower than I would normally do at home", and "During the washing tasks I did not (really) pay attention anymore to

get the laundry clean". The responses of the questions were anchored by (1) "strongly disagree" and (7) "strongly agree" (7-point Likert scale). With these questions was explicitly measured if the manipulation changed washing behavior during the experiment in comparison with normal washing behavior. All 5 washing behavior questions can be found in appendix C.

After the questionnaires on the computer the participants received the next task, which they had to accomplish on paper. Here they had to describe in two or three sentences (in story form) how they experienced the iCat or energy meter and how it has helped them carrying out the washing tasks. These written expressions were then analyzed using the Linguistic Category Model (LCM) of Semin and Fiedler (1991). This model can be used to categorize verbs as well as adjectives that are used in the interpersonal domain that represent enduring traits or characteristics (e.g. faithful, reliable), actions (e.g. to call, to hit) and states (e.g. to surprise, to amaze). The model classifies five categories of words; Descriptive Action Verbs (DAV), Interpretative action verbs (IAV), State action verbs (SAV), State verbs (SV) and Adjectives (ADJ). These categories of words differentiate between the abstraction levels of the language that is used. It is hypothesized that, participants that use a more abstract language in describing the iCat or energy meter, assign more agency to this actor. For a few examples of written expressions see appendix D. Since this measure does not directly asks for an explicit opinion regarding the amount of perceived agency of the iCat or energy meter, this is an implicit measure.

Finally the participants were presented a drawing task. On the top of the particular page, three figures in vertical position were presented. On the bottom of the page, three sections were displayed in horizontal position, in where the figures above had to be copied in a freely chosen order (see *figure 3.3* for an example). Such a page was presented three times to the participants, where each time two of the three figures were the same. In the social feedback conditions the iCat and a washing machine were presented all the three times. In the factual feedback conditions, these were the energy meter and a washing machine. The other figures that were presented during the drawing task were a brick, a banana and a television. Per condition there were made six different versions where the figures differed in order to try to control for order effects. This measure was added to the research because from literature was derived that an object which is attributed more agency is generally placed more to the left. Research of Maass and Russo (2003) and Chatterjee, Southwood, and Basilico (1999) demonstrate this tendency.

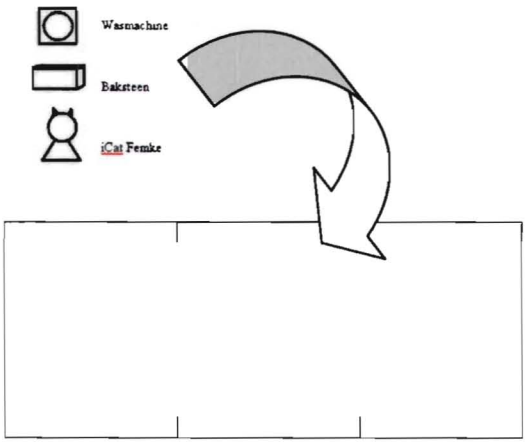

Figure 3.3. The figures that are presented vertically had to be copied in a freely chosen order in the horizontal sections.

Just like the measure of written expressions, this measure is also implicit. Participants will not directly know what the drawing task is about, and what it tries to measure. For a filled out example of the written expression task and drawing tasks, see appendix E.

Chapter 4 Results

In this chapter, the results of the research will be presented. First the most important measure, energy use, will be discussed. Secondly the participant's perceived agency is assessed by one explicit measure, and two implicit more explorative measures. Consecutively the results of the bipolar semantic differential, written expressions and drawing task will be treated.

4.1 Energy use

The dependent measure that was used for energy consumption was calculated by subtracting the energy use of a participant on a single washing task from the average energy consumption of that specific task for all participants. So, for example when a participant has a negative score, it means that the participant conserves energy in regard to the average energy score.

This relative energy score was submitted to a 2 (agency: low agency social feedback vs. high agency social feedback) x 2 (feedback valence: positive feedback vs. negative feedback) x 15 (washing trials: 1 to 15) MANOVA, with the washing trials within subjects. Here no significant effects were found, all F's < 1.

After close examination of the data it was decided that the energy use of the participants on the 15 washing tasks would be split into two phases; washing phase A (tasks 1 to 5) and washing phase B (tasks 6 to 16). This was done because it was expected participants needed some time to get acquainted with the type of feedback, and to establish a learning effect. Since no feedback was given within each of the 15 washing trails, it is plausible that the participants need some time to understand the connection between their actions and the feedback that was given. So, in a subsequent analysis the relative energy score was submitted to a 2 (agency: low agency social feedback vs. high agency social feedback) x 2 (feedback valence: positive feedback vs. negative feedback) x 2 (washing phase: A: trials 1 to 5 and B: trials 6 to 15) MANOVA, with the washing phases within subjects. Here a main effect for washing phase was found, $F(1, 56) = 5.37$, $p < .05$.

Secondly, an interaction of feedback valence x washing phase was found, $F(1, 56) = 5.12$, $p < .05$. More specific analysis indicated, that participants who had received positive feedback used

more energy during the first five washing trials (M = .01, SD = .17) than on the second ten washing trials (M = -.07, SD = .14), $F(1, 58) = 9.26$, $p < .01$. However participants who had received negative feedback used as much energy on the first 5 washing trials (M = -.02, SD = .17) as on the second ten washing trials (M = -.02, SD = .16), $F < 1$ (For graph see *figure 4.1*). Note that, as described, the means that are mentioned are deviations of the average energy score that was calculated by averaging the energy consumption of all participants on a specific washing task. This result indicates that participants who received positive feedback show a tendency to conserve energy over time. For participants who received negative feedback this conservation effect could not be observed. This result does not directly support the hypothesis that participant who had received negative feedback would consume less energy (**H3**); in fact indirectly the contrary was found. When the data was analyzed with washing phase, positive feedback showed a conservation effect over time; participants who received positive feedback used less energy in the second washing phase, compared with the first washing phase. This is not the case with participants who received negative feedback; here no difference between washing phase was found.

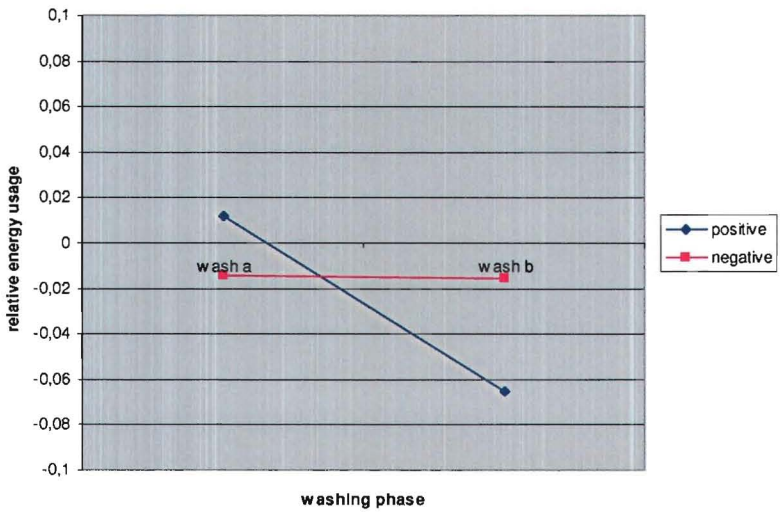

Figure 4.1. Graph of relative energy use for positive and negative feedback split by washing phase A and washing phase B.

