THE iCAT AS A NATURAL INTERACTION PARTNER:

Play Go Fish with a robot.

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Abstract

Rationale Currently, there is an increasing demand for research concerning robots which can interact in a social and natural way with humans. Presently, there is still a gap in knowledge about how socio-cognitive robots with the ability to show intentional behavior can be developed.

Research Question The goal of this research is to develop a platform involving the use of an iCat robot, which can be used to research natural interaction with child participants. Another goal is to find out how these children assess and rate this socio-cognitive iCat robot.

Method A prototype has been developed for this research, which will be referred to as the socio-cognitive iCat. This iCat behaves socially and takes the mood of the child into account. In order to find out how children rate this robot, another robot has been developed which will be called the ego-reactive iCat. As opposed to the socio-cognitive iCat, this robot does not take the mood of the child into account. To test how these two robots are evaluated as compared to each other, a scenario has been developed. Children play a simple card game called “Kwartetten” in Dutch, which is similar to Go Fish, against each iCat. In this scenario, the behavior of the socio-cognitive iCat is also determined by the score of the game.

Result The children were asked to fill in questionnaires about various topics before, during and after the experiment. The differences in results between the two iCats were small, probably due to a ceiling effect. However, the results of the observations revealed a lot more results. Afterwards, the valences of the children were rated, which indicated that children looked happier when interacting with the socio-cognitive iCat than with the ego-reactive iCat. Furthermore, the socio-cognitive iCat additionally tried to help the children out by giving small hints if they were losing. Due to this, the time that the children had the upper hand during the game while playing against the socio-cognitive iCat increased significantly as compared with the ego-reactive iCat. It is important to note that giving hints did not influence how often an iCat won or lost during the game.

Conclusion The platform has been successfully applied as a research platform, and can be used for a multitude of socio-cognitive research. Currently, the social or intentional behavior is separate from the game behavior, so it is possible to enhance the game with multiple players or use a different game all together, as long as the socio-cognitive part is informed who is winning and what the mood of the child currently is.

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Preface

I want to take this opportunity to express my gratitude to all the people for their contributions and support which helped me to accomplish this thesis. This thesis project required all of them to put in a lot of time and effort, and now the time has come to express my gratitude to the following people for their contribution and support, because I could not have done it without their help.

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Introduction

Current technology is beginning to overcome technical problems and limitations that have constrained robot development over the years, and it is now becoming apparent that it is important to look at the social side of the robot. Using the humanoid form in the creation of robots is now seen as the obvious strategy for integrating robots successfully into environments where humans live and work. The use of human-like features for social interaction with people can facilitate our social understanding of the robot. In other words, explicitly designing anthropomorphic features, such as a head with eyes and mouth, may facilitate social interaction. This highlights the issue that social interaction is a fundamental part of Human-Robot interaction, and exploring the mechanisms underlying anthropomorphism provides the key to the social features required for a machine to be socially engaging and for it to be successfully introduced in specific social situations.

In the past ten to fifteen years, there has been a huge rise in the number of Human-Robot Interaction (HRI) conferences. It is a growing research field with many application areas that could have a big impact not only economically, but also on the way we live and the kind of relationships we may develop with machines. Due to its interdisciplinary nature different views and approaches towards HRI need to be nurtured. In the highly interdisciplinary research field of HRI, a dialogue among such approaches is expected to contribute to the synthesis of a body of knowledge that may help HRI sustain its creative inertia that has drawn many researchers, from Human Computer Interaction, robotics, psychology, the social sciences, and other fields.

Let’s take a look at science fiction, for instance, where robotics is widely used. In a very popular TV series, Battlestar Galactica (2004), the robots become so humanoid that they don’t even realize that

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1 Anthropomorphism is the attribution of uniquely human characteristics and qualities to nonhuman beings or inanimate objects [49].
they are robots anymore. Science fiction writers and its viewers have high expectations of robotic development. They expect that technology will develop in such a way that not only will robots look like humans, but also understand the complex system of social behavior between humans.

To get anywhere near this level of robotic development, we want robots that can visually recognize people and objects, that can communicate with humans, using mature speech recognition software, that can act and behave humanly or react humanly to behavior of humans. For this there are still some obstacles to be overcome. For instance, fully automated speech recognition is not good enough yet to be used in a generic setting since it is currently based on using domain-specific knowledge. The recognition of objects or something as simple as having a robot look at a person’s eyes still doesn’t work optimally and does not mimic human behavior very well. It is clear that various fields will have to work together to get highly skilled robots with humanoid traits.

Currently many companies, universities and research institutes are working on robotic development. Companies like Philips and Sony are mainly working on the physical side of the robotic research and have developed the iCat and Qrio, where they try to solve difficult problems of facial expressions and fluent movement of joints of robots. Universities and research institutes like TU Delft and TNO mainly concern themselves with the more “softside” of robotic development, this includes but is not limited to, social interaction. How will a robot become more accepted in daily life? What kind of behavior should a robot have in certain scenarios?

This research will look at the social side of HRI research and will develop a platform for this. Before this is explained first a look at what has been done before in this field and what can be added that will add value.

1.1 Related work
In this section, a subset of references is discussed, focusing on related work that uses the iCat robot, the robot used in our setup as well.

In 2006, Heerink [1] researched the influence of a robot’s social abilities on acceptance by elderly users. Two iCats were used, in a Wizard of Oz experiment\(^2\), with two conditions; a more socially communicative and a less socially communicative interface. The more communicative iCat, listened attentively, showed nice and pleasant expressions, remembered personal details like names and admitted mistakes. Results of this research show that participants who were confronted with the more socially communicative version felt more comfortable and were more expressive in communicating with the iCat. This suggested that the more socially communicative iCat would be more likely to be accepted as a conversational partner.

In 2006, research was done by de Lange [2], with a social iCat robot that may help children in their daily health-care related activities. Three support roles with corresponding behaviors had been developed;

\(^{2}\) A Wizard of Oz experiment is a research experiment in which a participant interacts with a system that the participant believes to be autonomous, but which is actually partially operated by a human.
motivator, educator and buddy. The children that participated in this experiment proved to value the support roles positively, in particular the buddy role.

In follow up research, by Looije [3], a sensible robot (iCat) and a non-sensible robot was developed. The sensible robot was interested in the user (e.g. remembered his/her name) and showed social behavior on appropriate times as opposed to the non-sensible robot which did not. Children were asked to perform various tasks during the experiment, like answer questions about health related movies but also played a game of tic-tac-toe. One of the results from this experiment was that the sensible robot was found more empathetic than the non-sensible robot.

In 2008 a chess iCat was developed by Leite [4]. The iCat was used as an opponent and the state of the iCat was influenced by the move the player makes. According to the author, the children’s learning experience of chess is enhanced by the iCat’s expressions, since the children know when they made a good or bad move based on the expressions of the iCat.

1.2 Current Research
In the previous section in Related Work a lot of work is being done with social interaction with the iCat. The iCat turns out to be an excellent robot for this type of behavior. It has a wide range of facial expressions that can be expressed on it, and because of its size and the way it looks like, many humans feel immediately connected to it. The importance of this research stresses the fact that there are still a lot of problems to be solved before humans will accept robots in their living room.

Currently research has not paid much attention to the socio-cognitive side which describes integrating cognitive and social properties of systems, processes, functions and models. The difference as compared to the previous research is that the goal of the chess research was to use the iCat’s emotions as a tool to enhance the learning experience, and the goal of de Lange’s research was to use the iCat as a medium to enable diabetic self-care for children, but the iCat’s emotions were not the most important factor for the success of the experiment.

Another important aspect is the cognitive side of robotics. Cognitive robotics is concerned with endowing robots with human-like cognitive capabilities to enable the achievement of complex goals in complex environments. Robotic cognitive capabilities include decision-making, perception processing, attention allocation, anticipation, planning, reasoning about other agents, and perhaps reasoning about their own mental states. Robotic cognition embodies the behavior of intelligent agents in the physical world.

The research of natural interaction can be practically done anywhere where humans are interacting with each other. One could even imagine placing a robot on the street and letting it interact with humans. The disadvantage of such a scenario is that it is very unclear what the domain for the interaction would be and thus predicting all possible expectations of the user would be impossible, let alone having to sift through the background noise that might occur during such an experiment. To make this experiment feasible, a specific scenario was developed in which the participants could interact with a robot.
The scenario developed for this research is one where emotions play a factor and communication is not the main theme. Previous researches already did research with various games; this is good starting point to look for a scenario for natural interaction. The game tic-tac-toe, as used by de Lange, would be too limited, too short and involves too limited or no speech to be interesting enough to research natural interaction on. The chess robot used by Leite already becomes more interesting, in this research the iCat also showed various emotions to express his feelings about the progress of the game. But also with this game, not a lot of interaction is involved. The game used for this experiment is a game called “Kwartetten” in Dutch, which is similar to the game Go Fish. Two players will have to talk to each other to gain cards and thus points, but it will still keep the interaction light. This is in contrast to a game like monopoly, where expectations of humans about communication are a lot higher. Especially the negotiation part, the exchanging of streets, of the game is a whole research by itself.

An important term that will be used throughout this thesis is the intentional behavior of the iCat. This word is derived from the intentional stance, which is a theory of mental content described by Dennet [5]. It is one of the three levels of abstraction in which the behavior of an object can be predicted. The intentional stance is the highest and most abstract level, which concerns things such as belief, thinking and intent. An example of this intentional behavior is the prediction that a robot would be liked more if he would play less aggressively while playing a game of cards. When the human opponent playing this card game notices that the robot is trying to help him out because he’s losing, his impression that the robot has taken an intentional stance would be reinforced.

With all this background information in mind, one of the global goals of HRI can be presented:

*Can cognitive robotics enhance the anthropomorphic or intentional stance of a human towards a robot?*

This question will not be answered in this thesis, but this research will help in the development of cognitive robotics and trying to help develop a robot which will enhance the anthropomorphic or intentional stance of a human towards a robot.

The goal of this research is to develop an iCat robot to which a human will attribute intentional behavior. The kind of behavior that helps to trigger a feeling that the robot is showing intentional behavior in a human, will need to be researched. This robot will be referred to as the socio-cognitive iCat, because this robot will base his behavior on a more social basis. This robot needs to be developed, but in order to observe how whether intentions are attributed to the robot, another robot has to be developed that does not induce humans to attribute intentions to it, for comparison. This second robot is called the ego-reactive iCat, since its behavior is purely reactive and self-centered.

This will bring us to the main hypothesis of this research:

*H1: The behavior of the socio-cognitive iCat is evaluated more positively than that of the ego-reactive iCat.*

Various methods will be used to determine if the socio-cognitive iCat will be rated higher than the ego-reactive iCat. First of all a questionnaire will be used before, during and after the scenario to determine
the opinion of the participants. This will include questions about the friendliness and how much fun it was to play with each iCat. Secondly, observations will also be used to determine if one iCat was rated higher than the other one. This includes looking behavior, how often does the participant look at the iCat, but also what was the observed happiness of the participant with each iCat. Finally, various events from the game will be logged, who won and how often did a child cheat by refuting a card he had.

To help with H1, two questions need to be answered:

1. **What kind of behavior should an ego-reactive iCat have?**
2. **What kind of behavior should a socio-cognitive iCat have?**

Their behavior and what they do will be explained in the next two sections.

**Ego-reactive robot**

The first robot that is developed is one with reactive behavior. This robot will be called the ego-reactive robot because of his behavior. His interaction is solely based on his own ego-centered emotion. This robot will express happiness if he is winning and sorrow if he is losing. If his opponent is unhappy or happy he will not register or respond to this emotion and will continue expressing the same emotions as before. He will always react and play in the same manner and will be completely in his “own world” while playing. This is also why this robot is known as an ego-reactive robot and is chosen as a base-line for the other robot.

**Socio-cognitive robot**

The other robot will try to, up to a certain extent, mimic intentional behavior as displayed by humans. A subset of intentional behavior has been chosen considering it is unfeasible to implement a complete set of intentional behavior. A complete set would require massive research on intentional behavior of humans, a gigantic amount of programming skill and considerable amount of time. Hence the decision to use a subset was quickly taken. The socio-cognitive robot will try to take the emotions of the opponent into account. An example of this, is that when the opponent has been losing for a while, the empathetic robot will tone down his emotions and try to cheer up the opponent by saying something like “Cheer up, I’m sure you’ll win the next one!”.

In the next section the development of the project will be discussed.

**1.2.1 Development**

The first step is to implement the basic rules of Go Fish using Java. The basic game shell kept track of various game aspects and also creates a full-screen visualization of the hand of the child so the child is able to play the game.

The next step is to model the turn-based game, so the strategy-related logic behind the game is handled here. To be able to create this game flow, a graphical interface will be created which can visually model not only the game, but the entire scenario itself.
After these two steps, the turn-based game is implemented in Java, with the help of the fore-mentioned visual game representation interface. For each step in the visual representation, the turn-based java program informs the game program what has occurred, and what the updated game status is, and the turn-based game will react accordingly.

The development of this project has been partly done in an agent programming language called GOAL. In this language, agents derive their choice of action from their beliefs and goals. The GOAL system is used to implement the cognitive side of the socio-cognitive iCat.

Initially, the idea was to have a goal-based system driving the turn-based game. However, this introduced unnecessary complications, and thus the turn-based game that was implemented earlier in Java was rewritten in GOAL. The goal-based system proved to be more flexible, and was able to handle events that could occur at any moment in the course of the game better, such as when the user indicated that he had a complete set, or would like to quit the game.

After the creation of a representation of the turn-based game and implementing it in GOAL, the next step was to find a way for the iCat to be able to talk to the child during the game and during the scenario. To enable this, a sentence database was developed with different sentences for different events in the game.

**Emotion model**
So far, the iCat has not been expressing any emotions, so that is the next step. For this, an emotion system has been developed. This will determine an emotion based on each game event. For instance, giving a card away will generate an emotion of a certain value. The mood of the iCat will be based on these emotions.

**Behavior System**
Now the iCat has the ability to play Go Fish and talk, but no other behavior is being expressed yet. So the behavior system was developed. This would handle behaviors like looking at the child, mimicking looking through his cards but also being able to show the generated emotions and mood.

So far, two ego-reactive iCats have been created that can play a Go Fish with the child. Now, the crucial part of giving one of the iCats intentional behavior by extending the turn-based game written in GOAL, is done. It is determined what kind of intentional behavior the socio-cognitive iCat will show and at what moment. This is based on the score of the game and also on the mood of the child. To determine the mood of the child a co-experimenter will observe the child during the experiment and will indicate when he observes a change in the mood.

**Evaluation**
To validate H1, three questionnaires were developed, which the child filled in at different stages of the experiment. In order to ensure that the results of the experiment are not completely dependent on the answers filled in the questionnaire, various observations were made. These include, among other things, how often the child looked at the iCat, how often the child laughed, what percentage of the time the
child was winning, what percentage of the time the iCat was winning, and what percentage of the time there was no clear winner.

1.3 Overview of this master thesis

This master thesis is divided into several parts, and begins by distinguishing important components of how to define a robot and examples of each type in chapter 2. The design space will be introduced which defines robots into three categories based on its appearance: humanoid, abstract and iconic. The Uncanny Valley is then explained in depth. Some examples of recent robots are shown and sorted by their place in the design space. With each robot, a short discussion is given about the looks, the appearance, its abilities etc. In the end an explanation will be given of why the iCat has been chosen.

In chapter 3 the design of the interaction scenario is discussed. Here some topics about natural interaction in human-robot interaction are researched, like the use of speech. Thereafter, the scenario used for this project is explained.

The next chapter is the functional design of the experiment. Here the details of the scenario Go Fish are analyzed. Also the important parts of a cognitive architecture and the architecture used for natural interaction are discussed. As part of the scenario a chance model is designed to be able to play a game of Go Fish in a natural way. Finally the emotion model for interaction is discussed. This is divided into two parts; the detection of emotions of the child and the generation of emotions of the iCat. Finally the added behavior of the socio-cognitive iCat over the ego-reactive iCat is explained.

In chapter 5, the developed software is discussed. Here the details of the user interface of the game, the experimenter and co-experimenter interface will be discussed. How various parts communicate with each other, GOAL combined with Java, will be explained and finally some details about the graphic representation will be explained.

In chapter 6 the results of the experiment are evaluated. First the hypotheses are described which are there to confirm or refute the main hypothesis. In the section after that, the method of the experiment is explained. This section includes the setup of the experiment, the design, the independent, dependent and control variables and finally the procedure of the experiment. In section 6.3 the results of the collection of statistical data is discussed. This is divided into two parts; the objective measurements and the subjective measure. Finally the chapter is rounded off with a discussion of interesting findings during the experiment.

The conclusion of this thesis can be found in chapter 7.
Human Robot Interaction

In this chapter an overview is given about Human Robot Interaction. This will help with determining, what kind of robot there are, how are they defined, what are their capabilities and how will that help with social interaction. First a short background is given about how to define robots and what is important to pay attention to when using social robots. Social robots differ in their purpose from other robots in that they are specifically designed to be used in interaction scenarios with humans. An example of non-social robotics can be found in Search-and-Rescue scenarios, where their appearances are secondary to their capabilities: rescuing humans.

In the section after this various robots are presented which have been used in social robotic research. After this a robot is chosen on which robotic research will be done during this experiment.

2.1 Robot definitions

2.1.1 Design Space of Robots
As comics’ designers have known for decades, the particular representation used to portray characters in a comic can influence dramatically the way people identify and sympathize with its characters. Humans are more likely to identify with Dilbert then with Albert Einstein. Many people can identify with the former; it represents an iconic ‘universal’ character. An Albert Einstein representation stands for Albert Einstein, a unique individual with a particular biography and
personality [6].

Figure 1 gives an overview of anthropomorphism applied to various robot heads (the body was not taken into account), this triangle is known as the Design Space. At the corners of the triangle the extremities of primary categorization for robots employing anthropomorphism can be found. At the lower left, “Human”, correlates to as human as possible. “Iconic” is more a cartoon like figure with a minimum set of characteristics which is still able to be expressive; like “^__^”. The “Abstract” corner is a more mechanical functional design of the robot, with minimal human-like aesthetics. The Design Space should not be considered as a tool to measure where a robot is, but more as an indication where it belongs. The Design Space was originally designed by McCloud for comics [7], but turned out to be suited for robotics too.

2.1.2 Uncanny Valley

When designing robots, the uncanny valley is a well known problem in robot design. Mori first acknowledged this in 1970 [8]. His original formulation of how the uncanny valley looks like, can be found in Figure 2. The vertical axis represents the familiarity humans have with the object; the horizontal axis shows a sort of similarity, human likeness with the object. First of all a distinction can be made between mobile and immobile objects. Humans can feel much more familiar with moving objects then with immobile ones, as can be seen by the more extreme curve. At the right side of the graph a sharp drop can be noticed which is known as the ‘Uncanny Valley’. The main idea of Mori was that at a certain stage of realistic design the expectations of the object start to outweigh the functional capability, leading to disappointment for the ‘viewer’. This inconsistency results in a drop in the familiarity experienced by the viewer, creating the local minima ‘Uncanny Valley’. Also, note in the graph the reference to the prosthetic hand. At first glance, when the hand is laying still it already looks and feels awkward, but that feeling is enhanced when it also starts moving.

The acceptance of the ‘Uncanny Valley’ is widespread, although the empirical data has yet to fully substantiate Mori’s claims [9]. Still this research is very important, because once an accurate mapping has been established it will be possible to

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3 Object ranging in this case from a prosthetic hand, dolls to robots or humans.
estimate the position of research platforms by comparison with technologies already placed on the ‘Uncanny Valley’.

A point of interest with the ‘Uncanny Valley’ is the notion that various additional hypotheses are to be considered, that may enhance or reduce the ‘depth’ of the valley. Intensive testing on these hypotheses [9] has yet to be done.

- Size; so far, most robots are designed on child height, tasks that are more complex might require a more full-grown human, which could be perceived as a bigger threat.
- Age of Test Subjects; [10] hypothesized that young children are more fearful of humanoid robots.
- Habituation; robots might become less ‘uncanny’ when they are more part of our daily life.
- Culture; people might react differently based on their cultural up bring. In the West a typical “robots will take over the world” scenario is prevalent, in contrast with Japan where robots might also fight an evil human or robot. Still also in Japan, there is a concern about the impact that robots may have on society, a possible explanation could relate to their higher exposure to robots in real life [11].
- Religion; in Christianity souls are only assigned to humans, thus religious people might view this as man’s attempt to become God-like.

2.2 Robots
This chapter will show some robots from the three corners of the design space (see also Figure 1). None of the robots presented here are purely in one corner of the design space. They are mostly focused on one particular corner and that’s how they are placed in this chapter. With each robot some figures about its capabilities are presented and a small discussion of what made this robot interesting to review it here is provided.

The acronym DOF is used a lot in this chapter and is used as a measurement of the freedom of the robot. It stands for Degrees Of Freedom and is the number of independent joints in a robot. As a comparison a human body has over 200 DOF. [12]

2.2.1 Humanlike robots

2.2.1.1 Albert-Hubo
Albert HUBO is an android robot. It is composed of a head, which takes after Dr. Albert Einstein, and HUBO’s body. The development period took about 3 months and was finished in end 2005. The head part is developed by Hanson-Robotics. Its skin is a special material, Frubber, which is often
used in Hollywood for special effects. The head has 35 joints, so it can impersonate various facial expressions using independent movements of eyes and lips. It has 2 CCD cameras for vision recognition. Inside the body a battery pack is hidden which gives it about 2½ hours of independent operation time.

By using a remote network, it is possible to access the Albert HUBO from an external computer. Albert HUBO was announced first at the 2005 APEC Summit in Pusan, Korea. It was praised from many World leaders, such as the USA president, the Japanese Prime Minister and so on.

In total Albert HUBO has 66 DOF; 31 for the head, 6 for each arm, 5 for each hand, 1 for waist and 6 for each leg. It is 1.37m tall and weighs about 57KG. Other interesting functions are its dynamic biped walking, various facial expressions, its ability to produce speech, recognize faces and being able to make gestures based on motion capturing techniques. [13]

It is an interesting robot, because it uses a human head placed on a clearly robotic body. When looking at the head itself, without movement, it looks like an exact copy of Einstein and perhaps even alive. This feeling of aliveness quickly disperses as soon as the head starts moving, a simple notion of the ear vibrating unnaturally already makes one realize this is not a human head. The complete feeling of uncannyness happens when looking at the full robot; a human head on a robot body, it looks like an experiment gone wild.

2.2.1.2 Geminoid HI-1

Geminoid HI-1 is a remote-controlled android system that is a copy of Hiroshi Ishiguro, who is also the developer and designer of the robot. Geminoid was developed with the idea to resemble a human as closely as possible. This android is 140 cm tall sitting in a chair (it cannot stand) and has 50 DOF. Its face has 13 DOF, which gives it the possibility for natural facial expressions. [14]

Compared to the previous robot, this is already a step ahead, at least this time the whole robot is human like. When looking at Figure 5 it may take a moment before one notices which one is the copy and which one is the real one. Still, when observing the videos, you start to notice that things seem unnatural. The way his head always looks down, the jerky movement of the body, the limited or disabled lower body doesn’t help either.

Figure 5 Hiroshi Ishiguro with his robot alter ego.
2.2.2 Abstract robots
In the previous chapter two humanlike robots were discussed, now from the abstract corner some robots will be presented.

2.2.2.1 Qrio
QRIO ("Quest for cuRIOsity", originally named Sony Dream Robot or SDR) was to be a bipedal humanoid entertainment robot developed and marketed (but never sold) by Sony to follow up on the success of its AIBO toy. QRIO stood approximately 0.6 m and weighed 7.3 kg. [15]

Because QRIO development has been canceled, and only prototypes have been developed and shown, it is hard to find reliable data about this robot. Still, the robot is impressive due to its fluent moving capabilities. There is a video of 4 Qrio’s doing a dance [16], which looks extremely natural because they move so lifelike. Qrio might not feel so uncanny due to its typical look of how Western people perceive how a robot should look like. A disadvantage is that you might not get as emotionally attached to it as you would with a more humanoid robot (see also Figure 8).

2.2.2.2 Asimo
Asimo (“Advanced Step in Innovative Mobility”) is an abstract robot created by Honda Motor Company. It has been developed to be a helper for people. Its height, of 130 cm, makes it a good size for helping around the house, to assist people in a wheelchair or lying in bed.

Honda’s development of a humanoid robot began in 1986. In 2000, Asimo was completed and in 2005 the first demonstration of the new Asimo was presented, which has significant advancements in robot mobility.

The new Asimo has a total of 34 DOF, which is quite an improvement over the original one which has 24 DOF. [17]

One of the most impressive features of this robot is its capability to run up to 6 km/h. But it always walks as if it is walking on the tip of its toe, very carefully to prevent falling, which gives it a bit of an infant look. Besides that, it has the appearance of an astronaut with its helmet closed, which makes it quite uncanny to look at.
2.2.2.3 Aibo

Figure 8 various "facial" expressions of Aibo.

AIBO (Artificial Intelligence roBOt, homonymous with "companion" in Japanese) is one of several types of robotic pets designed and manufactured by Sony; there have been several different models since their introduction in 1999. AIBO is able to walk, "see" its environment via camera, and recognize spoken commands. AIBOs are also considered to be autonomous robots, since they are able to learn and mature based on external stimuli from their owner or environment, or from other AIBOs.

The AIBO has various input devices, a color video camera, a stereo microphone, thermometric sensor, infrared distance sensor and three-axis acceleration sensor.

For feedback purposes it is able to show red and green lights on its nose, play sound files and give feedback through motion, like tail wagging. All this has the effect that the owner of an Aibo is not communicating with just some computer, but something that is more alive. [18]

AIBO is probably one of the best known robot companions which shows signs of intelligence and emotion. Interestingly enough, it is known that people have formed emotional attachments to this robot even though it doesn’t look at all human-like. This probably has to do with the fact that humans like to anthropomorphize inanimate objects. AIBO might have been uncanny, with lights indicating its mood, but because it is so well known and it has been accepted to look like this, it has lost a lot of its uncanniness (see also 3.1.7).

2.2.3 Iconic Robots

2.2.3.1 eMuu

The eMuu is developed by Bartneck in cooperation with Philips Research and Eindhoven University of Technology. It is an extended Muu with the ability to express emotions and thus called emotional Muu or eMuu. [19]

This robot is a good example of a simple iconic robot. It can move its head and change the shape of the mouth and eyebrow, but it cannot blink. The movement of eMuu is generated by using Mindstorm Lego motors.

Because eMuu is an iconic robot it is not immediately as uncanny as some of the humanoid robots discussed in chapter 2.2.1. Still it probably becomes uncanny when trying to have a natural conversation
with this one. The eye cannot move and constantly looks into “space” which is quite awkward when chatting with someone. Also, the fact that the eye does not blink at all does not help with this feeling.

### 2.2.3.2 iCat

The iCat is a research robot, designed by Philips, to stimulate human-robot interaction research. It is the first available plug-and-play desktop robot capable of mechanically rendering facial expressions.

It is 38 cm tall and equipped with several servos that control different parts of the face, such as the eyebrows, eyes, eyelids, mouth and head position. It also incorporates touch sensors in its ears and feet, a webcam in its nose, stereo microphones and loudspeakers.

To facilitate developers, the robot comes with proprietary Open Platform for Personal Robotics software. This software excludes computer vision and speech recognition, but has scripting and graphical tools to develop animated dialogues.

![Figure 10 Various facial expressions of the iCat.](image)

### 2.3 Choice of Robot Platform

There are multiple reasons why the iCat is chosen to be used for a project to research human-robot interaction. The first important reason is that the iCat is more iconic than abstract or humanoid. The advantages of an iconic robot over another type of robot have already been explained in the Introduction. In short, the main advantage is that an iconic face can represent the user, while a detailed face represents somebody else. This will probably make it easier for humans to communicate and identify with an iconic robot. Furthermore, humans interacting with an iconic robot will have lower expectations of its capabilities. This will allow us to focus the research on finding out whether cognitive robotics can enhance the intentional stance towards a robot. When using a humanoid robot, users might already expect a robot with cognitive capabilities and might not be impressed and might even be disappointed by the implementation.

A second important reason is that the iCat is not a very uncanny robot. In Figure 11 you can see where the author estimates where the various robots are placed in the Uncanny Valley graph with respect to the mobility line. When determining the place of each robot, human interaction was kept in mind. For instance, with AIBO it is known that people create emotional attachment to it, so it has high familiarity but it is not as human-like as the iCat, which has the ability to show facial features which is very important factor in human-robot interaction. On the other hand, Geminoid is a lot more human, but is a lot lower on the familiarity scale because of his uncanny behavior. This has been done for all robots and the result can be found in Figure 11.

Finally another reason is that the iCat has been designed by Philips to assist in research specifically for interaction purposes. Meaning that Philips took into account how the iCat should look, what kind of
facial expressions it can make, etc. This kind of design issues will be looked at in depth in the next chapter.

Figure 11 A mapping of the robots discussed in this chapter placed on the uncanny valley.
Design of Interaction Scenario

This chapter will introduce important aspects of natural interaction between a robot and human. The aspects highlighted are not only specifically aimed at the iCat, but give a more broad view of the different possibilities.

It has been shown that the research of interaction (also body language interaction cues) plays an important role in human-robot interaction. Humans apply a social model to sociable robots and will in many cases approach interactions with electronic media, holding a set of preconceived expectations based on their experiences of interactions with other humans. If these social equivalences extend to the interpretation of human-like body language displayed by a robot, it is likely that there will be corresponding benefits associated with enabling robots to successfully communicate in this fashion. [21]

3.1 Human-Robot interaction

3.1.1 Face Visually

Faces help humans to communicate, regulate interaction, display our emotions, elicit protective instincts, attract others, and give clues about our health. Several studies have been carried out into the attractiveness of human faces, suggesting that symmetry, youthfulness and skin condition are all factors. An average face – a composite face made up from the arithmetic mean of several individuals’ features – is fundamentally and maximally attractive, and that attractiveness has a social effect on the way we judge and treat others [22].

Human infants seem to have a preference for faces, and it appears that even newborns posses an ‘innate’ ability to spot basic facial features, such as a pair of round blobs situated over a horizontal line which is characteristic of two eyes located above a mouth [22].
In communication, faces are the focal point of any humanoid robot. While designing a robot face, the Uncanny Valley should be kept in mind and realize that it is hard to make a face look realistic. Another difficulty with faces is that they are expensive to make and maintain. Although these obstacles exist, there are still good reasons to use a face:

1. Expressions are a widely used feedback mechanism and are easily understood by a human interaction partner.
2. A face gives the user an understood focal point for interaction. A face affords interaction.
3. It can present visual clues to help understand the capabilities. Clearly-presented communicative features will encourage intuitive interaction. Also a face gives clues of the ability level of the robot; a two year old face implies two year old cognitive and manipulative abilities.
4. Variable expressions can assist the robot in its role; it can make a toy robot look cute or express surprise in interaction games [23].

The iCat has therefore been a good choice for using in this social robotic experiment. The iCat has a clear distinguishable face and has the ability to express a wide range of facial expressions that can be expressed. The iCat also has not been preprogrammed with a fixed set of expressions, but can also show intermediate expressions, for instance, looking a bit happy.

3.1.2 Speech
Speech is a powerful method to communicate emotions. If a friend, for example, does not show up for a meeting, it is possible to express anger through a telephone call. Although this is restricted to speech, the friend will most likely understand the emotional state you are in. It is possible to convey the emotional state by the content of the message, such as “I am angry” but also through the sound of the voice. [19]

When using speech with robots a choice has to be made between using synthetic speech and using recorded natural human speech. The main thing to keep in mind is that a synthetic face should be consistent with the speech. A synthetic face is consistent with synthetic speech (Text-To-Speech), but inconsistent with recorded natural human speech. The reasons are that the synthetic face and the synthetic speech are both non-humanoid and have obvious machine-like marks. They appear consistent together and enhance each other and the social appeal of the overall interface. On the contrary, the synthetic face and natural human speech do not mix well. Users probably feel confused or disturbed by the combination of clearly-human speech and clearly-nonhuman face [24]. Therefore the use of speech will be used to communicate with children during the experiment. The iCat will use game and scenario related speech, which will be done on a basis of a Text-To-Speech synthesizer to be able to match the expectations of the user. To recognize speech, a Wizard of Oz setup will be used, which will have to recognize various scenario and game related speech.

3.1.3 Eye contact
Looking people into their eyes is the first step towards making a positive impression. Failing to look at others causes suspicion as they wonder what signals are being masked. Refusing to make eye contact is seen as sending messages of arrogance and gives the other the feeling of being insignificant. Each
culture has its own subtle rules concerning eye contact; here the guidelines for American society will be discussed.

When having a normal conversation, eye contact plays an important role as the regulator of turn taking. To start a conversation, eye contact needs to be established first with the listener. If that person looks back, “permission” has been granted to begin speaking. As soon as the conversation begin, you will find that the speaker looks away from the listener, only glancing back intermittently to check in. When the speaker is finished, eye contact is made with the listener to signal he can take the role of speaker. If the speaker wants to prevent to be interrupted by the listener, avoid his gaze. Without eye contact, the listener will find it more difficult to interrupt, which will keep the speaker in control of the conversation.

Listeners look more at the speaker in order to show responsiveness and interest, typically looking at the speaker about 75% of the time in glances lasting 1-7 seconds. If, as a listener, you want to make a verbal contribution, it is important that eye contact is reestablished with the speaker. [25]

During the experiment the experimenter determined when to look at the child, as it turned out that automatic eye contact behavior was too difficult to implement. During parts of the scenario the iCat automatically looked at the child, but during the game the experimenter recognized speech so this would also indicate that the child was talking and that the iCat should look in the direction of the child.

3.1.4 Blinking
Blinking is not as important as a communication mean, but a blinking rate deviating from the average does indicate some social or mental problems. For instance a reduced blinking rate is associated with Parkinson’s disease. On the other hand, excessive blinking could indicate a Tourette syndrome, strokes or a disorder in the nerve system. The average blinking rate with an adult human is about 10 times a minute. [26]

The iCat blinks automatically once every while. This is not done in a very fixed rhythm as with human and not as often as humans do, because the time the iCat takes to blink is too slow and the servomotors produce too much noise which would become too big a distraction during interaction. The result is to let the iCat automatically blink after five seconds of inactivity.

3.1.5 Facial Mirroring
The principle of facial mirroring is a much deeper psychological effect than it appears. Humans are endowed with a mechanism that makes them share the “fortunes” of others. A human observer enters an “emphatic” relationship with someone performing some action. This empathetic relation does not only concern the emotion of others, but also the ability to feel their actions. An example of this is the shared pain one can feel when he sees somebody fall.

This also triggers another effect; because of the empathy with others, humans are compelled to desire the happiness of others. If others are unhappy, the observer also is unhappy, because the other’s unhappiness intrudes the feelings of the observer.
So facial mirroring occurs because we share the emotions of others. If the observer sees that somebody smiles at him, it means that the other is happy, triggering a feeling of happiness within the observer. Thus setting visual cues to show happiness in motion, would involve giving a smile back. The same principle also applies to other emotions. [27]

The principle of facial mirroring has been partly implemented in the socio-cognitive iCat, in which the cognitive structure tries to mimic this behavior. This can be seen during the game, when neither players are winning and the child is expressing happiness, the iCat will also become more happy in his expressions.

3.1.6 Iconic robot
There are some important differences to keep in mind when working with a more iconic robot versus a humanoid robot. An important difference was already explained in 2.1.1, which was that a humanoid looking robot will be seen as ‘someone else’ and an abstract design is often seen as ‘something else’ [22].

An advantage of iconic robot over a humanoid robot is that people will have lower expectations of it. If a robot looks human, talks like a human and acts like one, humans will expect it have complete understanding of human behavior. [28] This has to do with people exaggerated expectations of things that resemble humanness.

3.1.7 Habituation effect
Not much information can be found in literature, but this effect is briefly discussed in [10]. It says that the familiarity of a robot will change your behavior towards it. For instance, a user might become more familiar with the way a robot looks and over time think that this robot does not look as uncanny as the user initially thought it was. Another effect might be that the user has learned to be more tolerant to mistakes the robot makes, because the user knows what to expect.

3.1.8 Other interesting natural researched topics
With natural interaction there are many other interesting natural research topics, however not all of these can be researched, are practical enough to use or interesting enough to use for this research. Here a short list of other topics that have been research but are not is used in this research project are presented.

*Filler insertion* is useful in combination with speech recognition. Considering speech recognition needs some time to recognize what has been said, this will give a pause with speech and will break the flow of conversation. To prevent this breaking, a filler could have been used to bridge the gap. [29]

Humans use *nodding* in face-to-face conversation to indicate their agreement or to backchannel rather than speak. Backchannels are non-verbal “utterances” offered instead of spoken utterances to indicate that the speaker may continue because the hearer is at least following the speaker’s utterances [30]. If a humanoid robot could respond with a correct nodding behavior, users would be more comfortable talking to it. [31]
Reacting to environmental stimuli when something strange happens, a loud sound, it looks unnatural for the robot to neglect the stimuli and keeps the interaction moving as if nothing happened. [29]

Proximity has got to do with the fear of robotics. When a robot gets too close, it might be felt as if it is threatening.

Involuntary waving motion is the effect observed when you ask a human to sit still. He will constantly move a bit, the same principle can be applied to robotics, where the robot will always move a bit to look more natural, more alive.

3.1.9 Summary
In this part, various aspects of natural interaction have been determined. Here a short summary of the important parts which need to be addressed in the design of the iCat robot is presented:

- A face with that is able to show various expressions
- Speech to interact with the participant
- Eye contact
- Blinking of the eyes
- Facial Mirroring

A face is one of the most important aspects of natural interaction; it is the focal point of interaction and the location where humans can get information about the state of the robot. For that reason it is also important that the robot has the possibility to express his emotional state clearly by means of mouth, eyes and eyebrows.

Speech is another important aspect in the scenario. Without it, the scenarios discussed will not be possible and also there will be limited need to look at the iCat. If, for instance, a game of Go Fish is played and the iCat would not talk, the participant will probably only look at the screen because that is where all game related information would come from. Speech can either be (pre-) generated by means of a text-to-speech system or it can use pre-recorded voice, this will be determined in the next part.

Eye contact is used when the iCat itself is speaking or when the participant is talking. When humans communicate they look about 75% of the time at the listener. The listener will look almost continuously at the speaker, because eye contact is required to establish when the listener is allowed to make a verbal contribution. To mimic this behavior, it is important to pay attention to this problem.

Blinking is not the most important thing in natural communication, but not blinking at all will be seen as quite unnatural. A blinking rate which deviates a lot from what is perceived as normal will indicate social or mental problems (with humans), so this again will not help with natural interaction.

Facial mirroring is the last topic listed that will need to be addressed in the design of the iCat. When humans converse they make an empathic relationship, this makes humans feel the pain of another person when they hurt themselves. This triggers another effect; humans are compelled to desire the happiness of other.
3.2 Scenario
One of the goals of this research is to discover if a cognitive architecture can help with the intentional stance of the user towards the robot. This is a very broad research field and can be researched practically anywhere where humans interact with each other. The usage of a scenario will help to limit the scope of the task environment in such a way that it is possible to instruct the participants to play a game, and not try to have a general conversation with the iCat. With a scenario at hand, it is possible to predict how the participants will react and what they will expect, and create matching behavior and speech.

Another advantage of a scenario is that it is easier to measure if there was an effect and what the effect was, because typically, a designed laboratory setting provides more control over variables that have potential impact on what is to be measured. We want to have this control to identify which factors contribute to natural interaction.

3.2.1 Participants: Children
Children are an excellent group in order to find out whether more intentional behavior will be ascribed to the robot. According to [32] children are still able to develop a symbolic relationship with a robot and regard it as a person notably if its appearance is human or animal like. Adults on the other hand, have abstract knowledge which enables them to clearly distinguish between a person and a machine, independent of its physical appearance.

The emotion and the mood of a child are also much easier to determine than that of an adult. Children behave and express more true to their own feelings as compared to adults. Adults have a tendency to cloud their internal emotions and might display different emotions than their internal ones.

3.2.2 Game: Go Fish
After reviewing previous research it became apparent that using a game in a scenario, is a good starting point from an interaction point of view. Especially since the participants of the experiment are children, they will probably feel more at ease in this familiar territory. A game of tic-tac-toe was used in previous research by Vincent [2], which was a great success, but this game did not suit all of the criteria used for this project. When searching for a suitable game multiple criteria were used:

- Game will be enjoyed by children specifically in the age range from 9 to 12
- A game that is sufficiently challenging but also relatively easy to grasp for children
- Duration about 10 minutes per game, due to attention span of children and experiment time.
- A game that can be played at reasonably challenging level by the iCat
- Does not require capabilities that cannot be supported by the iCat platform or other state of the art technology (e.g. no advanced speech required)
- Controlled or limited interaction

The first three criteria were chosen because they are aimed at the target group. The volunteers for this project are in the age range from 9 to 12, and there is limited time to do the experiment per child.
Therefore, it is important to have a game that is easy to grasp, but which will also be sufficiently challenging to hold the attention of the child.

The fourth requirement has to do with the challenge. It is important that it is possible to play this game at such a level of difficulty that the iCat will be seen as a reasonably challenging opponent. The iCat should not be able to win all games, but it should not lose all games either. In theory it should have the same level as the children.

The iCat does not have arms or any other means to interact with the outside world. It is therefore important the game chosen does not require this ability. Furthermore, it is also important that there are no advanced speech requirements which could be important when playing a game such as poker. In poker, for instance, humans might be able to pick up subtle differences in voice intonation, indicating a bluff.

Finally, interaction requirements must fit current technology as best as possible. It is infeasible to expect the iCat to play a game of “Truth or Dare”, considering that a dare will require physical capabilities and truth will require a personality to be able to answer a question, let alone the requirements for understand the “truth”.

It is clear that a game like tic-tac-toe does not suit all criteria; especially the criteria of time duration and enjoyability. Most children aged 9 – 12 will find tic-tac-toe too childish and will not find it a challenging game at all, especially if they have to play it for 20 minutes.

The Dutch version of Go Fish (adapted for 2 players) turned out to be a good candidate. Both players have to interact with each other to be able to gain cards (and thus points). Another advantage of Go Fish is that it will keep the interaction ‘light’, meaning that the user can focus on playing the game and have fun, instead of focusing too much on interacting with the robot. Go Fish is also a good game because of its simplicity to learn and play this game.

As explained in the next section, Go Fish is a chance game and thus there is imperfect information available during the game. This makes it impossible to completely control the flow of the game, assuming that the cards are dealt at random and that the iCat does not have knowledge of the cards in the deck or the hand of the child. An example of a game where control is possible would be a game of chess, where all information is known by looking at the board. This game does give a lot of opportunity to control the flow of the game because of its perfect information.

Due to the fact that Go Fish is a game with imperfect information, collecting empirical data poses a challenge, because the results can be dependent on who wins the game, and what the flow of the game was.

3.2.2.1 Rules
Go fish requires a deck which consists out of 36 cards, containing 4 suits and 9 ranks. For example a Rank is called “Monkey’s” which has 4 different suits; red, yellow, green, blue. The goal is to get as many complete ranks as possible, for this you need all four suits of a rank.
At the beginning of a turn 7 cards are dealt to both players and the players don’t reveal these cards to each other. The remaining cards are placed faced down in a draw pile. For the first game the initial player is chosen randomly. For all the follow up games, the one who lost the previous game will start.

During a turn a player can ask the other player for a specific suit and rank. It is important to note that the player who requests this card must already hold at least hold one card of the request rank. So if, for instance, the player is holding the “Blue Elephant” he can then ask the other player: “Can I have the Yellow Elephant?” The player is then obligated to hand it over if he has this card in his hand, otherwise he can deny it by saying: “Go Fish!”

![Figure 12 Four different Suits and Ranks.](image)

![Figure 13 Visual representation of Go Fish.](image)
If you receive a card from a player, you get another try to ask another card. Otherwise the player has to draw the top card from the draw pile, until the draw pile is empty and then the players just play on until all cards have been played or a winner is announced. The winner is the one who obtained more than 5 sets; it is then clear that the other player cannot win anymore. [33] [34]

The game has been visually represented in Figure 13, starting at “Game Started”. Depending on who starts you either follow the lines left or right. At the bottom 3 events can be found that can happen at various times during the game.

3.2.2.2 Challenge
In [35] the factors that make a computer game captivating have been studied. One of the main factors, according to this research, is the challenge factor. How challenging something is can be determined by splitting it up into two parts:

A. Is there a clear goal in the activity?
B. Is the outcome of reaching the goal uncertain?

A: Go Fish is a game with clear goals. The main goal of the game is to win. This can be achieved by achieving the sub-goal of getting a complete set to get a point. Points are gathered by collecting complete sets, which are 4 different colors of the same rank. The main goal is achieved by achieving the sub-goal of getting a complete set as many times as possible. Thus upon winning 5 complete sets out of the total 9 sets available, there is a clear winner.