Thirdly, an interaction was found between agency and washing phase, $F(1, 56) = 5.51$, $p < .05$. More specifically, participants who had received feedback from a high agency iCat used more energy during the first five washing trials (M = .04, SD = .17) than during the second ten washing trials (M = -.04, SD = .13), $F(1, 58) = 9.66$, $p < .01$. This was in contrast with participants who had received feedback from a low agency iCat. Here participants used the same amount of energy

on the first five washing trials (M = -.04, SD = .16) as on the second ten washing trials (M= -.04, SD = .17), $F < 1$ (For graph see *figure 4.2*). In addition, within washing phase A, a marginally significant difference was found. Participants in the high agency conditions used more energy in washing phase A (M = .04, SD = .17) than participants in the low agency conditions in washing phase A (M = -.04, SD = .16), $F(1, 58) = 3.22$, $p = .078$. These results indicate that participants who had received feedback from a high agency iCat conserve energy over time. This is in contrast with the participants who received feedback from the low agency iCat where no conservation effect was found. Although no direct main effect was found for high agency versus low agency, an indirect effect was found when the data was analyzed with the separation of washing phase. Participants in the high agency conditions used less energy in the second washing phase compared with the first washing phase. Participants in the low agency conditions did not demonstrate this difference. This finding is in line with the hypothesis, that participants that have received feedback from a high agency iCat consume less energy than participants who received feedback from a low agency iCat (**H2**). However eventually the participants of the high agency conditions overall did not consume less energy than participants of the low agency conditions; only a conservation effect over time could be demonstrated. Also participants who received feedback of the low agency iCat seem to more directly conserve energy which was shown by the marginal significant difference between low and high agency in washing phase A.

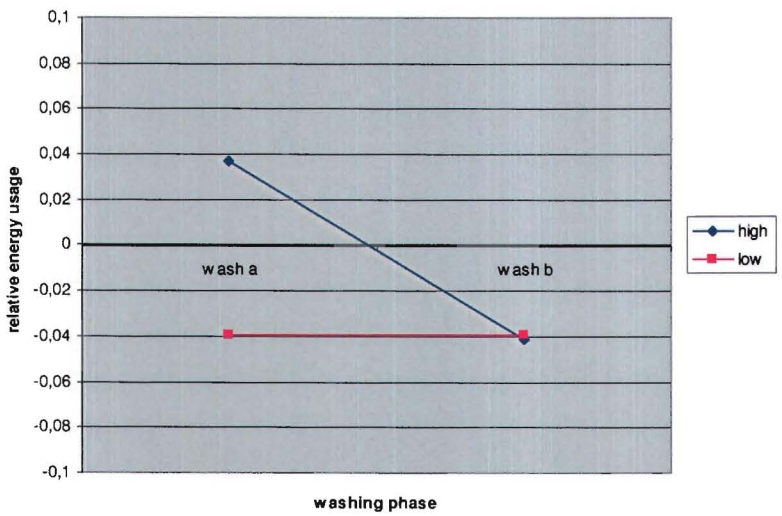

Figure 4.2. Graph of relative energy use for high agency and low agency feedback split by washing phase A and washing phase B.

Fourthly, a three-way interaction was found between agency x feedback valence x washing phase, $F(1, 56) = 4.20$, $p < .05$. Further analysis indicated that participants who had received negative feedback of a high agency iCat used more energy on the first five washing trials ($M = .04$, $SD = .17$) compared with the last ten washing trials ($M = -.04$, $SD = .13$), $F(1, 56) = 4.95$, $p < .05$. Also participants who had received positive feedback of a high agency iCat used more energy in the first five washing tasks ($M = .04$, $SD = .17$) than in the second ten washing tasks ($M = -.04$, $SD = .13$), $F(1, 56) = 5.95$, $p < .05$. This same energy saving tendency (over time) was found for participants who had received positive feedback from a low agency iCat. Here the participant used, just like the previously mentioned conditions, more energy at the first washing phase ($M = -.02$, $SD = .17$) compared with the second washing phase ($M = -09$, $SD = .15$), $F(1, 56) = 4.59$, $p < .05$. In contrast with the previous three conditions, the participants who received negative feedback of a low agency iCat used *less* energy in the first five washing trials ($M = -.06$, $SD = .17$) than in the second ten washing trials ($M = .01$, $SD = .18$), $F(1, 56) = 4.71$, $p < .05$. In addition these two last effects (low agency positive feedback versus low agency negative feedback) differed significantly from each other indicated by an effect of valence x washing phase, $F(1, 28) = 6.77$, $p < .05$. Also both negative conditions (negative feedback given by high agency iCat, and negative geedback given by low agency iCat) differed significantly from each other, indicated by an effect of agency x washing phase, $F(1, 28) = 10.61$, $p < .01$. Furthermore, no effects were found for high agency x feedback valence x washing phase, and positive feedback x agency x washing phase, both F's < 1. For a graphical representation of the results, see *figure 4.3*.

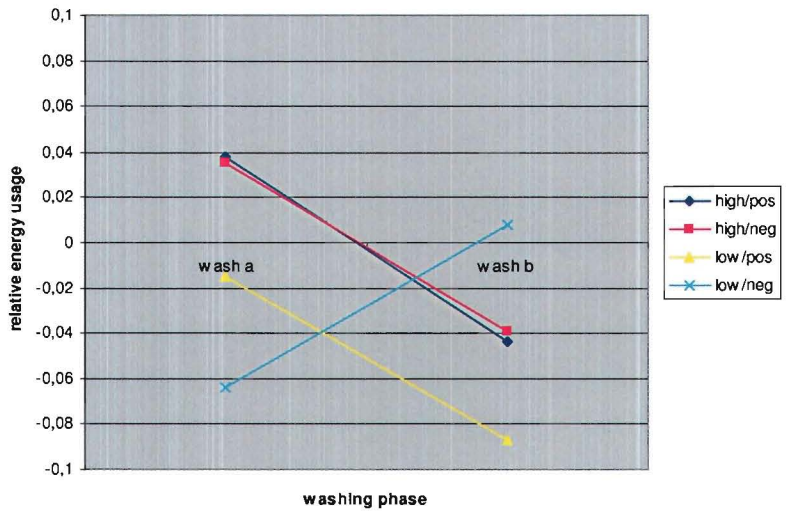

Figure 4.3. Graph of relative energy use for high agency positive and negative, and low agency positive and negative feedback split by washing phase A and washing phase B.

An intresting finding was that when negative feedback was provided by a low agency iCat, participants were using more energy over time. This is in contrast with the other conditions, where participants conserved more energy over time. This remarkable result, which was not quite expected, will be further discussed in the discussion section of this report.