B: The outcome of Go Fish is also unclear for a long time, especially when both players are evenly matched in playing capabilities. This is because Go Fish is highly dependent on chance, so even when it looks like one player is clearly winning, it can still swiftly turn around when the other player receives excellent cards from the deck. There will be a difference in the uncertainty level between the two iCats. When a child is not very good at Go Fish and he’s losing, he will receive hints from the socio-cognitive iCat which should improve his chance of winning, and make the game less certain (the child won’t lose for sure anymore). On the other hand, since the ego-reactive iCat does not give hints when the child is losing, the child might think that he will certainly lose and this will probably influence his behavior towards the game.

3.2.2.3 Control
Another important aspect of gaming, as discussed in [36], is the level of control someone has over a game. Control demands a certainty of level of predictability. It is shown that the balance between control and uncertainty is important. When there’s too much control there is no more space for surprise element. Various design issues were kept in mind when trying to create a feeling of control for the child:

1. User Interface
The user interface shows various bits of information about the game on the screen. This consists of showing the hand of the child, the score of both players and the amount of cards the iCat is holding. To enhance the feeling of control and involvement the child has complete control over his cards. One of the requirements will be that cards can be freely moved over the screen, sort the cards in any way the child
wants and the child has to actively give a card away when he indicated he has the requested card. It will probably be easy to implement that all these events were handled automatically, but then there would be no actual involvement of the child in the game anymore and he would not have a feeling of being in control of the game at all.

2. Cheating
Unlike many card games, Go Fish is very much dependent on the honor system. Lying about the contents of one’s hand is difficult to prevent. This principle has been incorporated into the design of the game. Cheating is possible and won’t be noticed by the iCat. This will also give a feeling of control, if a child cheats and the iCat immediately says something about it, does this imply he knows the cards of the child? That will not create a good base for trust. Cheating will be monitored and logged without the knowledge of the child, as it can indicate an interesting difference between the two iCats. For instance, if it turns out that children cheat a lot more with the ego-reactive iCat as compared to the soccognitive iCat, this probably indicates that children dislike the behavior of the ego-reactive iCat so much that they have resorted to cheating.

3. Quitting
During the game, at any point, the child has the ability to give up. This was according to one of the advices the author got from [4], where some participants indicated they wanted to quit earlier but this was not possible in their setup. If a child wants to quit, he will just say that he wants to quit to the iCat. The results of this quitting behavior will be taken into account, which means that if a lot of children quit earlier, it is a clear sign that something is wrong with the game or with the behavior of the iCats. On the other hand, if none of the children quit, this will indicate that the game was challenging and interesting enough to play for 20 minutes in total.

3.2.3 Embodiment: iCat
In chapter 2.2 various robots have been discussed and in 2.3 it is explained why the iCat is very suited for this research. In short the iconic capabilities and previous research on which this research can be based make the iCat an excellent choice for the embodiment. The two next sections will clarify some choices related to the robot platform that are relevant for the scenario design.

3.2.3.1 Names
Both iCats have been given unisex names. The socio-cognitive iCat has been named Robin and the ego-reactive iCat has been named Kim. Although few conclusive results have been published about gender impact on perception of robot personality, believability and engagement, it is believed that it is better to stay on the safe side and not force a gender for the iCat. In [37] they discovered that children tend not to attribute genders to robots, although they did tend to give the robot human facial features and a humanoid shape, when they were asked to draw pictures of a robot. Still little is known about whether, or how children attribute gender to robots, and how this may lead to some kind of gender stereotype for robots.

3.2.3.2 Go Fish
Only one iCat will play at one time against one child, this will make the game scenario a lot easier to manage. Now only two players play a game against each other, instead of three players. When using
three players other factors also start to play, for instance how do the two iCats or two children interact with each other? Will the child feel left out when two iCats start interacting too much, or when both iCats gain most of the points. This will make the scenario bigger than necessary. It may be interesting to consider the more involved scenario of more than two players in the future because during testing and during the experiment a lot of people asked if they could play against both iCats.

3.3 Conclusion
A scenario has been developed in which natural interaction can be researched. This is very important because natural interaction can be observed anywhere, but it has to be put in a certain context in order to be researched. The scenario developed has child participants between the ages 9 to 12, who will play a game of Go Fish against an iCat. Go Fish has been deemed to be a good choice for this research, because it is a fairly easy game either known to children or that can be explained in a short amount of time.

Also, in this chapter various aspects of natural interaction and their relation towards the iCat have been discussed. Besides this, a suitable scenario has been found in which natural interaction can be researched. In the first section the following parts have been discussed, which are important to pay attention to when looking at human-robot interaction:

- A face with the possibility to show expressions
- Understanding speech and generation of speech to interact with the participant
- Eye contact
- Blinking of the eyes
- Facial Mirroring

The first point is easy to realize, because the iCat already has a face with the possibility to show facial expressions. An appropriate way has to be found to let both iCats use speech generation to interact with a child, meaning that either pre-generated speech or a Text-To-Speech synthesizer can be used to generate a Dutch voice. It will also need to be determined how to understand speech, either autonomously or based on a Wizard-of-Oz setup.

Eye contact is an important part because when having a conversation, eye contact is a non-verbal signal used to communicate important information about the speaker’s mood and about the actual meaning of the conversation. It indicates who the speaker is and who the listener is. The next section will determine if this can be done autonomously or if other solutions need to be found.

Blinking of the eyes can either be done autonomously or via a Wizard-of-Oz again. The difficulty with blinking is that it needs to be done at an appropriate moment and it also depends on how much time the iCat needs to blink.

Finally, facial mirroring is an important part where attention needs to be paid to. Whether both iCats will have this behavior and how this will be implemented will be determined in the next section.
Functional Design

In the previous chapters the background and the scenario for this research have been explained, in this chapter the functional design will be discussed.

In the first section important requirements of a cognitive architecture are explained. What parts should a cognitive architecture contain and how are they related to this research.

After this section, an agent programming language is discussed that is used for this project: GOAL. Here the reasons why this language has been chosen for this project and its capabilities will be explained.

In section 4.3 the strategy of the game Go Fish is explained. A chance model is explained which determines the chance that the child holds a certain card. Also a model is explained that estimates what information the child knows about the hand of the iCat. The chance model is used to determine what card to ask, this is explained in the last part of this section.

In section 4.4 the emotion model of the iCat is explained. The emotion model is split into two parts; emotion detection and emotion generation. The detection part is done manually by a co-experimenter. This was determined to be the most reliable way to determine the mood of the child.

On the other hand the emotion model also specifies the generation of emotions for the iCat. This consists out of mood generation and the conversion of game events into valence values. The combination of both creates an emotion which can be expressed. When there is no active valence value, the mood will be used to show an expression.
In, in section 4.5 the behavior of the socio-cognitive iCat is explained. The intentional behavior is mainly dependent on various goals that are active within the GOAL system. Goals are fired at different moment during the game, depending on who is winning, and what the mood of the iCat and the child is.

4.1 Cognitive architecture
The cognitive architecture is used to handle the intentional behavior of the socio-cognitive iCat. For this the GOAL system is used (see 4.2), which is based around goals. First various parts that are important for a cognitive architecture to have are discussed. After this the GOAL system is explained and why this is suited to use for this project.

4.1.1 Recognition and Categorization
Recognition and categorization are closely linked and involve the assignment of objects, situations, and events to known concepts or categories. In most cognitive architectures, recognition is a primitive process that occurs in a single cycle, whereas categorization is sometimes viewed as a higher-level function.

In the case of the iCat, the architecture does not do the actual categorization of checking which expressions match a certain mood. But the architecture does recognize the change in mood as indicated by the Wizard and will base decisions on this.

4.1.2 Decision Making
The ability to operate intelligently in an environment requires the capacity to make decisions and to select among alternatives; for instance, what card to ask for when it is the iCat’s turn.

To support decision making, the cognitive architecture must support some way to represent alternatives among choices. It must also offer some method to select among these alternatives. It is common to have this split into two steps. The first step is concerned with checking if the choice or action is allowable, typically this is done by associating it with some pattern and considering it only if the pattern matches a known pattern. Only a sub selection of cards are allowed to be asked in Go Fish (see 3.2.2.1 for the rules), the architecture will then only consider that move when these conditions are met. The second step is selection among allowable alternatives, this is done by computing a numerical score and then selecting the option with the highest scores (see 4.3 for strategy).

4.1.3 Situation Assessment
Intelligent agents exist in the context of some external environment that it must sense, perceive, and interpret. For this project the situation is already clearly defined by the use of scenarios. The iCat does try to assess his current situation; this can mainly be found in the game part. In the game, the iCat makes an estimation of who’s winning the game and based on this the iCat can react differently.

4.1.4 Planning
To support planning the agent must incorporate some environmental model that can predict the effects of its actions. The cognitive architecture must be able to represent a plan as an ordered set of actions, their expected effects, and the manner in which these effects will enable later actions. The plan is not
required to be a complete guide, as it may extend only a short time into the future or refer to abstract actions which can be expanded into different plans.

The iCat needs to plan ahead what his strategy is going to be for Go Fish. What cards should be asked next if the iCat gets another turn and what he should do if the child asks for a card which he doesn’t have, give hints or just refute.

### 4.1.5 Reasoning and Belief Maintenance

Planning seems closely related to reasoning, but is quite different. Planning is concerned about achieving objectives in the world by taking actions, whereas reasoning is the art of drawing mental conclusions from beliefs or assumptions the agents already holds. This can be illustrated by making the decision to give hints to the child because he looks unhappy and is losing the game.

To support reasoning the cognitive architecture must be able to represent relationships among beliefs. Generally this is implemented by the use of first-order logic, but other implementations are also possible ranging from production rules to Bayesian networks. The representation of facts can either be logically or probabilistically sound, but this is not required, it can also be an approximation or a heuristic, but still prove to be quite useful.

Belief maintenance is a final important factor. During reasoning new facts might have arisen and it is important to track these for consistency. At a later stage the agent might find out that certain facts don’t hold anymore and need to be abandoned or altered.

### 4.1.6 Execution and Action

To be able to support activity in the environment the agent acts in, it must be able to represent and store motor skills that enable it. This may be done solely in terms of primitive or component actions, but it is also possible to specify a more complex multi-step skill. The latter may be a previously stored plan from memory or one that the agent has generated.

Examples of stored plans are the sleep animation, or the animation that can be displayed on the iCat when waking up. Other execution of action involves changing the facial expressions on the iCat.

### 4.1.7 Interaction and Communication

Interaction and communication is the most important part of the agent, considering this will be the main part of research. The communication between the agent and the user can happen on various levels, e.g. speech and body language, and the agent must be able to represent the knowledge it intends to gather or that it believes the user intends for, in this form.

The cognitive architecture must support a mechanism to transform knowledge into the way it will be used for communication. The most common form of this is spoken or written natural language, which involves following conventions for that language. The generation of language can be seen as a form of planning and execution and the understanding of language as perception and inference. However, the specialized nature of natural language requires special attention, because of the many additional issues involved. This is also one of the reasons why spoken language will need a Wizard of Oz setting to be able to have a high rate of correctly recognized speech.
4.1.8 Remembering
Remembering is the ability to store and encode the results of cognitive processing in memory and to retrieve or access them later. An agent cannot remember an external situation or its own physical actions; it only can recall cognitive states that describe those events about them. This idea is easily extended to memories of problem solving, reasoning, and communication. To support remembering of cognitive activity, it must store the structures generated during that activity, index them, and retrieve when needed. For the iCat this can be used to remember previously asked cards and determine a good strategy surrounding this. This structure is often referred to as episodic memory. [38]

4.2 Cognitive programming language: GOAL
A cognitive programming language is a computer language that facilitates the development of agents that derive their choice of action from cognitive notions such as beliefs and goals. In this thesis the language GOAL has been used. Cognitive agents programmed in GOAL reason with their beliefs and goals to derive which action to perform next. The implementation of the cognitive control component of the iCat, by means of a cognitive programming language, will determine how the child will perceive the iCat by means of its social behavior.

The language used in this project is named GOAL, which is under development by the TU Delft. GOAL is an acronym for Goal-Oriented Agent Language. The basic idea is that a set of actions which execute in parallel constitutes a program. The language GOAL is an agent-oriented programming language that incorporates notions such as belief, goal, and agent capabilities which operate on high-level information instead of simple values.

The main reason for choosing GOAL, is the belief of the author that by making use of relatively simple goals, the person interacting with the iCat will already get a feeling of ‘liveliness’. During the research thesis specific goals will need to be designed and tested, one can think of goals like: “Make sure the user does not look unhappy since the last game”. This goal can then be solved in various ways e.g. make sure the user wins this game.

The reason GOAL will be used and not a Cognitive Architecture is that Cognitive Architectures enforce the way the reasoning will be shaped. Examples of most known Cognitive Architectures are SOAR and ACT-R. The idea of these cognitive architectures is to mimic a human as completely as possible in all its ways; this is a very inflexible and enforced way of building cognition. The research of this thesis is not that broad and does not expect to be so complete that a user will think that it is interacting with a complete human (in an iCat shell that is). That is why, it is expected, that using simple notion like goals, will improve the intentional stance of a human towards the iCat.

We very briefly discuss the main concepts of the GOAL language to give the reader a flavor of what kind of programs can be developed in GOAL.

The program and action specification components of a GOAL agent are static and do not change at runtime. The agent’s belief and goal bases are dynamic and may vary over time. They change because of actions that are performed by the agent, which, apart from changing the agent’s environment, also update and modify the beliefs and, indirectly, the agent’s goals. [39]
knowledge base: a set of concept definitions or domain rules, which is optional and represents the conceptual or domain knowledge the agent has about its environment

belief base: a set of beliefs, representing the current state of affairs

goal base: a set of goals, representing in what state the agent wants to be

program section: a set of action rules, that define a strategy or policy for action selection

action specification: a specification of the conditions for each action available to the agent of when an action can be performed (its precondition) and the effects of performing an action (its post condition)

percept rules: a set of percept rules, which specify how percepts received from the environment modify the agent's mental state

---

**Figure 14** The six different sections in GOAL [53].

### 4.3 Strategy

In this section the strategy and the chance model for the game Go Fish is explained. Part of natural interaction requires the generation and detection of emotions as explained in the next section 4.4. In this section another important part of natural interaction will be developed; being able to mimic playing a game of Go Fish at a sufficient level of proficiency, in order to ensure game play is perceived as more or less natural. Imagine that the iCat would ask cards in a very inconsistent way, this will probably be noticed as a very unnatural way of playing this game. First of all, when the iCat asks a lot of different cards, the iCat will give away a lot of information. Secondly by asking random cards the iCat has a very low probability of winning the game.

Go Fish is a game with incomplete information. It is not always (and very rare even) to know exactly which cards the other player is holding. Also it is not known which cards are left in the deck.

The chance model has been used as a basis for the design of the decision-making part of the cognitive architecture. The chance model will be used to determine what the probabilities are that a player is holding a certain card. It is important to realize that this is not an attempt to make the best or a perfect Go Fish player and the values used are a clear overestimation, but one which will be able to play reasonably well and naturally against a child.

The iCat keeps track of the probably that the child is holding a certain card. The probabilities are updated during each of the following 5 game events: A card is requested, a card is received, a card is given away, a card is taken from the deck and a rank has been completed.
When the game is started the strategy will give all cards that the iCat holds a probability of 0 to be held by the child. All the other cards have a probability of 7/29 to be held by the child. There are 7 cards in each players hand and there are 36 cards in total.

**Child requests a card**

The iCat *does not have the requested card*, it is now known that the child has at least one card from this rank. To calculate the probabilities of the remaining cards the following formulae is used:

\[
Prob = \begin{cases} 
\frac{1}{3-R}, & R \leq 2 \\
1, & R = 3 
\end{cases}
\]

with R being the amount of cards the iCat is currently holding. The chance that the child is holding the requested card is 0, considering as a player you are not allowed to ask cards you own.

The iCat *does have the requested card*, it is now known that the child has at least one card from this rank and the card he just requested. The card the child just requested has a probability of 1 to be held by him. The remaining cards are calculated in the following way:

\[
Prob = \begin{cases} 
\frac{1}{4-P-R}, & (P + R) < 4 \\
1, & else 
\end{cases}
\]

with P the amount of cards which the opponent is holding of that rank (those have a probability of 1) and R being the amount of cards the iCat is currently holding of that Rank, both after giving away that card.

**iCat requests a card**

In both cases, the child has the card or not, the probability that the child is now holding that card will become 0, because either way he does not have the card.

**A card is drawn from the deck**

By the child, the probabilities of the child holding cards is updated. This is only done for cards which not have been completed and the probability of a card should never exceed 1. To all the other cards \( \frac{1}{D} \) with D the amount of cards left in the deck, is added to each card.

By the iCat, the drawn card now has a probability of 0 being held by the child.

**Rank complete**

A note is made that a set is complete and is not handled anymore by the strategy system. All cards of this rank have a probability of 0 being held by the child.

4.3.1 **Strategy implementation**

A model has just been described that shows how to calculate the probability of a child holding a certain card. The card which had the highest probability would then be asked by the iCat. During testing, it was determined the iCat played well enough with this model. Another adaption was to compensate for the fact that by just asking cards with the highest probability, the iCat would sometimes ask cards in a strange order. An example of this is when there are multiple cards with the same probability spread
over multiple ranks, the iCat could then ask: red chimpanzee, blue camel, blue chimpanzee and have a complete set of chimpanzees. This is strange, because as a human you would first like to secure a complete set before asking another rank. To combat this, the iCat would first pick one of the cards with the highest probability and then keep on asking cards from that rank. Only cards from the rank that had a probability higher than 0.2 would be asked. This probability was determined by testing when the probability was set to be higher than 0.2 the game play felt natural to the testers.

When the game started all cards that have not been asked yet, had the same probability. During the starting of the game this could result in unnatural order of asking cards. If for instance, the iCat requests the blue chimpanzee and the child refutes this, this does not affect the other cards. Now the child requests a rank of which the iCat is not holding any. Because the remaining cards of the chimpanzee have the same probability as other non-asked cards, the iCat could request another chimpanzee. That is strange, because a player, who understands the game well, would have asked for a chimpanzee after the iCat requested one. If the player did not request any chimpanzee’s it is fair to assume that it would be a bad strategy to request chimpanzees again. The strategy has thus been designed to ask 4 different ranks during the first 4 rounds of the game after which, normally, enough variation must have developed to continue on with asking cards in a normal way.

Another design choice was a system that was made in case something went wrong with asking more cards from the same rank, such as for instance, no cards were found with a probability of 0.2. In this case, the solution was that the iCat would look for a new card with the highest probability. The same principle was used for requesting four different ranks when the game started, it is possible that the iCat has less than four ranks, to solve this problem, the iCat would also pick a card with the highest probability after asking all ranks in his hand.

4.4 Emotion Model
A major part in this research was the emotion model. This is about the detection of the mood of the participant and the generation of emotions and mood of the iCat. In Figure 15 an overview can be found. In the next chapter each part will be discussed and explained.
4.4.1 Child Emotion Detection

In Figure 15 the emotion model used during the experiment can be seen. As can be seen the detection side of the model is quite simple, initially the model looked quite different, but after testing various scenarios this resulted in the most optimal, and most valid, method. The three different methods of detecting the mood of the child will be discussed in the next 3 sections of which the last one is the one that is actually used and implemented.

4.4.1.1 FaceReader

The initial plan was to use automated detection of moods of the child to determine the mood. Within the TU Delft it turned out not much software was available, which could be taken “off the shelf”. TNO has a license for some commercial software which could determine the valence value of adults and children. The software is called Noldus FaceReader (see 5.3.2.1).

After testing this software for some time, it turned out this solution was not as stable as hoped. Here the various problems are discussed in 4 short sections.

Figure 15 Overview of the emotion model.
Facial angle
First off, the direction of the face should be quite perpendicular towards the camera. In Figure 16 the estimated angles for which the emotion recognition work can be seen. The participants will probably fall outside this scope already when looking at the iCat which is standing next to the screen.

![Facial angle diagram]

*Figure 16 Estimated allowed angle allowed towards camera where emotion recognition is still possible.*

Complete face
Another problem was that the whole face must be visible on camera to recognize emotion. If the participant would lean on this hand recognition would fail. Also when a part of the face would fall outside the view of the camera emotion recognition would not work. This could be solved by placing the camera further away, but then recognition went down by quite a lot.

Movement
Motion of the face was also hard to track for the software. Considering that children are quite restless and move around quite a bit, this was not very optimal.

Transformation from valence to mood
One of the main reasons why automatic emotion recognition was not used, was due to the problem of converting valence values into a mood. In literature the author of this document couldn’t find any algorithms for this. That would mean that either one would need to be researched, or one needed to be tried and hoped for the best. Both solutions are unsatisfactory, considering that the first one is not part of this research and the second one will make the results of this research doubtful, because it is unknown if problems or other results are a problem with emotion recognition.

4.4.1.2 Parents
A second idea was using parents as a “tool” for mood recognition of their own child. Not much information about this idea could be found in literature, but it could have been an interesting way of doing it. Sadly this idea had to be canceled because it was too big a burden for the parents. They had to come to the school, get a crash course into mood recognition and attend a sessions for half an hour of observing their own child. Neither the school nor the parents were interested in this plan.
4.4.1.3 Co-experimenter
Finally the idea of the co-experimenter was applied. This way the main experimenter will not be a bias for the experiment and still there will be some mood recognition. The co-experimenter was also used to gather some statistics during the experiment, these were:

1. Talking time
2. Laughing events
3. Looking at the iCat events

This saved the main experimenter with some time looking through all the videos again.

4.4.2 iCat Emotion Generation
The purpose of the Emotion Generation side, as can be seen in Figure 15, is to determine when and what kind of emotions should be generated at various points during the game. This has been broken up into various pieces of which each has its own purpose. In the following sections the purpose of each node will be explained.

4.4.2.1 Game Score
Initially a formula was developed which estimated who was based on score and cards each player was holding. The formula is as follows:

\[ \text{Score} = (SI - SC) \cdot 10 + (CI - CU) \cdot 3 \]

With:
SI is sets iCat
SC is sets user
CI is cards iCat (in hand)
CU is cards user

This is a scoring based from the point of the iCat, this means a positive score means the iCat is winning and a negative score means the child is winning.

Having more cards than the other is seen as an advantage, because you are more likely to keep the upper hand by knowing which cards the other player has and be able to successfully ask the right cards. Also because a “bigger” hand has more options to chose from, it is also more likely to be successful in winning.