Furthermore the first hypothesis (**H1**), that users that received feedback from the iCat (social feedback) would consume less energy compared with users that received feedback from the energy meter (factual feedback) could not be confirmed. For this analysis the relative energy score was submitted to a 1 (factual feedback) x 1 (social feedback) x 15 (washing trials) MANOVA, with washing trials within subjects. No significant effects were found, $F < 1$. Also for the analysis that separated the washing tasks into washing phase A and washing phase B, no significant effects were found, $F < 1$. Although, as can be seen in *figure 4.4*, the participants of the social feedback conditions used less energy in washing phase A and in washing phase B compared to the participants who were in the factual feedback condition, nothing proved to differ significantly.

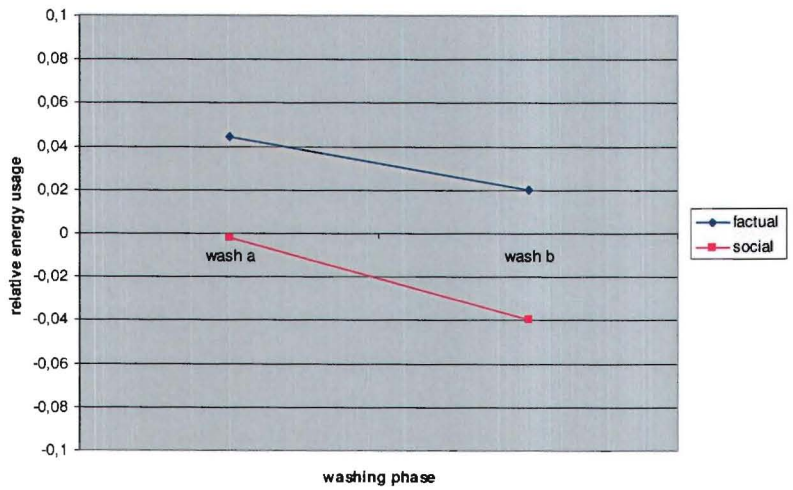

Figure 4.2. Graph of relative energy use for social and factual feedback split by washing phase A and washing phase B.

4.2 Agency questions

To asses the participants' perceived agency of the iCat, seventeen agency terms were presented. The agency terms were displayed on a 7-point Likert scale, where a higher score represented a higher level of agency. The averaged score of the seventeen items was submitted to a 2 (agency: low agency social feedback vs. high agency social feedback) x 17 (agency questions 1 to 17) MANOVA, with the agency questions within subjects. Notice that here the control condition (factual feedback) was not included since the agency terms do not have a real meaning in regard to the perceived agency of an energy meter. As expected, participant who had received their feedback from a high agency iCat perceived this iCat to have a higher level of agency ($M = 4.1$, $SD = .74$) in comparison with participants who had received feedback from the low agency iCat ($M = 3.6$, $SD = .81$), $F(1, 66) = 4.57$, $p < .05$.

This result shows that the agency manipulation has worked; the high agency iCat has a higher perceived agency score than the low agency iCat. Thus this also confirms the expectation that the participants perceived the iCat to have a higher level of agency in the high agency conditions compared to the low agency conditions.

4.3 Written expressions

Just like the previous measure, this measure was performed to assess the amount of perceived agency that the participants would assign to the iCat. However in this measure was not explicitly asked to the participants to rate "agency terms", instead they had to describe how they experienced the iCat (or energy meter) and how the iCat (or energy meter) had helped them carrying out the washing tasks. These descriptions were then analyzed with help of the Linguistic Category Model (LCM) of Semin and Fiedler (1991). The model classifies five types of words that are scored according to their abstraction level. How more abstract the words that are used, the higher the abstraction score. The scores that could be assigned to words ranged from 1 (very concrete) to 4 (very abstract). The average score that eventually was used in the analysis was calculated by adding the scores of the description of one participant, which was then divided by the total number of coded items in the description.

This analysis was done with help of a second coder. The second coder rated half of the descriptions that were made by the participants. The inter rater reliability was calculated with help of the cronbach's alpha, which turned out to be 0.850. Since this seemed a quite good reliability, the results of the first rater were used for further analysis.

The scores of the descriptions were submitted to a 2 (agency: low agency social feedback vs. high agency social feedback) x 2 (feedback valence: positive feedback vs. negative feedback) x 1 (LCM score) MANOVA. This analysis yielded to no significant main effect, however a marginal interaction effect was found between agency x feedback valence, $F(1, 54) = 3.02$, $p = .088$. More specific analysis indicated that participant who received negative feedback from a high agency iCat had a marginal higher abstraction score ($M = 3.61$, $SD = .83$) than participants who received negative feedback of a low agency iCat ($M = 2.60$, $SD = .69$), $F(1, 26) = 3.76$, $p = .063$. Further no (marginal) effects were found in this interaction, all F's < 1. This marginally significant result was in line with expectations that, participants who received feedback from a high agency iCat would have a higher LCM score than participants who received feedback from a low agency iCat. However this (marginal) effect was only found for the negative feedback conditions.

Besides this marginally significant interaction effect, also a marginally significant effect was found for type of feedback. Participants who received feedback from the iCat had a marginally higher abstraction score ($M = 2.88$, $SD = .75$) than participants who received feedback from the energy meter ($M = 2.39$, $SD = 1.11$), $F(1, 65) = 2.90$, $p = .093$. This marginally significant result is in line with expectations that the iCat should be perceived to have a higher amount of perceived agency compared to the energy meter. However should be noted that in the factual feedback condition (with energy meter) only 9 participants were coded, versus 58 in the social feedback conditions. Also should be taken into account that this measure is a rather explorative one that tries to measure perceived agency, thus it is questionable whether this result is a reliable one.

4.4 Drawing task

Just like the previous two measures, agency questions and written expressions, this measure tried to assess the amount of perceived agency that is assigned to the iCat. However in this drawing task this is tried to be done in a very explorative way. As described in the method section the participants had to copy the figures that were displayed vertically on top a page, in a horizontal

section that was displayed on the bottom of the same page. This was repeated three times. The results were coded as followed: the figures that participants could use received a number; the iCat or energy meter received number 1, the washing machine number 2 and the other figures (brick, banana or television) received number 3. The three drawing tasks (T1 to T3) were split into three sections (a to c), that each got the score of the object that was drawn on that place. A single example here is that T1a received a score of 1. This means that a participant drew the iCat or energy meter (1) on the most left position (a) in the first drawing task (T1). For every drawing task the position of the iCat or energy meter was then calculated and received a "1" for the most left position en a "3" for the most right position. After this the average of all three drawing tasks was calculated and used for further analysis. When participants identically copied the order of the presented objects, they were scored as missing values.

The average score of the drawing tasks was submitted to a 2 (agency: low agency social feedback vs. high agency social feedback) x 2 (feedback valence: positive feedback vs. negative feedback) x 1 (mean drawing task score) MANOVA. This analysis yielded to no significant effects or interaction effects, all F's < 1. Also no significant effects or interaction effects were found for feedback type (factual versus social feedback), all F's < 1.

It was expected that participant in the high agency conditions would have a lower average drawing task score than the low agency conditions. This lower score would imply that the iCat was drawn more to the left, which was expected from the literature (Chatterjee, Southwood, & Basilico, 1999; Maass & Russo, 2003). Also for feedback type a lower average drawing task score was expected for the social feedback conditions (iCat) in comparison with the factual feedback condition (energy meter). Unfortunately, none of these expectations could be observed.

Chapter 5 Discussion

In this chapter the results of the current study will be discussed and interpreted. Furthermore the results will be compared to existing literature and previous research. First the results of the energy use are discussed, after which the results of the perceived agency measures are treated. Finally the limitations of this study will be discussed.

5.1 Discussion

This research investigated whether the level of perceived agency of a social actor influences the conservation behavior of users of a simulated washing machine during washing tasks. Also the influence of the separation of positive and negative feedback of the social actor on conservation behavior was investigated. Furthermore this study tried to replicate the results that were found by the study of Ham and colleagues (2008), which found that social feedback, provided by a social actor, in their case an iCat, led to more energy conservation than when factual feedback by means of an energy (kWh) meter was used. Also they found that negative feedback provided by the iCat had the strongest effect on energy conservation behavior, compared to positive feedback.

5.1.1 Energy use

The results on energy usage for all 15 washing tasks showed no differences between the conditions. After close examination of the data it was decided to split the washing tasks in two phases; washing phase A (task 1 to 5) and washing phase B (task 6 to 15). This was done because it was expected that the participants needed some time to get acquainted with the type of feedback. Since no feedback was given within each of the 15 washing trails, it is plausible that the participants needed some time to understand the connection between their actions and the feedback that was given.

After this treatment of the data it was found that feedback of the high agency iCat led to energy conservation over time, whereas this effect was not found for feedback that was presented by the low agency iCat. This finding partly supports the hypotheses that users will consume less energy

when feedback is given by a high agency social actor, compared with a low social actor (H2). This only partly support the hypothesis since no difference in overall energy conservation of both washing phases was found of the high agency group compared to the low agency group; however a conservation effect over washing phase was demonstrated for the participants who received feedback of the high agency iCat. Contradicting to the hypothesis that users will consume less energy when feedback is given by a high agency social actor, compared with a low social actor (H2), was that participants who received feedback of the low agency iCat used marginally significantly less energy in the first washing phase, compared with participants who received feedback from the high agency iCat. A possible explanation for these results could be that the low agency iCat immediately caused a change in behavior, because the users was told that the iCat was a feedback device of the washing machine and they wanted to conserve energy. However this low agency iCat does not encourage people to even conserve more energy since it has no (shared) objectives and goals, which leads to no further energy conservation compared to the beginning. A reason for this behavior could be that the persuasive effect of a social actor with a low amount of perceived agency will not increase in strength, but stays the same over time.

In contrast to the low agency iCat, the high agency iCat first has to gain the confidence and trustworthiness of the users. Therefore when people notice that the iCat has the real intention to conserve energy, people will tend to adapt their behavior over time, as can be seen from the results. Because here the social actor is perceived to have a high amount of agency users will rely upon the feedback of this actor because they regard it to be competent, and also sharing the same goals and values (conservation of energy). Opposed to the low agency social actor, the high agency social actor will accomplish an effect that seems to be more effective over time.

In the current research both of the earlier mentioned findings of the study of Ham and colleauges (2008) could not be replicated; no differences in energy consumption were found between factual feedback and social feedback (H1), and neither a stronger effect of negative feedback on conservation behavior could be demonstrated (H3). In fact, positive feedback showed a conservation effect over time; participants in washing phase B used significantly less energy compared to participants in washing phase A. This effect was not found for participants who received negative feedback. This opposing finding could possibly be explained by the differences in experimental setup of the current study and the study of Ham and colleagues (2008). In the current study the participants were not able to immediately act upon the feedback that they received, but they had to, more or less "learn" the meaning of the feedback in regard to the

settings that they made. When the feedback would be provided after each change of setting, just like in the study of Ham and colleagues (2008), the participants would be able to adapt their settings directly after receiving the feedback. However when this feedback only is provided after multiple settings have been made, it is harder for the participants to assess which settings caused the feedback. This could have resulted in that the participants used the feedback differently in both of these studies. Because of this difference in feedback moment, the difference in expectation that negative feedback should lead to the greatest energy conservation could be explained. People who received negative feedback wanted to change their settings immediately since they want to avoid this negative feedback (Baumeister, Bratlavsky, Finkenauer, & Vohs, 2001). Negative feedback indicates a need for change, which drives people to adapt to these changing circumstances because of people's self-regulatory system (Bandura, 1989). When they are not able to receive an immediate response (as in the current study), on which can be acted immediately, this negative feedback becomes less important to change, because its origin is harder to assess.

Also research in other disciplines found that immediate feedback seems to be more effective than delayed feedback. Delayed feedback is feedback that is presented later on, compared to immediate feedback, which is presented instantly. Dihoff, Brosvic, Epstein, and Cook (2004) found that learning is enhanced by immediate feedback compared to delayed feedback, and Mason and Redmon (1992) also found that immediate feedback, in contrast to delayed feedback, led to the highest amount of accuracy in error detection in quality control.

Although this might explain why, in this study, no effect of negative feedback was found, it is harder to tell why positive feedback is more effective over time concerning energy conservation. Maybe negative feedback only works best when an immediate response is possible, while in the rest of the cases, positive feedback will be most effective. Other research also found that positive feedback is accepted without scrutiny, even when this positive feedback is not sincere (Fogg & Nass, 1997). Furthermore the current study explicitly separates positive and negative feedback, whereas the study of Ham and colleagues (2008) uses a combination of positive and negative feedback. This resulted in that the participants could not change negative feedback into positive feedback, which also could have led to the absence of the conservation effect for negative feedback. Further research on the effects of immediate versus delayed feedback and negative and positive feedback should be able to more clarify the differences that were found.

The other result of Ham and colleagues (2008) that could not be replicated is the difference in energy consumption between factual feedback and social feedback (H1). An explanation might be that, in the current study, the social feedback presented to the participants might be harder to interpret than factual feedback. In contrast with the study of Ham and colleagues (2008), the valence of feedback was separated in different conditions (only positive feedback and only negative feedback), which resulted in "non-reactions" the iCat. Such a "non-reaction" was presented by the iCat when for example a lot of energy was used in the positive condition. In this case the iCat would have closed its eyes, and would have given no further feedback. These reactions might be somewhat hard for some participants to understand, although the meaning of it was explained during the experiment. Especially when this reaction was displayed the first couple of washing trials, it could be harder for the participants to assess the meaning of the particular feedback. In contrast to the social feedback in this study, the factual feedback does not have such "non-reactions". The energy meter presents its feedback over the whole continuum of energy use. This different amount of "information" could have led to the absence of the previously found effect of social versus factual feedback. When these differences are not present anymore, the larger conservation effect of social feedback should be replicated.