The game score could then be divided into 5 parts:

<table>
<thead>
<tr>
<th>Losing</th>
<th>Potentially Losing</th>
<th>Neutral</th>
<th>Potentially Winning</th>
<th>Winning</th>
</tr>
</thead>
<tbody>
<tr>
<td>-25</td>
<td>-10</td>
<td>10</td>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

During testing it became apparent that this gave too less intentional behavior from the iCat. Also testers mentioned that they mainly look at the score to determine who is winning.

During the experiment a simple method was used; the player who has a higher score then the other player is winning, when the scores are equal there is no player winning.
4.4.2.2 iCat Mood

The mood is determined by input of the emotions (see 4.4.2.3). The mood is calculated by taking the exponential moving average (EMA) over the last 20 emotions. The EMA has been chosen because it has been successfully used in other research with the iCat. In [4] an iCat plays a game of chess against a child; here also an EMA is used for mood determination.

The advantage of an EMA over a simple moving average is that it gives more weight to recent events. This seems to be analogous to how humans determine their mood; recent events have more weight than events that happened a long time ago.

The formula for EMA is:

\[
M_t = \begin{cases} 
\frac{2}{N+1} \cdot E_t + (1 - \alpha) \cdot M_{t-1}, & t > 0 \\
E_0, & t = 0
\end{cases}
\]

With:
- \( M_t \) is the Mood at time \( t \)
- \( E_t \) is the Emotion at time \( t \)
- \( N \) is the amount of emotions

Initially the first 5 emotions are set to a value of 30. This will ensure the iCat starts off with a good mood. Also it will prevent the iCat from bouncing around too much with his mood, when the game just begins, that will look very unnatural.

During testing two problems with this system arose. The first problem was that initially all emotions were stored and used for mood determination. This caused for too much background noise and averaged the mood too much towards 0. To prevent this from happening, only the last 20 emotions are used to determine the mood.

The second problem was that because all game events are threaded equally and because the game events were cut off after 20 events, important events like set complete, got lost in time and the other events. In the mood system a baseline was introduced based on the game score. The baseline increased or decreased in 5 steps towards the new baseline. The baseline was determined as follows:

\[
B = \begin{cases} 
40, & (SI - SC) > 2 \\
-40, & (SI - SC) < -2 \\
(SI - SC) \cdot 20, & \text{else}
\end{cases}
\]

With:
- \( B \) is baseline
- \( SI \) is sets iCat
- \( SC \) is sets user
Now, when the iCat is clearly winning it will have a happier mood. Otherwise if in the last 20 events the iCat had to give quite a bit of cards away, he would have an unhappy mood, although he was still winning.

### 4.4.2.3 Game Event & Emotion

The game, see 5.2.1 for implementation details, generates game events. These game events go into Emotion where they are converted into valence values. The conversion is done with a lookup table, which can be seen in Table 1. These values are a mix of how expressive the iCat became from it, personal taste and the comment on it during pilot runs.

<table>
<thead>
<tr>
<th>Game Event</th>
<th>Valence</th>
</tr>
</thead>
<tbody>
<tr>
<td>iCat requests a card</td>
<td>30</td>
</tr>
<tr>
<td>Player refutes requested card</td>
<td>-30</td>
</tr>
<tr>
<td>Player requests a card</td>
<td>-30</td>
</tr>
<tr>
<td>iCat says “go fish”</td>
<td>30</td>
</tr>
<tr>
<td>Player confirms requested card</td>
<td>70</td>
</tr>
<tr>
<td>iCat gives requested card</td>
<td>-70</td>
</tr>
<tr>
<td>Waiting for player to request a card</td>
<td>0</td>
</tr>
<tr>
<td>iCat has a set complete</td>
<td>90</td>
</tr>
<tr>
<td>Player has a set complete</td>
<td>-90</td>
</tr>
<tr>
<td>iCat won the game</td>
<td>100</td>
</tr>
<tr>
<td>iCat lost the game</td>
<td>-100</td>
</tr>
</tbody>
</table>

*Table 1* On the left side the Game Events and on the right side of the table to corresponding valence values.

Testers mentioned that it was not very clear what the mood of the iCat was. To combat this, the valence values from the Emotion module are multiplied by 2. This will create valence values larger then 100, but this will be cut off in the Logic (see next chapter) at 100.

### 4.4.2.4 Logic

In the logic the behavior of the iCat is determined. This depends on which iCat is playing currently and on the input of the emotion and the mood.

**Speech**

For a more natural game of Go Fish the iCat should be able to communicate with the participant. To let the iCat talk, a Text-to-Speech (TTS) synthesizer will be used. The specifics about this TTS can be found in 5.3.2.2. The advantage of TTS over pre-recorded speech is that is makes use of the Windows® Speech API 5. The software of the iCat is able to recognize some of the phonemes[^4] and creating matching mouth moments. In Figure 17 two examples of such phonemes can be observed.

In Appendix A the list can be found of (Dutch) sentences that were said by the iCat. Most sentences have to do with the game and are the exactly the same for both iCats. More about this will be discussed in the Software Development.

[^4]: A phoneme is the smallest linguistically distinctive unit of sound in a language.
When the iCats asks something he will wait about 10 seconds for a reply. After these 10 seconds, he will ask an appropriate question, for instance if he asked if the child has a blue chimpanzee he will then ask after 10 seconds if he knows it yet.

![Image of two phonemes: /q/ on the left and /o/ on the right.](image)

**Figure 17** Example of 2 phonemes on the left a /q/ and on the right a /o/

**Idle behavior**
Both iCats will have the same behavior when idling. This can happen when the iCat has requested a card and the opponent takes some time to respond. After about 5 seconds of waiting, the iCat goes into idle mode. It then blinks and starts looking around in some random direction until the next event happens.

**Looking at the participant**
As established in 3.1.3 looking at the participant is an important part. At TNO internal software was developed that makes the iCat look at the user. It uses the standard settings from OpenCV (see 5.3.1.4) to find the location of face on a video stream and then centre the iCat on this face. When the camera was properly placed, it worked quite well, but this has the same problems as the FaceReader concerning angles (see 4.4.1.1). Another problem was that when it did work, the iCat was constantly moving around a bit to keep the iCat centered on the face, even when a person did not move, due to noise the recognition of the centre of the face moved. This felt very unnatural and was hence dropped.

Still the iCat needed to look at the user, a simple solution was used. The height of the face of the child was estimated and the iCat was placed under an angle so he would face the child when looking forward.
Expression
The expression of the iCat is on a scale of -100 to 100. In Figure 18 from left to right, valence value 100, 0 and -100 can be observed on the iCat. For values between 0 and 100 only the position of the mouth is affected. For values between -100 and 0 also the eye brows move along. This made it more clear that the iCat is sad and not in an angry mood as observed by the test group.

The values shown in-between are done on a linear basis.

The emotion expressed is determined by which iCat is currently playing and if it is actively showing an emotion.

Mood
For both iCats the mood is shown in the same way. How the mood is calculated can be found in 4.4.2.2. The result of this calculation is the valence value shown on the iCat. This will be shown when there no other emotions being shown.

Emotion
If there is input from the emotion part, then this will be displayed as soon as there is a possibility. This can be delayed by a speech event, when the iCat is talking it cannot show an emotion, so it will be shown after speech. The expression of an emotion will always last 3 seconds and will then go back to the mood.

The expression will normally be calculated as: \( \text{Expression} = \text{Emotion} + \text{Mood} \)
The reason that expressions are calculated like this is that now when the iCat has a bad mood and a good game event happens the iCat does not look very happy all of a sudden. For instance, imagine the mood is -50 and the iCat requests a card (a valence of 30), the expression will then be 
\[-50 + 30 = -20.\]

4.5 **Intentional behavior**

The intentional behavior of the iCat can change the outcome of speech and emotions by changing emotions the mood can also be changed. The intentional behavior is located inside the Logic module, but considering this is such an important part of the research, it has gotten its own section.

As mentioned in 4.2 GOAL will be used as a cognitive architecture. This is a goal based system and thus for various intentional behaviors goals were used.

4.5.1 **Win**

This is the initial goal when the game is started. When playing a game, initially everybody always plays to win; this is the same for the iCat.

4.5.2 **Cheer up**

The socio-cognitive iCat tries to cheer up the child a bit if, for instance, he has a losing hand. When the child asks for a card and the iCat doesn’t have it, the iCat will say something like “Better luck next time!”.

4.5.3 **Give hints**

When the child is losing, the socio-cognitive iCat will give some hints to help the child out. These are of course game related hints and will be hints about the hand of the iCat. When the child asks about a card which the iCat does not have but he has another color, he will give him the hint of saying “If I were you I would try a different color”, otherwise he would advice the child to try a different rank altogether.

4.5.4 **Lose a set**

When the child is badly losing the socio-cognitive iCat can also purposefully lose a set. It does this when it knows (for sure) it can get a complete set. When asking for multiple cards of a set, he will then by “accident” ask a card he already asked again. Now the child can ask these cards back and gain a complete set.

4.5.5 **Happier mood**

Sometimes the mood need to be increased, this is done by increasing the “positive” emotions and by decreasing the “negative” emotions. Increasing the mood can be used in situations where the iCat is winning and he is not showing a happy mood.

4.5.6 **Be happy**

The difference between increase mood and be happy, is the way they are calculated and when they are applied. Be happy is used when neither of the players are winning and the child is in a good mood. The iCat will then express happier emotions. While increase mood is specifically there to increase the mood to a certain level and then stop increasing.
4.5.7 What’s up
This will be used when the child has been unhappy for a while. The socio-cognitive iCat can then ask the child if he’s ok, or if he would like to continue on with playing a game. For the final implementation this has been removed from the system.

First of all, if the child indicates he would like to quit, this will give a problem for statistical analysis, because a game has not been fully completed. If for instance, this goal was used, a question like “Are you still enjoying playing?” is also not possible, because if the response is negative, there have to be some consequence, like asking if he would like to quit.

Secondly, it could give too broad questions. The question asked could be “You don’t look happy, do you want to quit?”. If the child then answers “No it’s ok”, a normal person would ask on “What is up then?” such a question will leave the scope of the scenario, because this could be answer in almost an infinite amount of ways.

4.5.8 Emotion multiplier
Sometimes the socio-cognitive iCat uses an emotion multiplier; this multiplies the emotion by a certain factor before it is used.

4.5.9 Overview
In this section an overview is given when the various goals are used and other events. The table is split into 3 parts, depending on who’s winning at that time. The rows are for the mood of the socio-cognitive iCat and the columns for the mood of the child.

**iCat winning**

<table>
<thead>
<tr>
<th>Intentional behavior</th>
<th>The mood of the iCat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unhappy</td>
</tr>
<tr>
<td>Unhappy</td>
<td>Cheer up</td>
</tr>
<tr>
<td></td>
<td>Give Hints</td>
</tr>
<tr>
<td>Neutral</td>
<td>Cheer up</td>
</tr>
<tr>
<td></td>
<td>Give Hints</td>
</tr>
<tr>
<td>Happy</td>
<td>Cheer up</td>
</tr>
<tr>
<td></td>
<td>Give Hints</td>
</tr>
<tr>
<td></td>
<td>Be less expressive in emotions: Emotion multiplier of 0.625</td>
</tr>
</tbody>
</table>
### Neutral game

<table>
<thead>
<tr>
<th>Intentional behavior</th>
<th>The mood of the iCat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unhappy</td>
</tr>
<tr>
<td>Unhappy</td>
<td>Give hints</td>
</tr>
<tr>
<td>Neutral</td>
<td>Give hints</td>
</tr>
<tr>
<td>Happy</td>
<td>Give hints</td>
</tr>
</tbody>
</table>

### Child winning

<table>
<thead>
<tr>
<th>Intentional behavior</th>
<th>The mood of the iCat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unhappy</td>
</tr>
<tr>
<td>Unhappy</td>
<td>What’s up?</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutral</td>
<td>What’s up?</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Happy</td>
<td>What’s up?</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When the table was being designed it is important to realize that two conflicting goals are at play here. On the one hand, when 2 humans are playing, you want to make friends (or stay friends) but you also don’t want to do this by just losing severely (which is not very natural). The resulting table is probably a good compromise between the two worlds.
5

Software Development

In the previous chapter the scenario used for this experiment has been explained. In this chapter the implementation of the all the software that is used to create a platform for natural interaction between the iCat and the child is described, along with the underlying hardware used.

In the first section a short background will be given of the soft and hardware used. In section 5.1 a short background is given of the languages and the robot used for this project. In 5.2 the actual implementation is discussed. This includes all the development done for this project, like the design of the game, a way to visualize a flow in scenarios and various Graphical User Interfaces made for this project. Finally a short overview is given of other software package that have been used or researched for this project.

5.1 Software and hardware background

In this section the software and hardware background used in the experiment setup will be shortly discussed.

5.1.1 Java

The main programming language for this project is Java, since the GOAL system was developed in Java and communication with this would go easiest in a Java environment. In addition, the author of this thesis was already quite fluent in Java programming.

5.1.2 iCat

The iCat is the main robot used for this research and was discussed in 2.2.3.2. Here, a short summary will be given. The iCat is a yellow robot about 38 cm tall and developed by Philips. Its strong point is its ability to show facial expressions.
The iCat comes with proprietary software to help developers, which is called Open Platform for Personal Robotics (OPPR). This software is developed for C++ and for another programming language called Lua. However, the software did not support Java, and this issue needed to be resolved since the rest of the project was developed in Java.

Fortunately, it was found that software had been developed at TNO that enabled communication with the iCat over a TCP/IP port. This only included one way communication, but that was sufficient for the project. Thus the solution was to use the TCP/IP port to send commands to the iCat from the Java project, without requiring a response from the server.

5.1.3 GOAL

A detailed explanation of GOAL has already been given in 4.2, but a quick review of the important points is given here. GOAL is an agent programming language and the strong point of this language is its goal oriented design. It consists of six parts, of which the belief and goal base are the only non-static parts. The belief and goal base can be adapted from outside by making use of percept rules, in which information is transformed into goal logic.

5.2 Implementation

For the project various parts had to be implemented. A game of Go Fish had to be developed which handles all game events, but also shows a visual representation of this game. The flow of the game also had to be developed and handled. This was done completely in Java and another implementation of the game flow was made partly in Java and partly in GOAL. The behavior of both iCats also needs to be handled, for which a behavior system has been developed in Java, which can handle both iCats at the same time.

Other parts were the experimenter and co-experimenter interfaces on which they could input their observations of the experiment. Based on these observations statistical information, or information which can be used by the iCat to behave in a certain way is calculated. As mentioned, speech recognition is not good enough to be used with children, because the sheer amount of possibilities to confirm or refute something are near endless.

A technical note on how the parts are connected over the network. All the Java code was connected with each other by means of Remote Method Invocation by which it is possible to directly connect to a method of a class. Connections with the iCat are done over a TCP/IP tunnel.

An overview of the architecture can be observed in Figure 19. The dotted lines show a zoomed in version of the node. This has been done for both the GOAL GUI and the GOAL side, for which multiple parts are inside one part.
Figure 19 Overview of the designed and implemented architecture
5.2.1  Go Fish
The first step for the scenario was to develop an implementation of “Kwartetten” for the project as no suited implementation was found. This consisted of creating a game shell which holds all information about which cards the iCat has, which cards the child has, a deck to draw cards from, the game score as well as an event list containing all game events and keeping track of who the current player is. Also, a graphical interface was implemented for the child, see Figure 20. Here the child can see his own hand, the game score, how many cards the iCat is holding, whose turn it is and move his cards freely around in the designated area to sort them; in Figure 20 on the left an unsorted hand and on the right an example of how it can look like after a human has sorted them.

The game also kept track of various game events that could be retrieved later by other parts. These are directly linked to the Strategy as discussed in 4.3:

- Game Started
- User Requests Card
- iCat Requests Card
- Card refuted
- Card given away
- Set completed
- iCat wins
- User Wins

![Figure 20](image.png)

**Figure 20** Two screenshots of the Game. On the left when the cards are dealt to the player and on the right an example of when a player has sorted them.

When the game implementation is given the command that a new game has started, it will shuffle a deck which contains nine different Ranks and 4 different Suits, which totals to 36 cards. The cards have partly been developed, because a normal “Kwartet” set has different pictures per Rank, here a color scheme was used. The nine ranks are: Bat, Camel, Chimpanzee, Dog, Giraffe, Goldfish, Shark, Lion, and Rhinoceros, these images were taken from the internet. They had to be edited to place the Dutch name
of each species underneath the picture and in the top right the color of the suit was placed; Blue, Green, Red and Yellow.

After the deck has been shuffled, each player gets 7 cards drawn from the top of the deck. The cards given to the child are placed on the screen and now the child has the option to re-arrange the cards in any way he wants. This solution has been chosen over, pre-sorting the cards, because it will give the child more control over his game, this has been discussed in 3.2.2.2.

A child can give a card away by dragging a card over the dashed line. To make sure that the child cannot give away the wrong cards, or does not do so by accident, the dragged card is checked against the requested card.

5.2.2 Visual representation of game and scenario flow

After the implementation of the game shell, a turn-based system needed to be implemented in Java. A graphical interface was created to be able to model the game flow and the scenario in an easy way. The graphical editor interface is a simple system designed to create various nodes which are connected by edges, see Figure 21.

Figure 21 Editor.
As can be seen, each node and edge has a name on it. This specifies what needs to be done, the node can represent the state of the user or the iCat and the edge represents a condition depending on which goes to the node.

![Diagram](image)

**Figure 22 Part of visualization.**

In Figure 22 an example of how the graphical visualization can be used in practice can be seen. At some point during a conversation the system may arrive at the “How are you” node. Here the iCat say: “How are you?” after taking into consideration the current expression or behavior of the iCat. After that two answer ‘types’ can be expected; Negative or Positive. These are defined as types because there are many ways to answer in a positive and negative way, positive for instance:

- Good
- I’m doing well
- I’m doing well, thank you
- Fine
- Great
- ...

Once a positive or a negative response has been given by the user, the corresponding node with it can be executed.

The node itself contains no actions in the graphical visualizer, it is used in a way to visualize the flow, code to do an action need to be written by the designer himself. For instance, when designing the game, when the child refutes a card, code needs to be attached to that node to inform the game implementation that the child refuted.

It is important to remember that a node needs to have a unique name; otherwise it is not possible to guarantee that the correct node is picked from the network. If the designer wishes to share the same code for another node, it is advised to add a number to the name of the other node; e.g. if the first node is “Set complete” then second would be “Set complete(2)”. 
5.2.2.1 Edges

In the case that multiple edges branch out from a node the edge chosen is based on the criteria defined per edge. If there is only one edge to take, the program waits for a certain amount specified in the scenario flow. This will be indicated by the keyword “wait” after which a number in millisecond can be placed.

For edges there are 4 keywords:

- Wait
- R for Recognize
  - TO for TimeOut which is used in combination with Recognize
- M for Method

Wait has already been explained. In Figure 22 an example of Recognize and TimeOut can be seen. When a “Positive” response has been recognized, the graphical visualization will flow from “How are you” to the “Good” node. If after 10 seconds still no answer has been given the system will go to “Time Out” and then move back (after 100 milliseconds waiting) to “How are you” where again after 10 seconds a time out can occur.

In Figure 23 an example of the use of methods can be seen. The numbers indicate the order in which they are checked or executed. So “M: 1 setComplete”, will first check if a positive result will come out of the check of “setComplete”. In the Java code a check needs to be written for “setComplete” to see if the iCat has a complete set, if so, it will return true and the system can go to the “Set complete” node. If the edge returns a false, the next edge will be tested, until one can be executed. In this case the second method is a wait, so if the iCat doesn’t have a complete set, he will directly ask for a next card.

![Diagram of multiple edges](image)

Figure 23 Example of multiple edges.

5.2.2.2 Implementation

The visualized graph will be stored by the editor in an XML file with all the information. The editor can read and write XML files. For easy access, a package has been developed which can just use the graph by indicating what xml file to open. The precise information about this XML layout has been moved to the appendix, see [reference].
5.2.3 Turn-based Java implementation
Using the system developed in the previous section, a turn-based game development can be done now. Here the actual flow of the scenario and the game is developed and code behind each node and edge is developed.

In Figure 24 the latest version of the GUI for a complete implementation of an ego-reactive iCat can be seen. In the game part of the visual representation behind each node, code has been written to communicate with the game. For instance in the node “Set complete” the system communicated with the Go Fish game to find out if the iCat has a complete set. Also after a player has requested a card, it is checked if the iCat has this card, this can be found on the edge “M: giveAwayCard”, this method checks with the Go Fish game if the iCat has the requested card, if this is the case, the card will be given away in the node “Give away card” and the child gets another turn to request a card.
5.2.4 GOAL turned-based implementation
Initially, the idea was to have a goal-based system driving the turn-based game. However, this introduced unnecessary complications and thus the turn-based game that was implemented earlier in Java was rewritten in GOAL. The game scenario developed in the turn-based Java implementation was kept used as a model to make the goal based implementation.

Like in the Java system, a sort of finite-state machine was developed, but then with beliefs as a nodes. This gave more flexibility then the implementation in Java, because it was now possible to immediately jump to a belief which falls outside the normal flow of a game. When a child indicates he has a complete set, the goal based system can, after completing the current behavior action, jump to the belief of that “child has a complete set”. This proved to be much more stable and flexible.

5.2.5 Sentences database
After the creation of a representation of the turn-based game and implementing it in GOAL, the next step was to find a way for the iCat to be able to talk to the child about the game and about the scenario. To enable this, a sentence database was developed with different sentences for different events in the game. It was important to have multiple sentences per event, otherwise the iCats will be seen as very static and robot like.

The database is split into two parts, the first part is about the sentences that can be said by an iCat during the game and the other part is about sentences the iCats say when they are not playing a game of Go Fish. For the first part, per game event, different sentences have been developed. When the iCat gives a card away he will say something like: “Here you go”, and two other sentences like this have been developed in Dutch.

The second part of the database is concerned about the scenario in which Go Fish was placed. This consists of three parts. In the first part, both iCats introduce themselves and ask the child for his name. This will break the ice a bit and will familiarize children that they are allowed and can talk with the iCats. After the child has said his name, one of the iCats will tell him he has a very beautiful name. The iCats also explain that they only have domain knowledge about Go Fish (in a way children understand). Now the child is asked to fill in a questionnaire.

For the socio-cognitive iCat, additional sentences have been developed that display intentional behavior for the first part. These sentences concern events like, cheering the child up by saying, for example “Next time I am sure you will get a set!” and giving hints about cards: “If I were you I would ask for a different card!”. However, it has been kept in mind that the main research is on natural interaction, and excessive focus on sentence development might mean that the child would prefer one iCat over the other, mainly based on the number of sentences that one of the iCats uses. For this reason, extra sentences for the socio-cognitive iCat, as compared to the ego-reactive iCat, have been kept to a minimum.