A remarkable result of this experiment was that, when the low agency iCat provided only negative feedback participants used more energy over time; in washing phase B the participants used significantly more energy, compared to washing phase A. An explanation for this effect could be that participants became "reactant" towards the iCat and did not want to trust or listen to it because they were annoyed, or felt threatened by it in their freedom. Reactance is the psychological phenomenon that evokes an emotional reaction that is in direct contradiction with certain rules or regulations that threaten behavioral freedom. Reactance occurs in response to a threat of this behavioral freedom (Brehm, 1966). In the negative low agency social feedback condition this could be a cause for the opposite result of the energy usage of the participants. Here participants showed a tendency to use more energy in time; they used significantly less energy during washing phase A, compared to washing phase B. Because the participants in this condition only received negative feedback, given by the manually operated low agency iCat, they eventually might not take its feedback seriously anymore. Actually, users could get annoyed and will do the opposite of want the iCat wants to achieve. In the positive condition however this "reactance" might not take place because here positive feedback is given instead of negative. In this situation (low agency), participants tend to be more susceptible for positive feedback. This is also in line with literature that praise from computers is extremely powerful, and that it makes

people feel better about themselves, their performance, the interaction and about the computer (Fogg & Nass, 1997). Furthermore an explanation why reactance might be shown by the participants of the low agency iCat, could be that the social connection of the participants towards the low agency iCat is not as strong as the social connection of participants towards the high agency iCat. The low agency iCat might not be seen as much as a social actor compared to the high agency iCat, because it does not have goals, intentions and is not autonomous. Therefore the participants will earlier express such feelings towards the low agency iCat by ignoring its feedback.

5.1.2 Perceived agency measures

The current study also investigated an implicit and explicit measure for measuring perceived agency. As explicit measure a 17-item bipolar semantic differential was used. Result of this explicit measure showed that the agency manipulation has worked, whereas participants in the high agency conditions, as expected, reported higher scores on the agency measure, compared to the participants in the low agency iCat conditions. Furthermore this scale proved to be reliable because of an internal validity of the list (Cronbach's alpha) of .876 was found. Because of its success, the 17-item bipolar semantic differential explicit agency measure (see appendix B) may also be used to assess the amount of perceived agency of a social actor in future studies.

As an implicit measure written expressions regarding the energy meter or iCat were analyzed with help of the Linguistic Category Model (LCM). Results showed that participants who received negative feedback of the high agency iCat had a marginally higher LCM score, compared to participants who received negative feedback of the low agency iCat, implying a higher amount of perceived agency for the participants in the high agency iCat condition. This measure proved to be partially supporting the hypothesis that participants who received feedback from a high agency iCat perceive it to have a higher level of agency compared to participants who received feedback from the low agency iCat . This only was true for when negative feedback was provided. Furthermore participants who were in the social feedback conditions (with iCat) had a marginally higher LCM score, compared to the participants who were in the factual feedback condition (energy meter), implicating a higher amount of perceived agency for the social feedback conditions. However this last result was based on a limited amount of observations. Although this implicit measure of written expressions did not really yield to significant results, it

did clearly show the right direction regarding perceived agency. Therefore this rather explorative measure is promising for further research that also investigates the perceived agency of a social actor. Also other research that used similar ways of measuring mental attributions towards objects by means of verbal expressions and verbal responses proved to be successful (Abell, Happe, & Frith, 2000; Barrett & Johnson, 2003).

5.2 Limitations

The current study has several limitations; first of all, the research was conducted in a controlled experimental setting where the participants were assigned two goals; get clean laundry, and use as little energy as possible. In real life, participants might not be interested in energy saving, but only in a clean laundry. Further research in field experiments could investigate whether the experimental setting plays a role in energy conservation behavior. Besides this, the operationalization of the social actor that is used in this study (the iCat) could have played a role in the outcome of this research. In future research also other operationalizations of social actors can be used, to get further insight of these possible effects.

Secondly, the current research separated positive and negative feedback. This was an important part of gaining insight in the persuasive effects of the valence of the feedback of a social actor. However, this separation resulted in less feedback, and also in "non-reactions" of the iCat which could have resulted in the absence of the stronger effects of negative feedback. Also it is a possibility that negative feedback supports positive feedback or vice versa. Further research on combined feedback should be done to gain more insight in the effects of valence of feedback.

Finally in the current study feedback was provided after all settings of the washing machine were completed and the button start washing machine was clicked. This resulted in a lot less moments in which feedback was given by the iCat, in comparison with the study of Ham and colleagues (2008). The results regarding the influence of perceived agency and valence of feedback might have been different when feedback was presented after each change of setting of the washing machine.

Chapter 6 Conclusions and recommendations

In this final chapter conclusions will be drawn about the results of this study and a practical application will be suggested. Finally recommendations for further research will be given.

6.1 Conclusions

The main goal of this study was to investigate the influence of perceived agency of a social actor on the conservation behavior of users of a simulated washing machine during washing tasks. Also the separation of positive and negative feedback of the social actor on conservation was investigated. Furthermore this study tried to replicate the results by Ham and colleagues (2008), who found that social feedback provided by a social actor led to more energy conservation than when factual feedback was used, and also a stronger conservation effect for negative feedback.

The results showed that perceived agency has influenced users, which resulted in an energy conservation effect over time. Thus when a social actor, in the current study the iCat, is perceived to have a high amount of agency, users will tend to conserve more energy over time and also adapt their behavior more than when it is perceived to have a lower amount of agency.

The greater effect of negative social feedback on energy conservation that was found by Ham and colleagues (2008) could not be replicated. Since it was not possible for the users in the current study to act immediately upon the negative feedback that was given, it is likely that the impact of this negative feedback lost its persuasive strength. Positive feedback however showed that users conserved energy over time. This conservation effect can be explained by the higher susceptibility of people for positive feedback when they are not able to act immediately. This is also in line with other research that people are susceptible for positive feedback and praise. Another explanation could be that the effects of the separation of positive and negative feedback differ from combined valence of feedback.

The other result which was found by Ham and colleagues (2008), that feedback provided by a social actor led to more energy conservation than feedback given by an energy meter could not be replicated as well. The absence of this effect is most probably due to a difference in experimental

design, which mainly was the separation of positive and negative feedback into different conditions. This separation of feedback resulted in the absence of feedback when a particular setting was done (for example high energy use in positive condition). This is in contrast to the energy meter that provided feedback on the whole continuum. In further research that provides the same amount of information to users the larger conservation effect for social feedback should be replicated.

The findings of this study can have several practical applications. Besides an application as conservation apparatus for washing machines, an interactive social actor can also be used for the conservation of energy in a domestic setting. This could either be an embodied social actor, like the iCat, but can also be a disembodied social actor (for example an interactive virtual agent). As can be derived from this research, this social actor should be perceived of having a large amount of agency for the greatest persuasive effects regarding the conservation of energy. The best persuasive way of interacting should be further investigated regarding positive and negative feedback, and immediate versus delayed responses of the social actor. In the future such an interactive full domotic system, that controls for example the temperature and lighting in different rooms with help of a social actor, could be extremely helpful in regard to the conservation of energy. Some recommendations for further research that could be helpful for the development of such an interactive domotic system will be presented in the next paragraph.

6.2 Recommendations for further research

In this study actually two variables are used in regard to the persuasiveness of the social actor. The first variable is the source that is used; in this case the iCat (social source) or energy meter (factual source). Secondly the type of message can also be seen as a variable. In the current research the iCat provides an evaluative message (for example: great!), whereas the energy meter provides a factual message (for example: 1,0 kWh). This last example of a factual message can also be provided by a social source. It would be interesting to find out which of both feedback types provided by a social actor yields to the largest amount of energy conservation.

For the replication of the results regarding the current study it would be interesting to manipulate the perceived agency of the social actor in a different way than the current research did. Also another social actor, instead of the iCat, could be used in experiments to find out whether the

persuasive effects of that actor differ in comparison to the iCat. Furthermore could be investigated what the influence is of embodiment of the social actor, on perceived agency and behavioral change in regard to the conservation of energy. This could be important since a disembodied agent might save a lot of money in a future practical application compared to an embodied agent.

Finally it would be interesting to investigate the long-term effects of the persuasiveness of social actors. Current and past research on the persuasive character of social actors only focuses on effects within the experiments, and no attention is paid to whether these effects stay the same, or change, when users are confronted with it regularly. This is quite important because when eventually such a full domotic system, that makes use of interactive social agents will be introduced, it will be used on a daily basis.

6.3 Final remark

To conclude this report, this research can confirm the importance of perceived agency of an intelligent persuasive agent that controls several applications in a domestic environment, which was used as example in the beginning of the introduction. As results of the experiment suggest, people eventually tend to be more persuaded by a social actor that is perceived to have a high level of agency, and will actually change their behavior. Concerning the current threats with regard to climate change, this finding can help future developers of intelligent interactive persuasive systems to better design the system for optimal results concerning changing conservation behavior of its potential users.

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The influence of perceived agency and valence of feedback of a social robot on energy use during washing tasks

Master Thesis by René Segers

December 2008

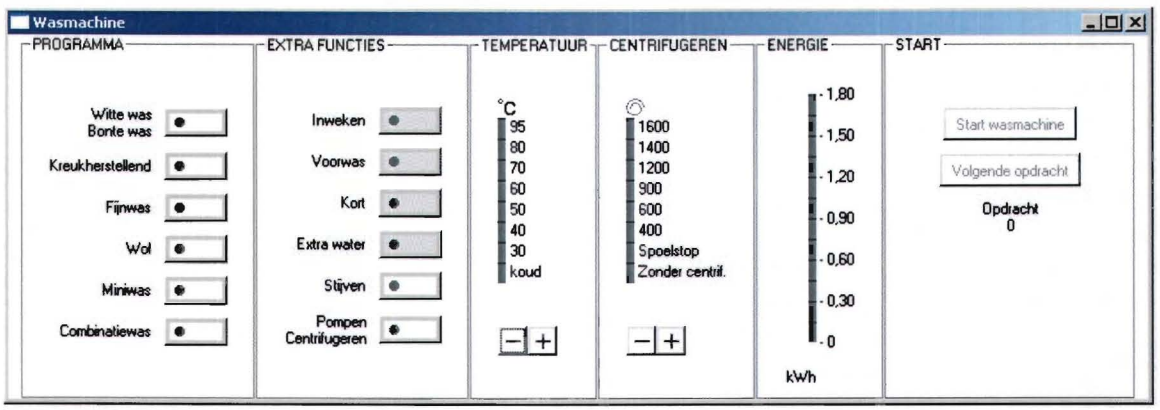
Appendices

Eindhoven University of Technology
Human Technology Interaction

Appendix A Different washing machine conditions

Factual feedback condition

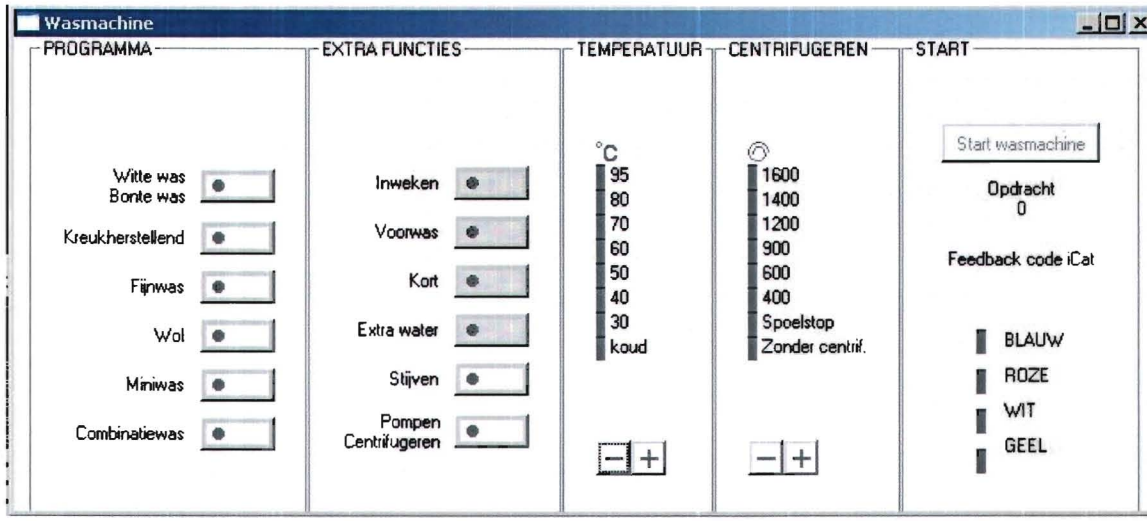
In the factual feedback condition an energy meter was added on the washing machine display, which displayed the amount of kWh (between 0 and 1,8 kWh) that a particular washing trial consumed. This value was shown after the settings of the washing machine were completed, and the start washing machine button was clicked. Furthermore no feedback was given in this condition. In the picture below the washing machine display that was used in this condition is shown.



Low agency social feedback conditions

In the low agency social feedback conditions (positive and negative) an extra space was added in the washing machine display in which the feedback code which had to be entered onto the control panel of the iCat is displayed. There were 4 color codes that matched the colors of the control panel of the iCat: Blue, Pink, White, and Yellow. This color code was given to the participants after they had completed the settings of the washing machine, and they had clicked the button start washing machine. After this color code had been presented, the participants had to enter the code on the control panel of the iCat, after which the iCat gave a reaction (either positive or negative dependant of the particular condition where the participant was in). The display of the washing machine that was used in the low agency social feedback conditions is shown below.