When the iCats are switching, the child is asked if he enjoyed his time with the first iCat and if he can fill in questionnaire 2, after which the second game is started. Finally, both games have finished and the child is asked to fill in questionnaire 3 after which the experiment is finished.
5.2.6 Behavior and Emotion system
So far the iCat has not shown any behavior yet or shown any emotions; this will be the next step. For both iCats a standard behavior system has been developed. Both iCats can be addressed directly, by retrieving the ego-reactive or socio-cognitive iCat, or by asking the system who’s currently the main iCat. This last option was particularly useful during the game, where only the current iCat has actions; the other iCat is sleeping (see 6.2.2 for experiment details).

In the behavior system, there are 3 modes:

- Sleeping
- Idling
- Active

To represent sleeping the standard animation in the iCat package was found suitable enough. This makes the iCat nod slightly with his head, but makes no sound. Sleeping is the state the iCat is in when connected to the system, this way when the children enter the experiment they see two iCats sleeping. Sleeping is also done during the game when the other iCat is playing a game. This will make the iCat not seem unnatural in his behavior, because he is “just sleeping”. When the iCat “wakes up”, a standard animation is shown again. It will then enter idle state.

In the idle state the iCat does nothing for 5 seconds, after that he will blink and starts to look around. This is to represent a sort of natural behavior; looking around, taking in the room, trying to find out what is there. Mostly this behavior will be cut-off after 5 seconds, because during the game, the iCat would wait 10 seconds before asking the same question again.

Finally there is the active state, this will handle the behavior of the iCat when something active needs to be done. The system knows various active events:

**Looking at cards**, this will emulate the behavior when somebody looks at his cards trying to find out if he has a card or if he wants to request a card

**Looking at the user**, the iCat cannot actually look at the user, but because this is an important part, the iCats have been placed in such a way that they face the user. The height of the child is estimated beforehand, so the iCat will look at the correct height.

**Showing emotions and/or speech**; the system will make sure that first the sentence is said and then the corresponding emotion. The iCat comes with lip-sync software, but it is not possible to give a mood to this, so it will always end with a smile. The system will make sure to overrule this problem by forcing an emotion to be shown immediately after a speech event is finished. The speech is generated by a text-to-speech system called Fluency (see 5.3.2.2), which can generate Dutch speech from text. When there is no speech indicated, the system will show the emotion immediately.

The emotion system used is analogous to the one explained in 4.4.2. In short a valence value is generated based on a game event, for instance when the iCat has to given a card away this results in a valence value of -70 (see Table 1).
The valence value is passed on to the behavior system, where the current mood is added to the valence value. This will result in a new value which can be displayed on the iCat. In Figure 18 three values can be observed, from left to right: 100, 0 and -100.

After the emotion has been displayed, a new mood is calculated. The value generated by the game event is used to update the mood. A history of 20 of these values is kept to determine the current mood by means of an exponential moving average (EMA). There is one disadvantage of using an EMA, important events get lost in the history, like winning a set. To combat this problem the score is used as a baseline for the mood (for more information see 4.4.2.2).

### 5.2.7 Intentional behavior

So far two ego-reactive iCats have been developed that can play Go Fish with the child, but now it is time to expand the behavior of one iCat with intentional behavior. This intentional behavior will be done in GOAL, and is analogous to the design in 4.5. In short, here it is determined when the socio-cognitive iCat will give hints or try to cheer up the child by saying something nice. The emotions can also be adapted, meaning that it can be made to display happier or more reserved emotions. The iCat can display more reserved emotions for instance when the child is unhappy and the iCat is winning, as it would seem mean of the iCat to be really happy or unhappy in this case. Thus the intentional behavior is based on 3 parts; the mood of the iCat, the mood of the child and the game score.

### 5.2.8 Mood detection

The intentional behavior is partly determined by the mood of the child. As was discussed in 4.4.1 there is no stable automated method yet for determining the mood of a child. To solve this problem a co-experimenter observes the mood of the child can indicate this by means of a GUI.

![Co-Experimenter view](image)

**Figure 25 Co-Experimenter view.**

The overview of the co-experimenter (Figure 25) was quite limited to keep instructions and learning curve quite simple. The co-experimenter also helped with gathering statistics, this included how often a child laughed, how much time a child talked with each iCat and how often a child looks at the iCat. All these functions can be observed in the GUI.
5.2.9 Centralized control system
To make all the connections between all parts one GUI is used for the main experimenter. Here all connections are made to the 2 iCats, one Go Fish game, one co-experimenter observation tool and the GOAL turn-based game. The GUI can be observed in Figure 26.

![GOAL GUI](image)

Figure 26 GOAL GUI.

The first thing that can be observed is the much less complex look of the visual representation. The difference with the previous version is that with this implementation the whole game layout has been moved to the GOAL system. This turned out to be more flexible and suited to implement the game in.

For this implementation the visual representation is only used for the really fixed parts. These are the introduction when both iCats introduce themselves and ask if the child can fill in a questionnaire. Then when the child has played his first game against one of the iCats, the overview will change again to show the intermediate part and finally after playing against both iCats a final overview will be presented.
As compared to the previous interface a lot more buttons can be observed. During the pilot it was found out that some extra functionality was needed that could arise at any moment during the game.

For instance, it is now possible to quit, gracefully, during a game and also when there’s not enough time to round off the experiment it can now be quitted.

5.3  **Additional software packages**

During the implementation phase and the prototyping phase where it was determined which software should be used for the final implementation, various packages have been tested. In this chapter all the software that was researched or used is discussed.

Here a list of all the software that was used for the experiment is summed up:

- Java Power Tools
- JGraph
- JGraphT
- Fluency

5.3.1  **Open source packages**

5.3.1.1  **Java Power Tools**

As taken from their own website: “The Java Power Tools enable the rapid development of Java graphical user interfaces”. This package has been used in the Game side to handle the behavior of the cards. The dragging and dropping and how to access those, are all handles by this package. [40]

5.3.1.2  **JGraph**

JGraph is a fully functional package for handling and showing graphs. This can be seen in Oz GUI, where the whole graph is represented with this package. [41]

5.3.1.3  **JGraphT**

JGraphT is an extension of JGraph which lies “on top” of it. The advantage is that the methods for accessing Vertexes and Nodes are much clearer defined and can be generalized via Java 5. Another advantage is that it’s much easier to create directed graphs. [42]

5.3.1.4  **OpenCV**

OpenCV is a library of programming functions mainly aimed at real time computer vision. It can detect and find faces in real-time from a video stream using out-of the box functionality [43]. This is used by the tool developed by TNO to make the iCat look at the user.

5.3.2  **Commercial packages**

5.3.2.1  **FaceReader**

The FaceReader is commercial software developed by Noldus Information Technology BV. It is a tool that is capable of automatically analyzing facial expressions and providing users with an objective assessment of a person’s emotion. This can be done either real-time or afterwards by analyzing video. [44]
5.3.2.2 Fluency

Fluency is a text-to-speech synthesizer for Dutch speech. This software is compatible with the software of the iCat, so the generated speech will also make the iCat lip-sync the speech [45]. The problem with this software was that all sentences needed to be timed beforehand, because it was unknown when the iCat would finish with a sentence and could continue on with his other behavior.
Evaluation

For this research two iCats have been developed, one being a socio-cognitive iCat with the ability to base his behavior on the mood and the score of the game, and the other an ego-reactive iCat which bases his behavior completely on the game. To determine if humans will attribute more intentional behavior to the socio-cognitive iCat, a research question has been formulated:

\[
H_1: \text{The behavior of the socio-cognitive iCat is evaluated to be better than that of the ego-reactive iCat.}
\]

To determine the answer of this research question, an experiment has been set up and the results have been evaluated. To confirm or refute hypothesis H1, various sub-hypotheses will be discussed in section 6.1.

In section 6.2 the method of the experiment will be discussed, which includes a detailed overview of the experiment setup, the dependent, independent and control variables, the questionnaire used and the precise procedure of the experiment.

The statistical results of the experiment and the result of H1 will be presented in section 6.3.

In section 6.4 the statistical conclusions and observations of the experiment will be discussed.

Finally, this chapter will be rounded off with a conclusion.

6.1 Background of hypothesis

To determine whether the main hypothesis H1 can be confirmed or refuted eight sub-hypotheses have been developed to test it. The background and the reason for each hypothesis are explained in this
section, and the way each of them was measured can be found in 6.2.3. This section has been split into three categories; child opinion, child emotion expressed and child communication.

6.1.1 Child opinion
These hypotheses try to determine the opinion of the child about four subjects: friendliness, losing capability, fun and honest playing.

How friendly the children found each iCat
The hypothesis is that the socio-cognitive robot will probably be seen as a friendlier robot in comparison to the ego-reactive one. The ego-reactive robot does not respond to the mood of the child at all, while the empathetic one does. Additionally, the empathetic robot gives hints and even asks if the child is still having a good time if he’s unhappy.

How well each iCat handles losing
The hypothesis is that the ego-reactive robot should handle losing a lot worse than the socio-cognitive robot. When the ego-reactive robot is losing it gets a really negative mood and expresses this. Meanwhile, the empathetic robot might take losing better, depending again upon how the child reacts.

How much fun it was to play with each iCat
The hypothesis is that the socio-cognitive iCat should be more fun to play with than the reactive one, because it tries to help the child out and tries to cheer him up.

How “fair” they thought each one played
Considering both iCats have the same strategy, the hypothesis is that the children should not notice too much difference. However, because the socio-cognitive iCat makes mistakes on purpose and gives hints, the child might be able to notice this and point this out.

6.1.2 Child emotion expressed
The expressed emotion can determine if the observations match the opinion of the child or, as mentioned in previous research, if the ceiling effect is observed in the questionnaires, then these two observations together can be used to distinguish effect from non-effect.

Observed mood
It is expected that because the socio-cognitive iCat tries to be happier, give hints and behaves friendlier overall than the ego-reactive iCat, the observed mood and arousal will be higher with the socio-cognitive iCat than with the ego-reactive iCat.

How often does the child laugh with each iCat
The ego-reactive iCat does not care at all about the mood of the child. Hence it is expected that a more empathetic iCat will make the child laugh more often.

6.1.3 Child communication
The communication part can also help to see if there is a difference between the two iCats. This part is concerned with how much a child talks with an iCat, and how often the child looks at each iCat.
How long does the child talk with each iCat
Again the ego-reactive iCat will only ask for a certain card and not change his behavior in any way. This probably doesn’t spark much interest in the child. On the other hand, a more adaptive iCat should spark the child’s interest and the child might talk to him more number of times.

Looking behavior
It is expected that a child will look more often at the socio-cognitive iCat than at the ego-reactive iCat, because first of all the socio-cognitive iCat will say additional things than the reactive iCat. This might already attract the attention of the child. Secondly, because this iCat might be liked better, children might also give it more attention by looking at it more often.

6.2 Method
In this section, the complete setup of the experiment and the methods used to obtain the hypotheses in section 6.1 are discussed.

6.2.1 Participants
For the experiment a primary school, “De Zuidwester”, located in The Hague participated. About a week before the experiment, the experimenter went by six classes from “groep” 6 to 8 (the final three classes of primary school). In each class, the experiment was shortly explained and it was also explained that participants were needed for the experiment. In all classes this resulted in ecstatic behavior and children needed to be picked by lottery. Thirty-six possible volunteers received a letter of consent for the parents, and in the end 27 children returned with the consent form filled in.

For the experiment, 24 children took part from which the data of 20 of them was deemed usable. Four results were not usable; three due to software errors and one because the experiment had to be terminated early because the experiment took longer than the time allocated.

The 20 participants were aged 9-13 (Median age = 11, SD = 1). They were awarded with a small present (eraser, sticker, etc) and a photo of the participant with the 2 iCats for taking part in the experiment, which lasted about 30 minutes.

6.2.2 Design
A within-subjects design was employed in which children played a game with 2 different iCats. A within-subjects design is an experiment in which the same group of subjects serves in more than one treatment, and so in this case, a child will play against both iCats. On the other hand a between-subjects design, for which each treatment has its own group of subjects, would mean that each child played only against one of the two iCats. In [46] the advantages and disadvantages of within-subject design are discussed and they will be presented here shortly.

Advantage within-subject
Power: A fundamental inferential statistics principle is that, as the number of subjects’ increases, statistical power increases, and the probability of beta error decreases (the probability of not finding an effect when one "truly" exists). The reason this is so relevant to the within subjects design is that, by using a within-subjects design you have in effect increased the number of "subjects" relative to a
between subjects design. This results in double the amount of “subjects” as compared to a between-subjects design, with equal group sizes.

Violation of assumption: The reduction in error variance is due to the fact that much of the error variance in a between-subjects’ design is due to the fact that, even though you randomly assigned subjects to groups, the two groups may differ with regard to important individual difference factors that affect the dependent variable. With within-subjects designs, the conditions are always exactly equivalent with respect to individual difference variables since the participants are the same in the different conditions.

Disadvantage of within-subject
The fundamental disadvantage of within-subject is referred to as “carryover effects.” In general, this means the participation in one condition may affect performance in other conditions, thus creating a confounding extraneous variable that varies with the independent variable. Two basic types of carryover effects are practice and fatigue.

When a within-subjects treatment negatively affects performance on a later treatment this is referred to as a fatigue effect. On the other hand when a within-subjects treatment positively affects performance on a later treatment this is referred to as a practice effect. The practice effect that can occur during this experiment is that after playing one game of Go Fish against the iCat, the child will have a better understanding of how the game works and will play a lot better. Because the child is playing better during the second game, his chance of winning might increase and thus also his enjoyment for the second game.

Luckily these negative effects can be greatly overcome by, for each child doing the experiment, letting half of them play with the ego-reactive and then the socio-cognitive iCat and the remaining half play first with the socio-cognitive and then with the ego-reactive. This way the fatigue and practice effects will affect the game played with each iCat in equal measure and so should not influence the results too much.
6.2.3 Experiment Setup

The child saw the game of Go Fish in front of him on a pc monitor. He used the mouse to make game moves, and had to request cards and other relevant game events by speech. Facing the child are two iCats, and since they looked exactly the same, each of them had a name-tag with its name on it, in order to differentiate one from the other.

During the experiment an Asus EEE laptop was available, which was placed in front of the iCat that was playing Go Fish. This laptop was used to make it seem as if the iCat was looking at the game on it, and so that the iCat could also pretend to look through his cards. The angle of the iCat’s laptop screen was such that the child could not look at it. Also, the iCat was placed behind the screen where the child was sitting, so that he faced the child. This ensured that they could not see each other’s screens.

The entire experiment was recorded on video for accountability and for statistical analysis purposes. A webcam was placed on top of the screen of the child. During the experiment itself the experimenter observed and checked whether the experiment was going well and that nothing was going wrong.

The experiment was done at the school itself. Initially the plan was to have the child and the experimenter in two different rooms. Due to space limitations the whole experiment was done in one room. This gave the advantage that the children were acquainted with the space. In order to give some privacy both to the child and the experimenters they were separated by a screen and the child had his/her back to the screen. The experimenters determined the mood of the child and recognized speech; all the other events were handled autonomously. Also some statistics were collected during the experiment itself.
### 6.2.3.1 Dependent variables

The dependent variables are the observed effects of the experiment. In total seventeen dependent variables were used, these can be observed in Table 2. The first three categories are explained in 6.1. The fourth category used in this table is the generic category. This is concerned with some generic things, like “who do children like best when they have to chose”, but also who won the game.

All the questions from the questionnaire are asked on a 5 point Likert scale, unless otherwise specified. The questionnaire used can be found in Appendix B.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Child opinion</strong></td>
<td></td>
</tr>
<tr>
<td>Friendliness</td>
<td>Questionnaire 2, question 1 and Questionnaire 3, question 1</td>
</tr>
<tr>
<td>Losing capability</td>
<td>Questionnaire 2, question 2 and Questionnaire 3, question 2</td>
</tr>
<tr>
<td>Fun</td>
<td>Questionnaire 2, question 3 and Questionnaire 3, question 3</td>
</tr>
<tr>
<td>Honest playing</td>
<td>Questionnaire 2, question 4 and Questionnaire 3, question 4</td>
</tr>
<tr>
<td><strong>Child emotion expressed</strong></td>
<td></td>
</tr>
<tr>
<td>Observed Valence</td>
<td>After the experiments have been finished one co-experiment who was not involved in the experiment yet will look at the videos and give a valence rating for each child and each iCat. A manikin test will be used, the scale used can be found in Figure 30 (in the Appendix).</td>
</tr>
<tr>
<td>Observed Arousal</td>
<td>To determine the arousal of the child, the same principle as the valence method will be used, but now the bottom second 9 point scale will be used.</td>
</tr>
<tr>
<td>Laughing events</td>
<td>Counted by the co-observer. Only laughing with sound was counted.</td>
</tr>
<tr>
<td><strong>Child communication</strong></td>
<td></td>
</tr>
<tr>
<td>Talking time</td>
<td>The time a child was talking to each iCat was recorded by a stopwatch application.</td>
</tr>
<tr>
<td>Looking behavior</td>
<td>The co-experimenter keeps track of each time the child looks at the iCat.</td>
</tr>
<tr>
<td><strong>Generic</strong></td>
<td></td>
</tr>
<tr>
<td>Expected fun</td>
<td>Before playing a game of Go Fish Questionnaire 1, question 5 was used. And after the child has played with both iCats Questionnaire 3, question 5 was used.</td>
</tr>
<tr>
<td>How entertaining is Go Fish with children</td>
<td>Questionnaire 1, question 6.</td>
</tr>
<tr>
<td>How positive is the child about the iCat</td>
<td>Questionnaire 1, question 3.</td>
</tr>
<tr>
<td>Who won the game</td>
<td>This is determined by who won.</td>
</tr>
<tr>
<td>Child winning time</td>
<td>This is based on the score, so for instance when it’s 2-1 for the iCat, the iCat is winning. The time the child was winning is divided by the total game time, which will result in a percentage of time that the child was winning.</td>
</tr>
<tr>
<td>iCat winning time</td>
<td>Same as previous method, except that here the time the iCat is winning is divided by the total time.</td>
</tr>
<tr>
<td>iCat preference</td>
<td>Questionnaire 3, question 6.</td>
</tr>
<tr>
<td>Preference explanation</td>
<td>Open-question; Questionnaire 3, 7</td>
</tr>
</tbody>
</table>

Table 2 The first column indicates the name of the dependent variable and the second column how to measure it.
6.2.3.2 Independent variable
For this research there is one independent variable which will be changed between the iCats:

*How social or intentional does the iCat behave.*

In short this will be determined by three parts:
- Emotion expression
- Game play
  - Giving hints
  - Make mistakes
- Sentences (e.g. cheer up)

6.2.3.3 Control variables
The control variables are the variables that are not changed throughout the trials of the experiment, so as to minimize their effect on the outcome per experiment.

<table>
<thead>
<tr>
<th>Control variable</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child</td>
<td>The same child will play a game of Go Fish with both iCats.</td>
</tr>
<tr>
<td>Robot</td>
<td>Apart from their name-tags, both the robots used have the same physical appearance.</td>
</tr>
<tr>
<td>Game</td>
<td>The game used to play with is the same Go Fish game.</td>
</tr>
<tr>
<td>Strategy</td>
<td>Both iCats use the same strategy to determine which card to ask.</td>
</tr>
<tr>
<td>Environment</td>
<td>During the experiment the location is not changed.</td>
</tr>
<tr>
<td>Questionnaire</td>
<td>For both iCats the same questions are asked in a questionnaire.</td>
</tr>
<tr>
<td>Expressions</td>
<td>Both iCats have the same range of expressions.</td>
</tr>
<tr>
<td>Speech</td>
<td>The same voice of the Fluency Text-to-Speech is used.</td>
</tr>
<tr>
<td>Mood calculation of the iCat</td>
<td>To calculate the mood, the same calculation is used.</td>
</tr>
<tr>
<td>Emotion table</td>
<td>Both iCats use the same table to determine the base valence. This valence is determined by the game event, so, for instance, when either iCat has to give a card away, a valence of -80 is shown.</td>
</tr>
</tbody>
</table>

Table 3 The name of the control variable can be seen in the first column, the explanation of it can be found in the second column.

6.2.3.4 Questionnaire
As shown with the dependent variables (6.2.3.1), a lot is dependent on the result of the questionnaire. The questionnaire is partly the same as the questionnaire used by de Lange, especially the first page of the questionnaire but the rest of the questionnaire was designed by the author. The questionnaire has been checked by various people who have experience with questionnaires to ensure its validity.

The questions have been made in such a way that children will understand them; a simple form of Dutch has been used and the questionnaire has been kept short so that it will be able to keep the children’s attention while filling in the questionnaire.

6.2.4 Pilot
To determine the progress and if any problems occur during the experiment, various pilots have been done on various students. Each of the pilots was tested by one of the students of the Media and Knowledge Engineering department who was present in the same lab. Their input has helped a lot in
determining the behavior of the iCat, in terms of what they thought of the sentences said, of the intentional behavior and in order to find bugs.

Results of each specific pilot test are not interesting to mention, but feedback over the following issues that have already been explained in this report, has been used to improve the system for the actual experiment:

- Game play, strategy
- Sentences
- Emotion generation
- Behavior of the iCat
- Automated looking behavior
- Automated emotion/mood recognition

6.2.5 Procedure
Participants were picked up from their class by the co-experimenter. The teacher already knew at what time approximately to expect the co-experimenter to come by and would point out which child participant was up next. The participant would then come along to the handicraft room where the experiment was setup. The iCats had already been put into a sleep mode.

In the room the participant was greeted by the main experimenter and directed to his seat. First, it was explained that he would play a game of Go Fish against each iCat. The screen on which Go Fish was displayed is explained and that the iCat has his own screen to watch Go Fish on. He was also told that the experimenters were sitting behind him, but only to observe if things go well, not to control the iCats in any way.

The participant was then asked if he was acquainted with the rules of Go Fish. Depending on the answer more or less time was spent on explaining the rules. The interface and how to use the mouse to control the game was explained. Mostly it was stressed that it is a good idea to sort the cards during the game so it is clear which cards you already own. This seemed to help the children make fewer mistakes during the game. Also, a piece of paper was put near the screen which showed which colors a complete set consisted of and one of the most important rules that you are only allowed to ask for a card of a rank if you have another card of that particular rank, see “Voorbeeld complete set” in the Appendix.

The questionnaire was also briefly discussed to see if there were any words they didn’t understand and to explain that they are 3 different questionnaires. Some children seemed to have difficulty with that.

Finally, any last questions the child had were answered, and he was told the iCats would now wake up and introduce themselves. After this short introduction part, the iCat would play his first game with the child and ask him to fill in questionnaire 1, while the other iCat went back to a sleeping mode. When the participant indicated he was finished with the questionnaire, the game started.