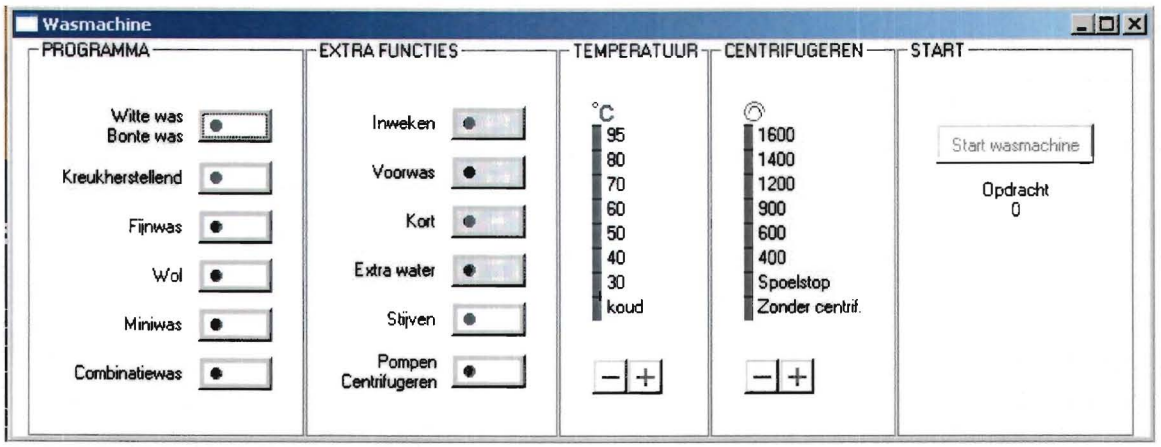
Furthermore the control panel on which the participants had to enter the feedback code, and the experimental setup of the low agency social feedback conditions are also shown underneath this text.



High agency social feedback conditions

In contrast to the other conditions, no extra energy meter or feedback code was added in the washing machine display of the high agency social feedback conditions (positive and negative). After the participants changed the settings of the washing machine, and consequently clicked on the start washing machine button, the iCat immediately gave a response (either positive or

negative) in regard to the energy use of the participant on that specific washing task. In the figure shown below the washing machine display that was used in the high agency social feedback conditions is shown.



Appendix B Agency questions (in Dutch)

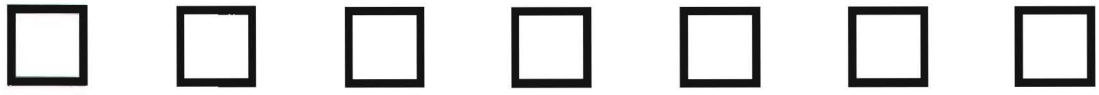
"Zet een kruisje in het hokje dat voor u het meest van toepassing is met betrekking tot de iCat"

Dom **Slim**

Onkundig **Kundig**

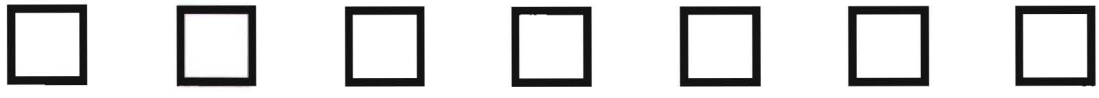
Passief **Actief**

Doelloos **Doelgericht**

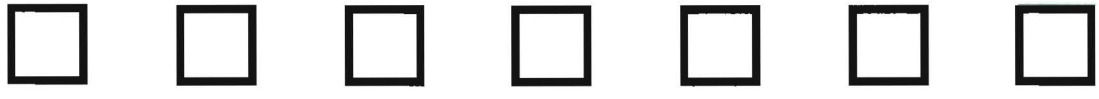


Niet sociaal **Sociaal**

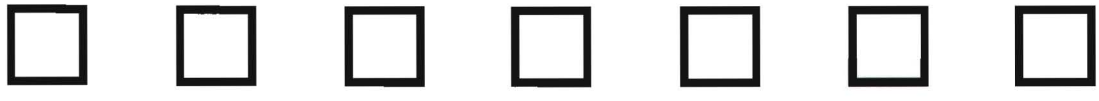
Zinloos **Zinvol**



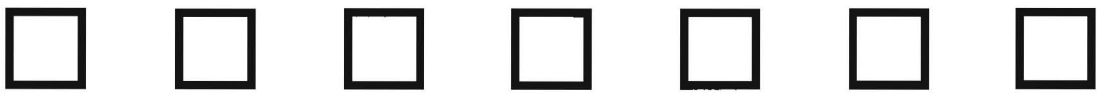
Niet overtuigend **Overtuigend**



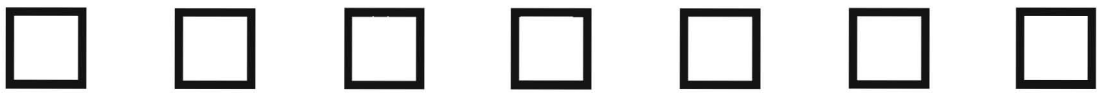
Onbetrouwbaar **Betrouwbaar**



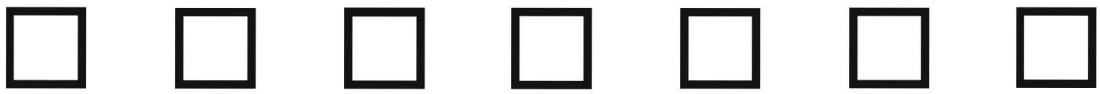
Onbehulpzaam **Behulpzaam**



Doods **Levendig**

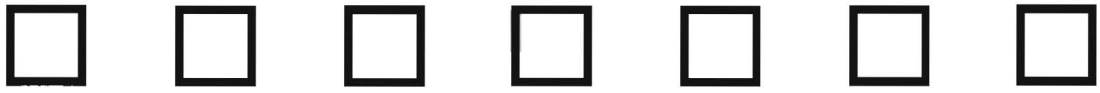


Willoos **Wilskrachtig**

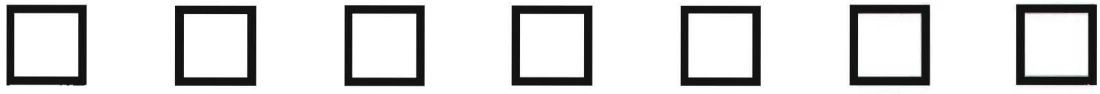


Ongevoelig **Gevoelig**

Mechanisch **Biologisch**



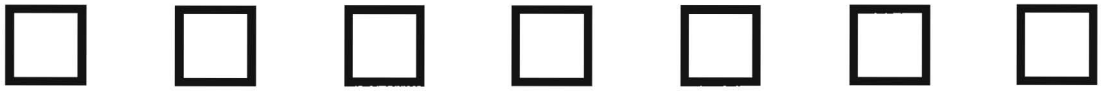
Initiatief-arm **Initiatief-rijk**



Intentieloos **Intentioneel**

Karakterloos **Karaktervol**

Niet autonoom **Autonoom**



Appendix C Washing behavior questions (in Dutch)