After about 10 minutes the first game of Go Fish resulted in a winner. The iCat then asked if he had a good time playing the game, and then went to a sleep mode. The other iCat then woke up. He will then
ask the participant to fill in questionnaire 2. In the mean time the experimenter will place the laptop in front of the iCat who is going to play now. When the participant indicated that he has finished filling in the questionnaire, the next game will start.

After about 10 minutes again, the game is finished. The iCat will ask if the participant can fill in the last questionnaire 3 and afterwards will wake up the other iCat so a photo of the two iCats and the participant can be taken. The experimenter now answers any remaining questions asked by the child. The child is also given the opportunity to take a present and then leaves.

- Pre test (4)
  - Instructions (4)
- Session 1 (15)
  - iCats introduce themselves (2)
  - Questionnaire A (4)
  - Play against one of the iCats (9)
- Intermezzo (2)
  - Switch iCat player (1)
  - Questionnaire B (1)
- Session 2 (12)
  - Play against the other iCat (9)
  - Questionnaire 3 (3)
- Round off (2)
  - Child takes a photo with both iCats (1)
  - Answer questions (1)

Figure 28 Experiment procedure. The number between parentheses indicates the estimated amount of time in minutes that each child spends on that specific item.

The numbers totals to about 35 minutes, this estimation is quite correct considering that during the experiment most experiments were finished within 30 minutes.

6.2.6 Materials

The software developed in chapter 5 and the experiment itself had various material requirements. On the participants side, the materials consists of two iCats. A laptop, which is connected to one of the iCats with the following software: fluency 4 for the text generation, OPPR required to run the basic iCat, the i3CDModule for the communication between Java and the OPPR, Java6 for the game and the Java game developed as part of this research. Another laptop is connected to the other iCat with the following software; Fluency 4, OPPR and i3CDModule. To view the game, a 19” monitor (1280x1024) was used on which a webcam was placed.

On the experimenter side the materials consisted out of a laptop with Java6 and the HelperGUI for the co-experimenter. A second laptop was dedicated to recording and showing the video from the webcam. Lastly, a pc with Java6, GOAL and the Goal-GUI for the experimenter was used.
All communication was done over a wired network, a switch and various network cables were needed to connect them.

### 6.2.7 Statistical analysis

To determine the results, various statistical tools have been used. For ordinal data, the questionnaires and the observed valence and arousal, the Wilcoxon Signed Rank test was used. To determine the significance for interval data, a Paired-Samples T Test was used. To check for correlation a chi-square test was used.

The goal of this research is to determine if the socio-cognitive iCat will be evaluated better than the ego-reactive iCat, for this reason one-tailed significance will be measured. For the results the following terminology will be used: trends have a significance lower than 0.10 and significant results have a significance lower than 0.05.

### 6.3 Results

Here the results of the experiment will be discussed. In Appendix C a complete overview of all data collected can be found, here the statistics can be found.

The table with overview of the results of the statistical tests has been split into two tables. In Table 4 the results of the Wilcoxon Signed Rank tests can be found and in Table 5 the results of the paired t-tests, for both tables in the caption a description can be found what each column contains.

<table>
<thead>
<tr>
<th>Dependent</th>
<th>Ego</th>
<th>Socio</th>
<th>Neg. Rank</th>
<th>Pos. Rank</th>
<th>Ties</th>
<th>Sig (1-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friendliness</td>
<td>4.50</td>
<td>4.50</td>
<td>4</td>
<td>4</td>
<td>12</td>
<td>1.000</td>
</tr>
<tr>
<td>Losing capability</td>
<td>4.50</td>
<td>4.30</td>
<td>5</td>
<td>2</td>
<td>13</td>
<td>0.412</td>
</tr>
<tr>
<td>Fun</td>
<td>4.60</td>
<td>4.75</td>
<td>1</td>
<td>3</td>
<td>16</td>
<td>0.129</td>
</tr>
<tr>
<td>Honesty</td>
<td>4.60</td>
<td>4.60</td>
<td>4</td>
<td>4</td>
<td>12</td>
<td>1.000</td>
</tr>
<tr>
<td>Observed Valence</td>
<td>5.25</td>
<td>5.90</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>0.028</td>
</tr>
<tr>
<td>Observed Arousal</td>
<td>5.10</td>
<td>5.45</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>0.090</td>
</tr>
</tbody>
</table>

**Table 4 Overview of the Wilcoxon statistics.** The first column contains the same dependent variables as seen in Table 2. The second and third columns show the mean for each dependent variable of the ego-reactive and socio-cognitive iCat respectively. The Neg. Rank means that the ego-reactive iCat was rated higher than the socio-cognitive iCat, and a Positive Rank means vice versa. Ties indicates when a child has given the same rating. The last column indicates the significance.

<table>
<thead>
<tr>
<th>Dependent</th>
<th>Ego-reactive (SD)</th>
<th>Socio-Cognitive (SD)</th>
<th>Sig (1-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laughing</td>
<td>.30 (.801)</td>
<td>.70 (1.593)</td>
<td>.060</td>
</tr>
<tr>
<td>Talking time</td>
<td>34.7 (11.4)</td>
<td>36.3 (10.9)</td>
<td>.164</td>
</tr>
<tr>
<td>Looking behavior</td>
<td>20.30 (13.6)</td>
<td>26.45 (11.5)</td>
<td>.037</td>
</tr>
<tr>
<td>Child winning time</td>
<td>13.0 (19.0)</td>
<td>23.3 (20.2)</td>
<td>.027</td>
</tr>
<tr>
<td>iCat winning time</td>
<td>31.4 (23.3)</td>
<td>25.9 (25.6)</td>
<td>.199</td>
</tr>
</tbody>
</table>

**Table 5 Overview of the T-test statistics.** The first column contains the same dependent variables as seen in Table 2. The second column shows the mean and the standard deviation, between brackets, of the Ego-reactive iCat, the third column of the socio-cognitive. The significance can be seen in the last column.
6.3.1 Child opinion
The first four rows show the opinion of the iCat as tested by a questionnaire. A clear ceiling effect can be observed, all ratings are very high (5 point Likert) and twice even there is no significance at all. This might seem odd, but the results have been double checked and it just happened that the same distribution occurred for these two. Because there are no significant results or trends to be observed, there are no conclusions drawn from this.

6.3.2 Child emotion expression
Here two trends and a significant result can be observed. The most interesting is that the expressed valence of the child with the socio-cognitive iCat is significantly higher than with the ego-reactive. This is a clear indication that there is already evidence to support that the socio-cognitive iCat is evaluated better than the ego-reactive. Although children did not mention it in their questionnaire, or it was not clear due to a ceiling effect, they did enjoy the experience much more when looking at their expressed happiness. On a more subconscious level children did pick up that the socio-cognitive iCat tried to be more friends or friendlier at least than the ego-reactive iCat.

There seems to be a trend in how aroused a child was with the iCats. This could be explained that children get more aroused because they have more chance of having the upper hand during the game, which makes it more excited (see also Child winning time in 6.3.4).

Finally the amount of time a child laughed with each iCat has been deemed significant, although a note should be placed with this one, because the general amount of laughing is very low and when looking at the results a huge outlier can be found for the socio-cognitive iCat which probably explains the difference.

6.3.3 Child communication
There is not much difference in how much time the children talk to each iCat. This is explainable because practically all of the speech the children said is related to the game. Because the game does not differ, the amount of talk time probably shouldn’t differentiate too much.

Looking behavior is significantly different. Children look more often at the socio-cognitive iCat than at the ego-reactive iCat. The co-experimenter who observed the children during the experiment mentioned that children seem to look more often at the iCat if they are happier. When placing these results next to the observed valence this does seem to be the case, but when doing actual analysis on it, the results are inconclusive and this statement cannot be confirmed. Perhaps with more research the correlation between could be made clearer.

6.3.4 Generic
The hint system seems to have done its job well, because thanks to the hints there is a significant difference in the percentage of the total game time that the child is having the upper hand. This will probably have a serious contribution to making a game more fun, taking the fair assumption that winning time is related to game pleasure.
Probably the iCat has to accept a little less winning time because he gave some hints, but this is not a significant difference, so the hint system is not so drastic that the iCat would even give up his own winning streak to make the child happy again.

It is interesting to see that there is a trend in the expected fun. Children rated, on a five-point Likert scale, how much fun they expected playing with both the iCats would be and afterwards how much fun it actually was. The average before was 4.45 (SD=.605) and afterwards 4.70 (SD=.657). The significance is .096 which indicates that there is trend in the expected fun. This result is surprising because the mean of the observed valence is not that high, but care should be taken with interpreting this result, because again a clear ceiling effect can be observed here.

### 6.3.5 Difference in behavior

In Table 6 an overview can be seen of what behaviors the socio-cognitive iCat expressed per child. An explanation of the three types of intentional behavior displayed can be found in 4.5. As can be seen in the table, while playing against some children none of these behaviors have been displayed by the iCat. This does not imply there was no intentional behavior at all, considering the expression of emotion could also have differed. On an average, the intentional iCat tried 0.55 times to lose a set, gave 2.05 hints and 1.2 cheer-ups per child as opposed to the ego-reactive iCat which gave none of these.

<table>
<thead>
<tr>
<th>Lose a set</th>
<th>Hint given</th>
<th>Cheered up</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 6 An overview of how often the socio-cognitive iCat made a stupid move, give hints and cheered up. Each row is a different child.
In Table 6 it can be observed that there was a child who got nine “cheer ups”. This child first played against the ego-reactive iCat and won and then played a game against the socio-cognitive iCat and lost. During this game he looked unhappy and was losing, thus he received a lot of cheers. From the observed valence it can be determined that this seemed to have helped, because for this child the observed valence was higher for the socio-cognitive iCat, although he did lose.

In the last row, a child can be observed who received 7 hints from the socio-cognitive iCat. He did lose in the end, but again it can be observed that his valence was higher than with the ego-reactive iCat. The number of hints a child receives turned out to be too random and this problem is also discussed in 6.4.2.

The event of losing a set didn’t occur very often with anyone, thus it will be difficult to determine if this has an effect or not on their mood. None of the children mentioned that the iCat made a stupid move. Apparently it was not that obvious for the children, but the children did manage to receive a complete set due to this fact.

### 6.3.6 Challenges of Go Fish

A challenge of collecting empirical data, which was confirmed by children in the questionnaire, is that they liked one iCat better because they won from him. In Table 7 an overview can be found of whom children indicated which iCat they liked best versus who won while playing against the socio-cognitive iCat. To clarify the table a bit; the rows indicate which iCat they liked best, so for instance, in the last column it can be seen that 8 children liked the ego-reactive robot the best and 10 liked the socio-cognitive iCat the best. The column indicates who won when playing a game against the socio-cognitive iCat. So there was one child who won from the socio-cognitive iCat but still preferred the ego-reactive. When a chi-squared test is used the two sided Asymptotic Significance gives a value of .017 which indicates there is a high correlation. Thus one should watch out with asking children which iCat they like best when playing a game of Go Fish, considering winning plays a major factor in liking an iCat.

<table>
<thead>
<tr>
<th>Crosstab Count</th>
<th>Who won against the socio-cognitive iCat?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Child</td>
</tr>
<tr>
<td>Which iCat do you like best?</td>
<td></td>
</tr>
<tr>
<td>Ego-reactive</td>
<td>1</td>
</tr>
<tr>
<td>Socio-Cognitive</td>
<td>7</td>
</tr>
<tr>
<td>Both</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 7 Overview of who the child liked best versus who won from the socio-cognitive iCat.
6.4 Discussion

During the experiment a lot of observations were made, which are deemed interesting enough to discuss here. Also improvements and errors are discussed in this section.

6.4.1 Observations

Child shows emotion after saying something

The co-observer mentioned that children showed an emotion after they had said something. It is an interesting observation because the iCat behaves in the same way, by first saying what he wants to say and then showing his emotion associated with his behavior. This could be a good indication of a successfully implemented method of showing emotions.

Some children start to talk like the iCat

During the experiment, it was interesting to see that some children, in a greater or a lesser degree, started to copy sentences the iCat said. Children started to ask cards in the same way, refute cards in the same way, etc. In reference [27] it is described that a mirror mechanism is used by humans in order to understand the meaning of actions done by others, their intentions and their emotions. Thus this mirroring of the iCats behavior by the children can be seen as them trying to understand the iCats’ actions and emotions. It is not known whether this mirroring is done more with one iCat than with the other, but this can perhaps be interpreted as a sign of observed intentional behavior by the children. Further research is needed to make a conclusive statement about this.

Children are very expressive

Probably not the most new finding about children, but it is good to emphasize again how expressive children are and that they clearly show in their behavior what kind of mood they are in. It is not hard for humans to determine whether they are enjoying themselves or not.

Children are very consistent with their speech

Children are told that they need to ask game related events to the iCat and also the iCats themselves specify that they have only been “taught” about playing a game of Go Fish. Children seem to understand that robots can have limited domain knowledge and do not ask other things to the iCat. This is a good indication that this process could be made completely independent as soon as good working mood and voice recognition software for children is available.

Interesting speech and behavior

Some interesting speech events by the child will be presented here:

“Good night”

One child said “Good night” to an iCat when it was going to sleep.

Cheater

A child accused the iCat of cheating; the iCat refuted a card the child asked, by which the child replied “You do have that one!”. Difficult to refute such a statement (also the iCat had none during the game).
“Why should I try another rank?”
When the child asked for a card the iCat didn’t have, he got the advice to try another rank. The child had his doubts and asked why. For this the iCat had no reply and after about 20 seconds the game just went on. It would be a good idea to implement a reply to something like this.

Goodbye
A child waved goodbye to the iCats when leaving the room.

“Can I touch them?”
A child showed signs of affection by wanting to touch them. At Philips the author had seen an interesting implementation to wake-up the iCat; by rubbing over the ears of the iCat. This is a good way to create affection for the iCat.

“Congratulations!”
When the iCat obtained his first set a child congratulated the iCat on obtaining his first set.

Nobody quitted earlier, although specifically mentioned
None of the 24 children that played a game wanted to quit earlier, which is partly surprising because at one point the experimenter was about to stop the experiment for one child who looked intrinsically unhappy. It was not canceled in the end because the game was almost over. What this result shows is that the game in combination with the iCat is interesting enough to keep the attention of children, and also that it does not evoke such strong emotions that children want to quit.

Chosen game was a good pick between too much fun and too less fun
The game of Go Fish was seen as a good pick for playing a game with children. The previous experimenters warned me against picking a game which is too much fun to play, because of the ceiling effect. The ceiling effect in the questionnaire still existed, but at least this was not because the game was too much fun to play.

Interesting comments by children
Here the comments made by the children, in the questionnaire, why they liked one iCat better than the other iCat will be discussed:

“I liked X better because I won from him”
This comment was quite commonly given by children, this could either indicate they didn’t notice the difference between the two iCats or that children have a high preference for the iCat they won from. In the statistics parts this correlation was also observed between winning from an iCat and liking best.

“The other iCat moved too much” and “The other iCat did not concentrate on playing the game”
Only two children gave this comment, but it would be a good idea to take a closer look at the idling behavior of the iCat. Especially because this was given by the child as a deciding factor in who he liked better.

“This iCat gives hints and helps out a bit”
Some children did notice that the socio-cognitive iCat tried to help them out and give some hints.
“This iCat was friendlier”
A child did notice that one iCat was friendlier in his facial expressions.

“I did not understand the other iCat so well”
After examining the video of this child playing against the iCats, it was found out that he had problems understanding the tips of the socio-cognitive iCat, like “Hint, try another type.”. This caused for some confusions.

6.4.2 Improvements

Gathering statistical information
For this research a questionnaire was used to gather the children’s opinions about the iCats. The problem is that, as with research from de Lange, the children give very high ratings on practically all questions, this is known as a ceiling effect.

Being able to repeat all sentences
It was not expected by the experimenter that children would have problems during the introduction mode and other outside game events, so there was no repeat mode implemented which would allow the iCat to repeat the questions or ask the question in other words. This caused for some awkward moments when the iCats asked “Do you feel like playing?” at which the child indicated that he did not understand him. At this point there was silence and the iCat assumed that the child had understood and went on with the rest of the scenario.

It is your turn
During testing it was indicated that it was not always clear whose turn it is, so to make this clear the iCat would always say “It is your turn” after the iCat had finished his turn. This worked excellent to get the children to get used to playing the game, but turned into a nuisance after a while when children understood the order of the game. The children would immediately ask for a card after the iCat was finished with his turn, but the iCat would just talk through the child while the child is talking.

Limited time problems
The experiment had to be done in quite a limited amount of time due to constraints from the school. Because Go Fish’s winner is also dependent on quite a bit of luck, half of the children won from the socio-cognitive iCat. This gives problems with seeing all of the behavior of the socio-cognitive iCat which is mostly aimed at showing behavior when the game is neutral or when the child is losing.

Questionnaire adaption
In the questionnaire there was no question asking if the children have played Go Fish before, because it was assumed that all children play or have played this game before. When explaining the game to children it became apparent that this was not the case and a learning effect could be observed while playing the game.

Another problem was that children got confused when they were asked which iCat they liked best. The names were placed in a fixed order and should have been placed in order of which iCat they played against. One questionnaire has been adapted by the experimenter to give the correct answer (based on
the comment of which iCat he liked better “the one who gives hints”) and one child had corrected it himself. It is unknown if this has caused for more incorrectly filled in questionnaires.

**Chance model**
The chance model had problems with calculating correct probabilities when the child asked a card he already owned. This has got to do with how the chance model works and assumed that the opponent does not ask a card already owned (one of the rules of the game). Still some children had problems with this and it should not give so many problems when asking for cards.

**Frequency of giving hints**
The socio-cognitive iCat should adapt his frequency of giving hints based on the flow of the game. During the experiment it was chosen to give hints based on a 50% chance of giving a hint. The problem with probabilities is that it can take a long time before the coin falls on the correct side and gives a hint. The hint system should be adapted to give more hints if the game goes worse for the child.

**Game sorting too complex**
A co-experimenter noticed that sorting the cards on the screen was too complex a task for some children. This would take up too much of their time, because each time they were asked a card or had to ask a card the child would search the screen to find the card or to find out which card to ask. Due to this, some children would barely look at the iCat because they were too busy looking only at the screen. A sorting system was specifically not implemented to keep children busy, perhaps an onscreen help could kick in to help children sort their cards if they don’t do it.

**iCat logging and recording**
During the experiment only video was recorded where the face and posture the child had could clearly be seen. This was needed for the experiment itself and was deemed to be the only necessary recordings. Afterwards it turned out that it would have been interesting to know how the iCat exactly behaved, did it express a happier mood and were there other, unexpected, behaviors. It is advised, that a video recording is made of the behavior of both the iCats and also that various events, like emotion expression, are logged to a file.

**6.4.3 Errors**
Only two real errors occurred during the experiment. Luckily both did not influence the experiment. The first error was that on the second day the videocard drivers of the laptop on which the child was playing a game got corrupted. In the morning it was observed that the game showed artifacts in the game, but it was not known what caused this and due to a time schedule this could not be solved then. During the break the problem was found and solved.

Another problem was that the video recordings of the second day contain no sound. The videos seem to have an audio track, but nothing can be heard on it. It is unknown why this happened as the other two days do contain sound. Luckily most observations were already made and written down during the experiment itself.
6.5 Conclusion

Based on the observations and results from the questionnaire, the experiment can be seen a success. The research question of this thesis can be confirmed based on the gathered results. The strongest evidence for this is that via a subjective measurement it was determined that children looked happier when playing against the socio-cognitive iCat than against the ego-reactive iCat. Another point which will help is that the children, on average, are having the upper hand during the game as much as the iCat does on average. It is also clear that the gaming experience was more positive with the socio-cognitive iCat as compared to the ego-reactive iCat.

There is still room for improvement for the intentional behavior of the socio-cognitive iCat. The iCat can have a better hints system and other intentional behavior should also be researched. Furthermore, it is important that a better questionnaire is developed for this research, so it will be easier to determine how children themselves rate the behavior of the iCats.
Conclusions and Future Work

Two robots have been developed which both have the capabilities to play Go Fish and interact with a child in an almost autonomous way. A platform has been developed that can be (re)used for research on socio-cognitive human-robot interaction. The experimental design is based on a Wizard-of-Oz setup since automatic speech and mood recognition is not yet able to provide the required functionality.

One of the goals of Human-Robotic Interaction research is to find out if cognitive robotics can enhance the anthropomorphic or intentional stance of humans towards a robot. To help solve this problem, the following hypothesis has been researched: The behavior of the socio-cognitive iCat is evaluated more positively than that of the ego-reactive iCat.

The experiment has been done with children, aged 9-13, playing a simple game of cards called “Kwartetten” in Dutch, similar to Go Fish. Child participants have been chosen, because recognition of their mood is much easier than the recognition of the mood of an adult. This is because children are more expressive of their emotions than adults. The scenario of Go Fish has been chosen, because playing a game is a familiar scenario for children and they are acquainted with playing this game.

To be able to play this game at a sufficient level of proficiency and in principle is able to win the game, a strategy has been developed. The strategy developed for the iCat was to ask for the cards which have the highest chance of being held by the child. For this an approximate chance model has been developed.

The socio-cognitive iCat behavior has been constructed in such a way that it gets affected by the state of the child and the score of the game, and derives his intentional behavior from these factors. For
instance, when the child looks unhappy and he is losing, the iCat starts to give hints. Another adaptation in this case involves the emotion expressed by the socio-cognitive iCat: the happiness expressed is reduced if he gains a card and he will reduce the expression of unhappiness if he needs to hand over a card.

The behavior repertoire of the socio-cognitive iCat is an extension of the behavior of the ego-reactive iCat. The ego-reactive iCat bases his interaction solely on his own emotion. So, if the ego-reactive iCat is happy because he acquired a lot of cards, he will express happiness, if he just lost a lot of cards he will express sadness. The mood of the child does not affect his state.

The behaviors of both the socio-cognitive iCat and the ego-reactive iCat have been implemented in GOAL. The flow of the game has also been implemented in GOAL; this is a separate part from the behavior of the iCats. Using this setup it is possible to also use a different game, or slightly different rules for the same game, and reuse the intentional behavior that has been implemented in GOAL. The only requirement is that the cognitive component has to be told who is winning and what the current mood of the child is.

### 7.1 Results and Discussion

The research question of this thesis has been confirmed. The most solid evidence that confirms the main hypothesis is based on observation of the children during the experiment; there was a significant difference between how happy the children appeared to be when they looked at each iCat. While playing with the socio-cognitive iCat, the children were smiling more and their overall mood was better than with the ego-reactive iCat.

The results suggest that children have relatively high expectations of the robot, but also indicate that after the experiment their expectations are more than met. At the start of the experiment, before playing with the iCat, children estimate their fun with the iCat to be 4.55 on average, on a 5 point scale. After playing two games with the two different iCats, children rated it to be a 4.70 average. These results indicate a trend, but when more research with additional children is performed I expect that a significant difference will be obtained.

Due to hints given to the children by the socio-cognitive iCat, the time that children have the winning hand is almost doubled. The total number of games won or lost by children from one iCat compared to the other, however, does not yield a significant difference. The fact that children has a winning hand against the socio-cognitive iCat twice as much as against the ego-reactive iCat makes a game played against the socio-cognitive iCat more interesting since there is a feeling of control for a significantly longer time.

Looking behavior also yields significant differences; children look more often at the socio-cognitive iCat than at the ego-reactive iCat. The relevant factors that explain this fact have not been identified. One factor that may be relevant is that the socio-cognitive iCat generates different sentences than the ego-reactive iCat and that causes the children to look more at the socio-cognitive iCat. Another relevant factor may be that when children enjoy the game less they look less at the iCat and are more focused on
the game. Considering they enjoyed the game better with the socio-cognitive iCat they will probably also look more at this iCat.

A trend was also found in observed arousal during the experiment. Children were more aroused when playing against the socio-cognitive iCat. This might be explained by the behavior of the socio-cognitive iCat, because he tried to help out the child more and tried to be friendlier which made the game more interesting. This is in contrast to the ego-reactive iCat, who just wanted to win the game.

Another trend has been spotted in laughing behavior, in which children laugh more often with the socio-cognitive iCat than with the ego-reactive iCat. The difference is not obtained because the socio-cognitive iCat tells funny jokes which the ego-reactive iCat does not. It is more likely that the socio-cognitive iCat tries to create a positive ambience by trying to be friendlier and by giving hints. This in effect made children laugh more with the socio-cognitive iCat.

7.2 Future work
Finally, a few points are discussed related to improving or expanding the capabilities of the platform as described in this thesis.

7.2.1 Emotion model
The emotion model used in this research has been based on a valence range. This is a one dimensional emotion mapping. There are other and more advanced models to represent emotions, for instance, the Pleasure, Arousal, Dominance (PAD) model [47]. This model allows to map all possible emotions in a three dimensional space. To implement such a model, first a mapping must be made from the PAD model to the expressions of the iCat, so that it is possible to show these emotions. Using a PAD model would allow the iCat to display a greater variety of emotions, and may result in larger perceived difference between the socio-cognitive and ego-reactive iCat.

7.2.2 Game
Another interesting setup to play the game of Go Fish may be to have the child play with both iCats at the same time. This setup was often asked for by children and testers. This would involve quite substantial changes to the implementation, however. First of all, one should think about how the two iCats are going to interact with each other. Are they going to team up against the child? Are they very mean to each other? Do they help each other out? A lot of extra scenarios will become available when they have to play against each other. Secondly, acquiring statistical information will become harder. It is, for example, not possible to do an in-between experiment, because both iCats play at the same time and this will influence the effect they have on each other.

7.2.3 Extension of the intentional behavior table
During this research, three factors determined the state of the socio-cognitive iCat: who is winning, what the mood of the iCat is, and what the mood of the child is. The intentional or cognitive behavior can be refined by taking into account the actual differences between the scores on these dimensions instead of reducing these dimensions to only three states: winning, neutral and losing. In that case, the emotions and behavior for the socio-cognitive iCat have to be implemented for a richer set of intermediate states, such as, for example, when the iCat’s score is a point higher than the child’s score.
It turned out that children, who were losing badly often did not understand the game completely. The iCat can be further enhanced with behavior to help such children out by giving more hints, and, for example, by telling what would be a good move to perform next. For instance, when the iCat asks for a blue chimpanzee and the child does not have this card, but the iCat knows that the child must have one other card of this rank, he can tell the child “If I were you I would try to get the other chimpanzees!”

Adding the dimension of time to the intentional or cognitive behavior table may also increase the perception of natural interaction. To illustrate what is meant, consider the case where a child is losing. Suppose that the iCat has gained a set and now is one point ahead; then, after a certain amount of time, it may be fair to assume that the internal mood of the child has changed into a somewhat more negative mood. The socio-cognitive iCat may take this into account and start giving more hints again, or try to cheer-up the child.

### 7.2.4 Hint system

Currently, when the iCat has a goal to give hints, there is a probability of 50% that it will give a hint. This percentage should not be fixed like this and could have been determined by the game state instead. For instance, when the child is losing by 3-0, the iCat may give hints more regularly say perhaps with a 95% chance. Another issue is that the iCat only gives one hint per round, and this could also be increased if the child is losing very badly.

The implementation of a chance model, which approximates the chance model that the child maintains mentally in order to play the game, could help with teaching the child the game. When the system notices that the child is losing and that he does not seem to ask for the right cards, this chance model could assist by giving the child more specific hints. For instance: “If I am not mistaken, you have the blue chimpanzee. You heard me ask before for the yellow chimpanzee. Now there is a good chance that I have either the red or green chimpanzee, so try it out next time!” Enhancing the system in this way is fairly complex, but seems feasible and may also increase the attribution of intentions to the iCat.

### 7.2.5 Looking behavior

There is some evidence of a correlation between how often a child looks at an iCat and how happy he is. This was observed by the co-experimenter who rated what the mood of the child was. After correlating the observed valence with the looking behavior it turned out that the available evidence is insufficient to make conclusions from. It may be interesting to investigate this relation in more detail, considering that if there is a correlation between the two, this could result in being able to create an automated mood detection system based on looking behavior.

### 7.2.6 Collecting statistical evidence

It was difficult to extract statistical information from the questionnaires as filled in by the children. De Lange also mentioned in his research a ceiling effect when using questionnaires. The author thought this could be combated by making the game not that much fun by itself, but apparently children still rate their opinion about the iCat to be very high on (smiley) Likert scales for almost all questions. It is advised that in the future a different method is used to determine what children think about various aspects of the setup because the ceiling effect observed makes it hard to draw conclusions or determine if a
difference is statistically significant. Perhaps it is useful to put more effort in investigating and validating a questionnaire and study whether, for example, using a continuous scale instead of a discrete (smiley) Likert scale gives better results.

### 7.3 Conclusion

The work presented in this thesis has contributed to the development of robots that can interact naturally in a human environment. A teacher remarked that after interacting with the iCat a child told him: “At some point, I had forgotten I was playing against a robot”. A statement like this most clearly expresses what we were aiming for in the research performed: designing a robot that is perceived to interact naturally with a human.

One of the differences of our research compared to other HRI game-related research is that it is done by means of a game based on chance. Most other research has confined itself to games of complete knowledge such as the game of chess or tic-tac-toe. A chance game adds a new dimension to interaction that is interesting to explore further in HRI research.

An interesting result, although not being the main goal of this research, is that the current setup has created a more positive user gaming experience. The socio-cognitive iCat gives simple hints, without undermining its own gaming position. This is actually quite a good accomplishment, since it mimics the case when an adult plays a chance game, where he might also help out a child by giving hints, but still keeping to the goal of trying to win the game. This has been successfully implemented in this research.

One of the things that may really give a boost to these types of experiments involves the use of automated recognition of the speech of a child. This should be relatively easy to implement considering that during the experiment children stick extremely well to the scenario. Children did not ask anything in the experiments performed that was not related to the experiment (i.e. game). An additional benefit is that implementing speech recognition will also significantly reduce the workload for the experimenter in the Wizard-of-Oz setup.

Another part that may be automated in future research concerns the detection of the mood of the child. When automated mood detection is combined with automated speech recognition the complete setup can then be automated. The implementation of automated mood detection is probably quite difficult to implement, and will require a lot of research input from fields like pattern recognition. This could perhaps lead to finding that there is a significant correlation between how often a child looks at an iCat during the game and the child’s mood and thus make mood determination easier.

Concluding, the development of the socio-cognitive iCat for performing HRI research can be considered a success. The socio-cognitive iCat is evaluated more positively on various dimensions compared to the ego-reactive iCat and is perceived as a more natural interaction partner. The combination of two different iCats in an experimental design using a game of Go Fish has provided a new interesting platform for research on HRI.
Bibliography


# Appendix A

## Sentence database

### Introduction mode for both iCats

<table>
<thead>
<tr>
<th>iCat</th>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kim</td>
<td>Hallo ik ben Kim en ik ben een iCat.</td>
<td>3.2</td>
</tr>
<tr>
<td>Robin</td>
<td>Hoi, ik ben Robin en ook ik ben een iCat.</td>
<td>3</td>
</tr>
<tr>
<td>Robin</td>
<td>En wat is jouw naam?</td>
<td>1.5</td>
</tr>
<tr>
<td>Kim</td>
<td>Wat een mooie naam!</td>
<td>1.5</td>
</tr>
<tr>
<td>Robin</td>
<td>Vandaag gaan we alle twee een spelletje kwartet spelen.</td>
<td>3.1</td>
</tr>
<tr>
<td>Kim</td>
<td>Mirek heeft ons alleen kwartetten geleerd.</td>
<td>3</td>
</tr>
<tr>
<td>Kim</td>
<td>Over andere onderwerpen moeten we nog steeds leren.</td>
<td>2.7</td>
</tr>
<tr>
<td>Robin</td>
<td>Heb je er zin in?</td>
<td>1</td>
</tr>
</tbody>
</table>

**Introduction mode — Yes**

<table>
<thead>
<tr>
<th>iCat</th>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kim</td>
<td>Dat is mooi!</td>
<td>1</td>
</tr>
</tbody>
</table>

**Introduction mode — No**

<table>
<thead>
<tr>
<th>iCat</th>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robin</td>
<td>Kom op! Het gaat heel gezellig worden</td>
<td>2.7</td>
</tr>
</tbody>
</table>

**Introduction mode — sleep**

<table>
<thead>
<tr>
<th>iCat</th>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robin</td>
<td>Helaas kan maar 1 van ons twee meedoen tijdens een spelletje kwartet.</td>
<td>4</td>
</tr>
<tr>
<td>%current</td>
<td>We hebben van tevoren al besloten dat ik ga beginnen.</td>
<td>2.8</td>
</tr>
<tr>
<td>%opposite</td>
<td>En ik ga even een tukje doen...</td>
<td>1.7</td>
</tr>
<tr>
<td>%current</td>
<td>Kun je nu eerst vragenlijst 1 invullen?</td>
<td>2.3</td>
</tr>
<tr>
<td>%current</td>
<td>Dan wacht ik daar even op.</td>
<td>1.5</td>
</tr>
<tr>
<td>%current</td>
<td>We gaan beginnen!</td>
<td>1</td>
</tr>
</tbody>
</table>

**Child start**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jij mag beginnen.</td>
<td>1.1</td>
</tr>
</tbody>
</table>

**My turn**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ik speel als eerste.</td>
<td>1.2</td>
</tr>
</tbody>
</table>

**iCat gives card away**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alsjeblieft</td>
<td>0.8</td>
</tr>
<tr>
<td>Mood</td>
<td>Say</td>
</tr>
<tr>
<td>-------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Any</td>
<td>Dank je</td>
</tr>
<tr>
<td>Any</td>
<td>Super</td>
</tr>
<tr>
<td>Any</td>
<td>Bedankt</td>
</tr>
<tr>
<td>Happy</td>
<td>Alweer een kaart!</td>
</tr>
<tr>
<td>Happy</td>
<td>Net wat ik nodig had!</td>
</tr>
<tr>
<td>Unhappy</td>
<td>Ach ja</td>
</tr>
<tr>
<td>Unhappy</td>
<td>[nothing]</td>
</tr>
</tbody>
</table>

**Received Go Fish**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jammer</td>
<td>0.5</td>
</tr>
<tr>
<td>Oh</td>
<td>0.3</td>
</tr>
</tbody>
</table>

**Child has a set complete**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gefeliciteerd!</td>
<td>1.3</td>
</tr>
</tbody>
</table>

**iCat has a complete set**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Super, een complete set!</td>
<td>1.2</td>
</tr>
</tbody>
</table>

**iCat requests card**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heb jij de %card?</td>
<td>.67+cardTime</td>
</tr>
<tr>
<td>Mag ik de %card?</td>
<td>.52+cardTime</td>
</tr>
<tr>
<td>Mag ik van jou de %card?</td>
<td>.95+cardTime</td>
</tr>
<tr>
<td>Heb jij voor mij de %card?</td>
<td>1.14+cardTime</td>
</tr>
</tbody>
</table>

**Time Out requesting card**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weet je het al?</td>
<td>0.8</td>
</tr>
<tr>
<td>Kom op, niet zo neuzelen!</td>
<td>2</td>
</tr>
</tbody>
</table>

**iCat says Go Fish**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helaas, die heb ik niet</td>
<td>1.8</td>
</tr>
<tr>
<td>Nee, die heb ik niet</td>
<td>1.5</td>
</tr>
</tbody>
</table>

**iCat says Go Fish + cheer up**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (in sec)</td>
<td>Say</td>
</tr>
<tr>
<td>-------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>1.2</td>
<td>&quot;Volgende keer beter!&quot;</td>
</tr>
</tbody>
</table>

**iCat gives hint (has another card of the requested rank)**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Als ik jou was zou ik een andere kleur vragen.&quot;</td>
<td>2.4</td>
</tr>
<tr>
<td>&quot;Hint, vraag een andere kleur.&quot;</td>
<td>2.2</td>
</tr>
<tr>
<td>&quot;Misschien moe je een andere kleur vragen?&quot;</td>
<td>2.1</td>
</tr>
</tbody>
</table>

**iCat gives hint (has none of the requested rank)**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Als ik jou was zou ik een ander type vragen.&quot;</td>
<td>2.4</td>
</tr>
<tr>
<td>&quot;Hint, ik zou een ander type vragen.&quot;</td>
<td>2.4</td>
</tr>
<tr>
<td>&quot;Misschien wil je een ander type proberen?&quot;</td>
<td>2.1</td>
</tr>
</tbody>
</table>

**Child’s turn**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Jij bent aan de beurt.&quot;</td>
<td>1.3</td>
</tr>
<tr>
<td>&quot;Het is jouw beurt.&quot;</td>
<td>1</td>
</tr>
<tr>
<td>&quot;Welke kaart wil je?&quot;</td>
<td>1.2</td>
</tr>
</tbody>
</table>

**iCat didn’t understand speech**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Kun je dat herhalen?&quot;</td>
<td>1.3</td>
</tr>
<tr>
<td>&quot;Sorry, ik verstond je niet.&quot;</td>
<td>2</td>
</tr>
<tr>
<td>&quot;Wat zeg je?&quot;</td>
<td>1</td>
</tr>
</tbody>
</table>

**iCat won game**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Hoera! Ik heb gewonnen&quot;</td>
<td>1.7</td>
</tr>
<tr>
<td>&quot;En nou heb ik ook nog gewonnen!&quot;</td>
<td>1.6</td>
</tr>
</tbody>
</table>

**iCat lost game**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;En nu heb jij deze ronde gewonnen.&quot;</td>
<td>2</td>
</tr>
<tr>
<td>&quot;En daarmee heb je dit spel gewonnen.&quot;</td>
<td>1.9</td>
</tr>
</tbody>
</table>

**Switch (intermediate part)**

<table>
<thead>
<tr>
<th>%current</th>
<th>%opposite</th>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&quot;Ik hoop dat je het leuk hebt gehad.&quot;</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;Ik ga nu %opposite voor je wakker maken.&quot;</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;Kom op %opposite niet blijven slapen!&quot;</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;Ik ga nu slapen.&quot;</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;Heb je het naar je zin gehad met %current&quot;</td>
<td>2.2</td>
</tr>
</tbody>
</table>

**Switch – confirm**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
</table>
Dat is mooi om te horen! Ik weet zeker dat je het net zo leuk zult vinden met mij! 4.9

**Switch – refute**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dat is jammer. Maar ik weet zeker dat je het met mij een stuk leuker zult vinden!</td>
<td>4.4</td>
</tr>
</tbody>
</table>

**Questionnaire 2**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kun je nu eerst vragenlijst 2 invullen?</td>
<td>2.3</td>
</tr>
<tr>
<td>Dan wacht ik daar even op.</td>
<td>1.5</td>
</tr>
</tbody>
</table>

**Rounding off experiment**

<table>
<thead>
<tr>
<th>Say</th>
<th>Time (in sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ik hoop dat je het naar je zin hebt gehad!</td>
<td>2.2</td>
</tr>
<tr>
<td>Kun je nog de laatste vragenlijst invullen? Dat is vragenlijst 3, dan wacht ik weer even.</td>
<td>5.7</td>
</tr>
<tr>
<td>Ik zal %current nog even wakker maken zodat je met ons op de foto kunt!</td>
<td>2.2</td>
</tr>
</tbody>
</table>
Appendix B

The three questionnaires can be found on the following 5 pages. The first questionnaire was a generic one and was used in all cases. The following two questionnaires are split up and shown depending against which iCat they played initially. For instance, if the child first played against the socio-cognitive iCat (named Robin), the child would see page 1, then 2 and finally 5. As where a child initially playing against the ego-reactive iCat (named Kim), would see page 1, then 3 and finally 4.
Questionnaire 1

Wat is je naam?

………………………………………………………………………………………………………………

Wat is je leeftijd?

...... jaar

1. Ik ben een
   jongen/meisje

2. Stel je voor dat een robot alles kan wat je maar bedanken kan. Wat zou jij dan willen dat een robot
   kan doen? Je mag meerdere hokjes aankruisen bij deze vraag.
   [ ] Praten
   [ ] Een spelletje spelen
   [ ] Als wekker of agenda gebruiken
   [ ] Als huiswerkhulpje gebruiken
   [ ] Iets anders, namelijk

………………………………………………………………………………………………………………

………………………………………………………………………………………………………………


☐ heel stom  ☐ stom  ☐ gewoon  ☐ leuk  ☐ heel leuk

4. Hoe vind je de robot?

☐ heel stom  ☐ stom  ☐ gewoon  ☐ leuk  ☐ heel leuk

5. Hoe leuk denk je dat het is om met de robot te kwartetten?

☐ heel stom  ☐ stom  ☐ gewoon  ☐ leuk  ☐ heel leuk

6. Hoe vind je het om met kinderen te kwartetten?

☐ heel stom  ☐ stom  ☐ gewoon  ☐ leuk  ☐ heel leuk
Questionnaire 2

1. Ik vind Robin vriendelijk.
   [ ] helemaal niet  [ ] niet  [ ] neutraal  [ ] waar  [ ] helemaal waar

2. Robin kan goed tegen zijn verlies.
   [ ] helemaal niet  [ ] niet  [ ] neutraal  [ ] waar  [ ] helemaal waar

3. Het kwartetten met Robin is leuk.
   [ ] helemaal niet  [ ] niet  [ ] neutraal  [ ] waar  [ ] helemaal waar

4. Robin speelt eerlijk.
   [ ] helemaal niet  [ ] niet  [ ] neutraal  [ ] waar  [ ] helemaal waar
Questionnaire 2

1. Ik vind Kim vriendelijk.
   ☐ helemaal niet  ☐ niet  ☐ neutraal  ☐ waar  ☐ helemaal waar

2. Kim kan goed tegen zijn verlies.
   ☐ helemaal niet  ☐ niet  ☐ neutraal  ☐ waar  ☐ helemaal waar

3. Het kwartetten met Kim is leuk.
   ☐ helemaal niet  ☐ niet  ☐ neutraal  ☐ waar  ☐ helemaal waar

   ☐ helemaal niet  ☐ niet  ☐ neutraal  ☐ waar  ☐ helemaal waar
Questionnaire 3

1. Ik vind Robin vriendelijk.

□ helemaal niet  □ niet  □ neutraal  □ waar  □ helemaal waar

2. Robin kan goed tegen zijn verlies.

□ helemaal niet  □ niet  □ neutraal  □ waar  □ helemaal waar

3. Het kwartetten met Robin is leuk.

□ helemaal niet  □ niet  □ neutraal  □ waar  □ helemaal waar

4. Robin speelt eerlijk.

□ helemaal niet  □ niet  □ neutraal  □ waar  □ helemaal waar

5. Hoe vind je het om tegen robots te kwartetten?

□ heel stom  □ stom  □ gewoon  □ leuk  □ heel leuk

6. Met wie vond je het leuker om mee te spelen?

□ Robin (laatste robot)  □ Kim (eerste robot)

Waarom vond je dat?

..........................................................................................................................................................................................
..........................................................................................................................................................................................
..........................................................................................................................................................................................
..........................................................................................................................................................................................
..........................................................................................................................................................................................
..........................................................................................................................................................................................