1 "Ik zette de instellingen bij de wastaken lager dan ik normaal thuis zou doen"

helemaal oneens							helemaal eens
	☐	☐	☐	☐	☐	☐	☐

2 "Ik lette bij de wastaken niet (echt) meer op de taak om de was goed schoon te krijgen"

helemaal oneens							helemaal eens
	☐	☐	☐	☐	☐	☐	☐

3 "Ik hield bij de wastaken geen rekening met de feedback die ik kreeg"

helemaal oneens							helemaal eens
	☐	☐	☐	☐	☐	☐	☐

4 "De Wastaken die ik moest uitvoeren komen overeen met de wastaken die ik thuis ook heb"

helemaal oneens							helemaal eens
	☐	☐	☐	☐	☐	☐	☐

5 "Door de feedback die ik kreeg ben ik anders/bewuster gaan wassen"

helemaal oneens							helemaal eens
	☐	☐	☐	☐	☐	☐	☐

Appendix D Examples of written expressions (in Dutch)

Written expressions

Beschrijf (verhalend) in twee a drie zinnen hoe u iCat Femke ervaren hebt en hoe deze u heeft geholpen met betrekking tot het volbrengen van de taken.
iCat Femke laat je nadenken over de keuzes die je maakt bij het wassen van kleren waardoor je milieubewuster gaat wassen.

Beschrijf (verhalend) in twee a drie zinnen hoe u de iCat ervaren hebt en hoe deze u heeft geholpen met betrekking tot het volbrengen van de taken.
In het begin trok ik me niet zoveel aan van de iCat, maar later in het experiment ging ik me meer focussen op zijn reactie. Ik paste me denk ik wel aan aan zijn reacties.

Beschrijf (verhalend) in twee a drie zinnen hoe u de energiemeter ervaren hebt en hoe deze u heeft geholpen met betrekking tot het volbrengen van de taken.
De energiemeter gaf goede feedback om je bewust te worden hoeveel energie je verbruikt. Dit zou me kunnen stimuleren om bijvoorbeeld met een iets lagere temperatuur te wassen of met grotere hoeveelheden. Wanneer zichtbaar zou zijn hoeveel een andere keuze scheelt in het verbruik zou dit effect versterkt worden.

Appendix E Filled out questionnaire (in Dutch)

Proefpersoonnr. 118

Beschrijf (verhalend) in twee a drie zinnen hoe u de iCat ervaren hebt en hoe deze u heeft geholpen met betrekking tot het volbrengen van de taken.

Ik wilde een zo positief mogelijke reactie krijgen maar vroeg me daarbij wel af of m'n was dan wel schoon zou zijn. Daar kreeg ik geen feedback op alleen op het water/energie verbruik. Het stimuleerde wel zo zuinig ~~mog~~ mogelijk te wassen.

Tekentaak

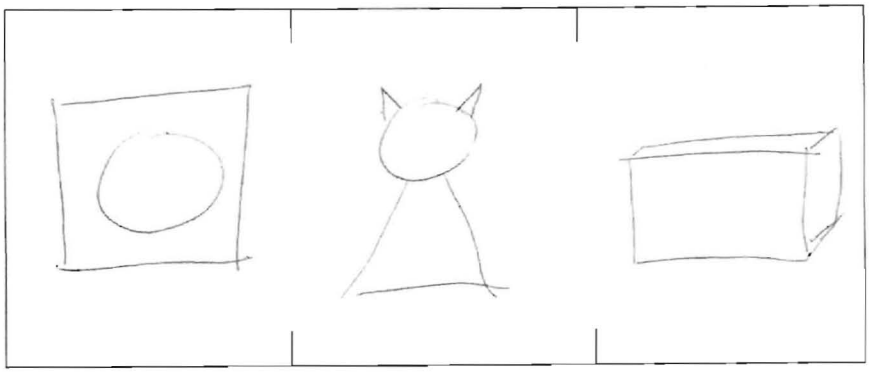
Teken de onderstaande figuren na (hoeft niet netjes) in het onderstaande veld. Het veld is verdeeld in drie "sectoren". Teken de figuren op 1e ingeving in een van de drie sectoren. Je moet alle drie de figuren gebruiken.

Figuren:

Wasmachine

iCat

Baksteen



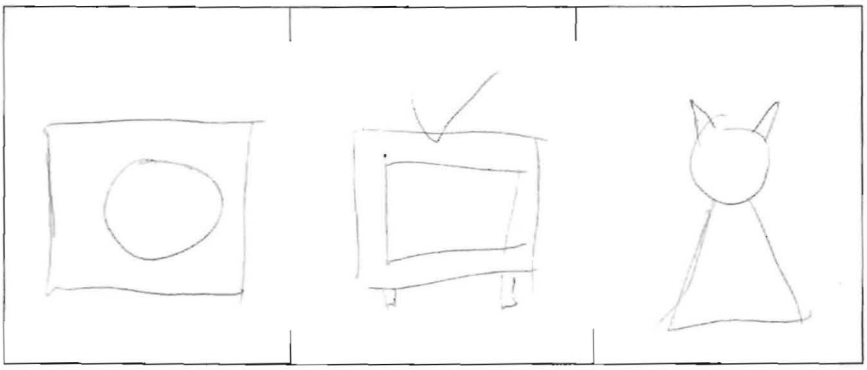
Tekentaak

Teken de onderstaande figuren na (hoeft niet netjes) in het onderstaande veld. Het veld is verdeeld in drie "sectoren". Teken de figuren op 1e ingeving in een van de drie sectoren. Je moet alle drie de figuren gebruiken.

iCat

Wasmachine

Televisie



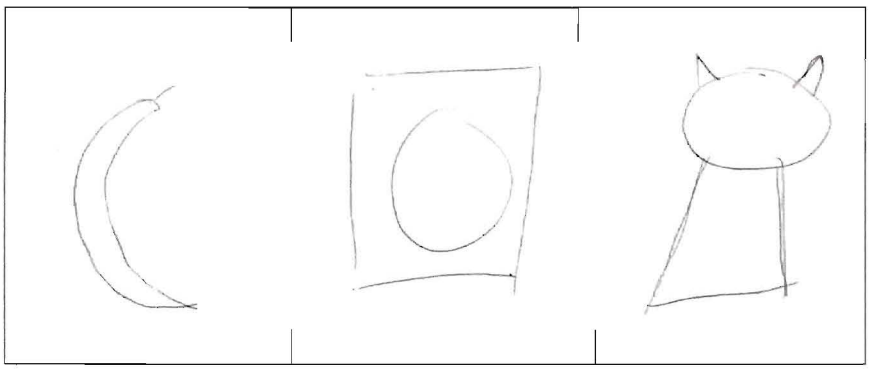
Tekentaak

Teken de onderstaande figuren na (hoeft niet netjes) in het onderstaande veld. Het veld is verdeeld in drie "sectoren". Teken de figuren op 1e ingeving in een van de drie sectoren. Je moet alle drie de figuren gebruiken.

Banaan

iCat

Wasmachine



EINDE VAN HET ONDERZOEK – BEDANKT VOOR UW MEDEWERKING