Bedankt voor het invullen van de vragenlijst!
Questionnaire 3

1. Ik vind Kim vriendelijk.
   □ helemaal niet □ niet □ neutraal □ waar □ helemaal waar

2. Kim kan goed tegen zijn verlies.
   □ helemaal niet □ niet □ neutraal □ waar □ helemaal waar

3. Het kwartetten met Kim is leuk.
   □ helemaal niet □ niet □ neutraal □ waar □ helemaal waar

   □ helemaal niet □ niet □ neutraal □ waar □ helemaal waar

5. Hoe vind je het om tegen robots te kwartetten?
   □ heel stom □ stom □ gewoon □ leuk □ heel leuk

6. Met wie vond je het leuker om mee te spelen?
   □ Robin (eerste robot) □ Kim (laatste robot)

   Waarom vond je dat?
   ……………………………………………………………………………………………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………………………………………………………………………………………

   Bedankt voor het invullen van de vragenlijst!
Appendix C

The color red indicates a major problem with the experiment, yellow indicates a smaller problem with the experiment. All four have not been used for statistical purposes.

| Q3 | Q4 | Q5 | Q6 | Kim (A) | Kim (A) | Kim (A) | Kim (A) | Robin (I) | Robin (I) | Robin (I) | Robin (I) | Q5 | Q6 | Reason |  |
|----|----|----|----|--------|--------|--------|--------|----------|----------|----------|----------|----|----|--------|  |
| 5  | 4  | 4  | 3  | 4     | 5      | 4      | 5      | 5        | 5        | 5        | 5        | 4  | 5  | Kim    |  |
|    |    |    |    | 5     | 5      | 5      | 5      | 5        | 5        | 5        | 5        | 5  |    | Robin  |  |
|    |    |    |    | 5     | 5      | 5      | 5      | 5        | 5        | 5        | 5        |    |    | Because I really like it, and because it was 4-4 and I won. And he was friendly and nice. |  |
|    |    |    |    | 5     | 5      | 5      | 5      | 5        | 5        | 5        | 5        | 5  |    | Robin  |  |
|    |    |    |    | 4     | 4      | 4      | 4      | 4        | 4        | 4        | 4        |    |    | Because I won from Robin. |  |
|    |    |    |    | 5     | 4      | 4      | 4      | 4        | 4        | 4        | 4        | 4  |    | Robin  |  |
|    |    |    |    | 4     | 5      | 5      | 5      | 5        | 5        | 5        | 5        | 5  |    | Because I won from Robin. |  |
|    |    |    |    | 5     | 4      | 4      | 4      | 3        | 4        | 5        | 5        | 5  |    | Robin  |  |
|    |    |    |    | 5     | 4      | 4      | 4      | 4        | 3        | 4        | 5        | 5  | 5  | Robin  |  |
|    |    |    |    | 5     | 5      | 5      | 5      | 5        | 5        | 5        | 5        | 5  |    | Kim    |  |
|    |    |    |    | 4     | 4      | 4      | 4      | 4        | 4        | 4        | 4        | 4  |    | Kim    |  |
|    |    |    |    | 4     | 5      | 5      | 5      | 5        | 5        | 5        | 5        | 5  |    | Robin  |  |
|    |    |    |    | 4     | 4      | 4      | 4      | 4        | 4        | 5        | 4        | 4  |    | Kim    |  |
|    |    |    |    | 4     | 5      | 5      | 5      | 5        | 5        | 5        | 5        | 5  |    | Kim    |  |
|    |    |    |    | 5     | 5      | 5      | 5      | 5        | 5        | 5        | 5        |    |    | Robin  |  |
|    |    |    |    | 5     | 4      | 4      | 4      | 5        | 4        | 4        | 4        | 4  |    | Kim    |  |
|    |    |    |    | 5     | 5      | 5      | 5      | 5        | 5        | 5        | 5        | 5  |    | Kim    |  |
|    |    |    |    | 5     | 5      | 5      | 5      | 5        | 5        | 5        | 5        | 5  |    | Robin  |  |
|    |    |    |    | 5     | 5      | 5      | 5      | 5        | 5        | 5        | 5        | 5  |    | Kim    |  |
|    |    |    |    | 4     | 5      | 5      | 5      | 5        | 5        | 5        | 5        | 5  |    | Kim    |  |
|    |    |    |    | 5     | 5      | 5      | 5      | 5        | 5        | 5        | 5        | 5  |    | Robin  |  |
|    |    |    |    | 5     | 5      | 5      | 5      | 5        | 5        | 5        | 5        | 5  |    | Kim    |  |
|    |    |    |    | 4     | 4      | 5      | 5      | 4        | 3        | 4        | 3        | 5  |    | Kim    |  |
|    |    |    |    | 4     | 4      | 5      | 5      | 4        | 3        | 4        | 3        | 5  |    | Robin  |  |
|    |    |    |    | 4     | 4      | 5      | 5      | 4        | 3        | 4        | 3        | 5  |    | Robin  |  |
|    |    |    |    | 4     | 4      | 5      | 5      | 4        | 3        | 4        | 3        | 5  |    | Robin  |  |
|    |    |    |    | 4     | 4      | 5      | 5      | 4        | 3        | 4        | 3        | 5  |    | Robin  |  |
|    |    |    |    | 4     | 4      | 5      | 5      | 4        | 3        | 4        | 3        | 5  |    | Robin  |  |
|    |    |    |    | 4     | 4      | 5      | 5      | 4        | 3        | 4        | 3        | 5  |    | Robin  |  |

101 | Page
<table>
<thead>
<tr>
<th>ICat start</th>
<th>Indicated mood Kim</th>
<th>Child winning % Kim</th>
<th>ICat winning % Kim</th>
<th>Laughed Kim</th>
<th>Talked time Kim</th>
<th>Looked At Kim</th>
<th>Winner Kim</th>
<th>Refused while had card Kim</th>
<th>Asked illegal card Kim</th>
</tr>
</thead>
<tbody>
<tr>
<td>autistic</td>
<td>0.34210527</td>
<td>0.29342106</td>
<td>0</td>
<td>0</td>
<td>47010</td>
<td>28 Child</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>autistic</td>
<td>-0.109561756</td>
<td>0.7410359</td>
<td>0</td>
<td>0</td>
<td>21451</td>
<td>19 ICat</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>autistic</td>
<td>0.18238994</td>
<td>0.4255765</td>
<td>0</td>
<td>0</td>
<td>23057</td>
<td>34 ICat</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>autistic</td>
<td>-0.30150753</td>
<td>0.50703518</td>
<td>0</td>
<td>0</td>
<td>23041</td>
<td>30 ICat</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>autistic</td>
<td>-0.39408866</td>
<td>0.454844</td>
<td>0</td>
<td>0</td>
<td>12418</td>
<td>24 ICat</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>intentional</td>
<td>0.25842696</td>
<td>0.53370786</td>
<td>0</td>
<td>0</td>
<td>36384</td>
<td>6 Child</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>autistic</td>
<td>-0.27626458</td>
<td>0.15045395</td>
<td>0.21400778</td>
<td>1</td>
<td>46936</td>
<td>24 Child</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>intentional</td>
<td>-0.6951456</td>
<td>0.07378641</td>
<td>0.34536106</td>
<td>0</td>
<td>43626</td>
<td>1 Child</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>intentional</td>
<td>-0.25849056</td>
<td>0.02264151</td>
<td>0.47924528</td>
<td>0</td>
<td>50925</td>
<td>2 Child</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>autistic</td>
<td>-0.28705442</td>
<td>0</td>
<td>0.5609756</td>
<td>0</td>
<td>36006</td>
<td>13 ICat</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>intentional</td>
<td>0.16384181</td>
<td>0.007532957</td>
<td>0.51789075</td>
<td>0</td>
<td>47205</td>
<td>32 Child</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>intentional</td>
<td>-0.54924875</td>
<td>0.3572621</td>
<td>0.08347245</td>
<td>0</td>
<td>35483</td>
<td>12 ICat</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>intentional</td>
<td>-0.15447155</td>
<td>0</td>
<td>0.398374</td>
<td>0</td>
<td>30072</td>
<td>6 ICat</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>intentional</td>
<td>0.8056112</td>
<td>0.18436874</td>
<td>0.008016032</td>
<td>2</td>
<td>41643</td>
<td>12 Child</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>intentional</td>
<td>0.80033004</td>
<td>0.22607261</td>
<td>0.16171618</td>
<td>3</td>
<td>49324</td>
<td>55 Child</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>autistic</td>
<td>0</td>
<td>0.12820514</td>
<td>0.08974359</td>
<td>0</td>
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<td>19 ICat</td>
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<td>0</td>
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</tr>
<tr>
<td>intentional</td>
<td>0.19517544</td>
<td>0</td>
<td>0.24122807</td>
<td>0</td>
<td>36270</td>
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Geachte ouders/verzorgers,

Graag willen we uw kind uitnodigen voor een onderzoek op de Zuidwester. Dit onderzoek wordt in samenwerking met TNO en de TU Delft gedaan. Het onderzoek is vergelijkbaar met onderzoek wat al meerdere keren succesvol is uitgevoerd door onderzoekers op TNO Soesterberg. Uit deze onderzoeken is naar voren gekomen dat de kinderen het erg leuk vinden om met de robot (de iCat, zie Figuur 1) om te gaan.


Het onderzoek bestaat uit het achterhalen of kinderen het verschil opmerken tussen de robots. De eerste robot die ontwikkeld is een “planmatige” robot. Deze robot reageert in elke situatie precies hetzelfde. Als voorbeeld; ook al is deze robot aan de winnende hand, hij zal nog steeds vrij negatief reageren wanneer hij een kaart moet weggeven aan zijn tegenspeler.

De andere robot die ontwikkeld is, reageert meer afhankelijk van de situatie. Deze wordt ook wel de intentionele robot genoemd, vanwege het meer natuurlijke gedrag. Mocht bijvoorbeeld uw kind het erg naar zijn zin hebben en de robot is niet aan de verliezende hand, dan laat deze robot ook blije emoties zien, omdat er een wisselwerking in emoties zit tussen personen.

Het onderzoek zal 20 minuten (maximaal een half uur) in beslag nemen en gebeurt onder schooltijd. Als beloning voor deelname aan het onderzoek ontvangt het kind een klein presentje en een foto van het kind met beide iCats.

Het onderzoek zal beginnen op woensdag 22 april en eindigen op 24 april. Als bijlage een document met meer informatie over het onderzoek en ook een deelnameformulier. Bij interesse kunt u het formulier ondertekenen en meegeven aan uw kind. Als u eerst nog wat meer wilt weten over het onderzoek kunt u natuurlijk ook contact opnemen.

Met vriendelijke groet,

Mirek Vink
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Faculteit Elektrotechniek, Wiskunde en Informatica
Mekelweg 4
2628 CD Delft
Telefoon: 06-46382820
E-mail: M.Vink@student.TUDelft.nl

Onder begeleiding van:

Prof.Dr. M.A. Neerincx
Telefoon: 0346-356298
E-mail: mark.neerincx@tno.nl

Dr. K.V. Hindriks
Telefoon: 015-2782523
E-mail: k.v.hindriks@tudelft.nl

Bijlage:
- Informatie onderzoek omgang met een sociale robot
- Deelnameformulier
1. Over TNO

TNO
De letters TNO staan voor Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek. TNO doet wetenschappelijk onderzoek voor toepassing in de samenleving. TNO bestaat uit een aantal instituten, waarvan TNO Human Factors in Soesterberg er één is.

Onderzoek bij TNO Human Factors
TNO Human Factors richt zich op het werken van mensen in een technische omgeving. Door ons onderzoek verbeteren wij prestatie, veiligheid en gebruiksvriendelijkheid. TNO Human Factors maakt deel uit van TNO Defensieonderzoek. Ongeveer de helft van ons onderzoek is voor het ondersteunen van de Nederlandse Krijgsmacht. De andere helft richt zich op bedrijfsleven en overheden. Naast de verantwoordelijkheid ten opzichte van onze opdrachtgevers hebben we ook een maatschappelijke verantwoordelijkheid.

2. Over TU Delft
De TU Delft is een technische universiteit in de stad Delft. De TU Delft draagt met haar unieke technologische infrastructuur, brede kennisbasis, wereldwijde reputatie en succesvolle alumni significant bij aan verantwoorde oplossingen voor urgente maatschappelijke vraagstukken, zowel nationaal als internationaal.

3. Doel van het onderzoek
Het uiteindelijke doel is het ontwikkelen van een robot met meer empathisch gedrag. Empathie is een ander woord voor inlevingsvermogen, de kunde of vaardigheid om je in te leven in de gevoelens van anderen. Empathie is een vaardigheid of persoonlijkheidseigenschap die belangrijk is in de omgang met mensen. Het empathisch vermogen speelt een hoofdrol bij emotionele intelligentie. Het kunnen verplaatsen in anderen draagt bij tot het kunnen begrijpen van emoties van anderen en de communicatie met je medemensen. Zonder empathie praat je langs elkaar heen of ontstaan er meningsverschillen.
Het ontwikkelen van een robot met dit gedrag kan een belangrijk punt zijn in de acceptatie van robots in de samenleving. Een empathische robot kan bijvoorbeeld patiënten in het ziekenhuis beter begrijpen doordat het zich kan inleven in de problemen van een patiënt.
In vorige, soortgelijke, experiment met de iCat is naar voren gekomen dat kinderen het leuk vinden om met deze robot te werken.

4. Opdrachtgever
Het project is een Master afstudeerproject van de TU Delft in samenwerking met TNO. Het project is vergelijkbaar met vorige projecten die op TNO zijn gedaan. Dit was als onderdeel van het SuperAssist project. Dat project beoogt met persoonlijke assistenten voor zowel de patiënt als voor medische en technische specialisten deze actoren te assisteren in het verwerken van informatie en zonodig te voorzien van advies op maat. Toepassingen zijn bijvoorbeeld assistentie bij het bijhouden en samenstellen van een dieet, lichamelijke oefening, medicijn gebruik en gebruik van medische apparaten.
Meer informatie: [http://mmi.tudelft.nl/superassist](http://mmi.tudelft.nl/superassist)
5. Experiment
Het experiment bestaat uit het spelen van een spelletje kwartet met 2 iCats. Een sessie begint met de introductie van de iCats door zichzelf. Hierna zal een van de twee iCats “slapen”, terwijl de ander een spelletje kwartet met het kind gaat spelen. Met elke iCat wordt 1 ronde van kwartet gespeeld. Het wordt verwacht dat elke sessie 10 minuten per iCat duurt. Nadat er 2 rondes gespeeld zijn, neemt de iCat afscheid van het kind en is het experiment afgelopen.

Voorafgaand aan het experiment zullen we uw kind een aantal vragen stellen. We zullen vragen stellen over of uw kind eerder met een robot gewerkt heeft, hoe hij/zij denkt dat een robot er uit zou kunnen zien en wat hij/zij vindt van de robot die in dit experiment gebruikt gaat worden. Na afloop van het experiment zullen we uw kind vragen om de robot te beoordelen aan de hand van hoe goed hij/zij de robot begrijpt, vertrouwd en hoe leuk uw kind de robot vindt. De antwoorden op deze vragen worden anoniem verwerkt.

Tijdens het experiment worden video-opnamen gemaakt van uw kind. Deze worden gebruikt om achteraf te kunnen analyseren of het experiment verloopt zoals verwacht en om te kijken hoe uw kind tijdens de interactie met de robot reageert (bijvoorbeeld of hij/zij om de robot moet lachen). Ook video-opnamen worden anoniem verwerkt en uiteindelijk vernietigd.

6. Tijdsplanning en duur van het onderzoek
Het onderzoek wordt uitgevoerd op de Zuidwester. Het onderzoek zal 1 keer plaatsvinden en ongeveer 20 minuten in beslag nemen.

7. Ethische aspecten, kwaliteit en persoonlijke levenssfeer
TNO en de TU Delft gaan zorgvuldig met uw kind om. Uw kind doet vrijwillig mee en als het kind aangeeft te willen stoppen zullen we dat dan ook direct doen. Ook als we zelf het idee krijgen dat hij/zij het niet prettig vindt, maar niets zegt, zullen we direct stoppen. We zullen eerst even uitleggen wat er gaat gebeuren. Ze krijgen dan precies te horen wat en hoe we meten.

Voorwaarden van het onderzoek
Het onderzoek wordt uitgevoerd volgens richtlijnen die internationaal erkend zijn en de gezondheid en veiligheid van de deelnemers bewaken.

Informatie en schriftelijke toestemming
Uw kind kan pas deelnemen aan het onderzoek nadat u deze informatie hebt gekregen en een verklaring hebt getekend. U kunt nog vragen stellen door met Mirek Vink contact op te nemen (zie de telefoon nummers op de eerste bladzijde) en pas als u tevreden bent over de informatie die u hebt gekregen stemt u in met deelname van uw kind aan het onderzoek. Daarvoor tekent u een verklaring, zie de laatste bladzijde.

Privacy en de toegang tot onderzoeksgregevens
Om de privacy te waarborgen, wordt de naam van het kind zoveel mogelijk gescheiden van de gegevens bewaard. De verwerking van de gegevens gaat anoniem. Het video materiaal dat wordt opgenomen om de reacties van het kind (emotioneel en verbaal) op te nemen gaan na analyse in het archief bewaard en worden met de andere individuele gegevens na 5 jaar vernietigd. Er zijn bepaalde mensen die het
onderzoek moeten kunnen inspecteren op betrouwbaarheid en kwaliteit en die inzage in gegevens kunnen vragen. Die inzage gebeurt altijd onder geheimhouding.

8. Vergoeding
Voor het meedoen aan het onderzoek ontvangt het kind een klein presentje en een foto (digitaal en/of uitgeprint) van uw kind met de iCats als aandenken aan het onderzoek.

Bijlage
Als bijlage zit aan dit informatiegerepakket de blanco verklaring. Deze moet worden ingeleverd voorafgaand aan het onderzoek.
Bijlage verklaring

Ondergetekende, ouder/verzorger van

Naam ................................

Geb. Datum ..............................

verklaart toestemming te geven voor het deelnemen aan een kleinschalig experiment met de iCat, waarmee een spelletje kwartet wordt gespeeld.

- De bedoelingen van het onderzoek en de daarbij gevolgde aanpak zijn tot mijn tevredenheid uitgelegd, ik heb de schriftelijke informatie over de proef gelezen en ik heb geen vragen meer.
- Ik weet dat mijn kind op elk moment zonder opgaaf van redenen tijdens de metingen kan stoppen en dat ook de proefleider zijn/haar deelname aan het experiment kan beëindigen als hij dat nodig vindt.

Den Haag, datum ........................................

Naam ouder: ........................................

Handtekening ouder: ...................................

Naam proefleider: ........................................

Den Haag, datum ........................................

Handtekening proefleider: ...................................
KINDEREN GEZOCHT
die willen kwartetten tegen een robot!

Wie: Kinderen in de leeftijd 9 tot 12 jaar
Wat: Twee keer een spelletje kwartet tegen een iCat (zie afbeelding)
Wanneer: Woensdag 22, donderdag 23 en vrijdag 24 april
Duur: 20 minuten (maximaal 30 minuten met uitloop)
Nodig: Toestemming van je ouders

Eventueel meer informatie:
Mirek Vink
Telefoon: 06 46 38 28 20
E-mail: M.Vink@student.tudelft.nl

Dit onderzoek is een onderdeel van een afstudeerproject van de TU Delft en TNO

Wil je meedoen? Vraag een brief aan je meester of juffrouw!
Voorbeeld complete set

Je mag alleen kaarten vragen waarvan je er minimaal 1 in je hand hebt!

Als je bijvoorbeeld deze kaart in je hand hebt

Mag je deze vragen
Appendix GUI

Oz GUI

1. The IP address
Here the IP address is filled of the pc where the game and the iCat software are running. For example, during testing this was the same pc and 127.0.0.1 is filled in. After a successful connect, the button and the input field is grayed out and cannot be used anymore.

2. iCat Hand
This list shows what the iCat is currently holding in his hand. During the actual experiment this doesn’t have much use, but it is useful during testing to see what the iCat is holding.

3. Requested Card
This is the card that is currently requested by either the iCat or the player.

4. Player Set Complete
When the player indicates that he has a complete set, this button must be pressed. It is not necessary to tell the system which set the player set, because normally this should be only one.

5. Turn
This indicates if it is the iCat’s turn or the player’s turn.

6. Event List
Again mainly used for debugging. It shows what event occurred at what time. These events are only received from the Game.

7. Listen
When the player is talking, this button must be pressed, to put the iCat into listening mode. Otherwise it might go on with other events.

8. Recognize
Here a list is presented with options that can be recognized. For instance, when it is the players turn, he can ask for a card. The Wizard is then presented with a list of colors and animal names. To confirm a requested card, the Wizard needs to double click on a word.

9. Overview
This shows an overview of how the ego-reactive iCat works. Initially the iCat is sleeping, and to wake him up, the wizard needs to double click on the “start” node. That node will then light up; it will follow the arrows based on the commands on them. In certain cases it is possible to force the ego-reactive iCat to “jump” to another node. A case in which this works is when the player initially indicates it has a card, the ego-reactive iCat is then waiting for a card. Then the player indicates it doesn’t have that card after all, the Wizard can then double click on “Player Refute” to make the iCat move on with not receiving a card.

10. Zoom slider
This sets the zoom for the overview.
GOAL GUI

1. **The IP address of the ego-reactive iCat and the game**
   Here the IP address is filled of the pc where the game and the iCat software are running.

2. **The IP address of the socio-cognitive iCat**
   Here the IP address of the pc where the socio-cognitive iCat is connected to.

3. **The IP address of the pc of the co-experimenter**

4. **Connect**
   When this button is pressed, the system tries to connect to all 3 pc’s to connect to 2 iCats, 1 game and 1 co-experimenter software.

5. **Ego-reactive or Intentional switch**
Before pressing on “Connect”, a choice needs to be made to tell which iCat starts first. A stands for autistic (the old name for ego-reactive) and I for intentional.

6. **Start button**
   This will start the scenario with both iCats. The start node is selected and handled.

7. **Listen**
   When this button is pressed the iCat goes in listening mode.

8. **User Set Complete**
   After a user has indicated that he has a complete set, the interface will check this and present the Wizard with a possible complete set. The iCat will congratulate the child and go on with his normal game events.

9. **Not Understood**
   This mainly a button for the Wizard, it can happen he doesn’t understand what the participant said, in that case this button can be pressed. The iCat will then ask him to repeat what he said.

10. **Child Mood**

11. **Cheat**
    In case the child tries to look into the screen of the iCat he can tell him not to do that.

12. **Don’t Know**
    When the child asks something outside the scope of the scenario this button can be pressed. The iCat will then say something to indicate that he has no clue.

13. **Give Up**
    If the child thinks losing is evident, he has the option to quit the game. The iCat will then ask if he’s sure about it, if so the game will be ended the iCat will be declared a winner.

14. **Debug Start**
    This button was mainly used during testing to skip the introduction part and immediately let one iCat wake up and start playing a game of Go Fish.

15. **Mirek Rescue**
    This will let the iCat say that he will send his accompanist in to help out (which is the main experimenter). This could be used when something goes wrong.

16. **Abort**
    During testing it was found out that when an iCat asks if an opponent has a card and the opponent confirms this, but then corrects this and say he doesn’t have it after all the system would hang and wait for the opponent to give a card. To solve this, this button can be pressed which aborts the waiting for a card to be given.

17. **Time’s Up**
Because a game of Go Fish is quite flexible in time, it was not possible to set hard deadlines in the system for how long a game should last. It was up to the experimenter to decide if it was taking too long and the game could be gracefully quitted by pressing this button. The iCat would then say something like: “Sadly we are out of time, but first let’s see who has one!”, after which a winner is declared and the game is ended.

18. **Time**
To determine how much time has passed, a simple stopwatch was shown here with how much time has passed since the game started.

19. **Overview**
Here an overview of the fixed scenario part is displayed. In Figure 29 the introduction of both iCats can be observed. This overview will change based on what part of the experiment needs to be done. There are 3 different part; first is an introduction mode, then after the first iCat is finished playing an intermediate mode where iCats are switched are done and finally the experiment rounds off with goodbye’s and a photo moment.

20. **Recognize**
Here a list is presented with options that can be recognized. For instance, when it is the players turn, he can ask for a card. The Wizard is then presented with a list of colors and animal names. To confirm a requested card, the Wizard needs to double click on a word.
Appendix Manikin

Figure 30 Used Self-Assessment Manikin test for Valence and Arousal. Dominance was not seen as an important factor in this research.