

Adaptive Emotional Expression in Robot-Child Interaction

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ABSTRACT

Expressive behaviour is a vital aspect of human interaction. A model for adaptive emotion expression was developed for the Nao robot. The robot has an internal arousal and valence value, which are influenced by the emotional state of its interaction partner and emotional occurrences such as winning a game. It expresses these emotions through its voice, posture, whole body poses, eye colour and gestures. An experiment with 18 children (mean age 9) and two Nao robots was conducted to study the influence of adaptive emotion expression on the interaction behaviour and opinions of children. In a within-subjects design the children played a quiz with both an affective robot using the model for adaptive emotion expression and a non-affective robot without this model. The affective robot reacted to the emotions of the child using the implementation of the model, the emotions of the child were interpreted by a Wizard of Oz. The dependent variables, namely the behaviour and opinions of the children, were measured through video analysis and questionnaires. The results show that children react more expressively and more positively to a robot which adaptively expresses itself than to a robot which does not. The feedback of the children in the questionnaires further suggests that showing emotion through movement is considered a very positive trait for a robot. From their positive reactions we can conclude that children enjoy interacting with a robot which adaptively expresses itself through emotion and gesture more than with a robot which does not do this.

Categories and Subject Descriptors

H.1 [Information Systems Models and Principles]: User / Machine Systems

Keywords

adaptive, expressive behaviour, emotion, gesture, robot-child interaction

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1. INTRODUCTION

One of the most promising fields in human-robot interaction is robot-child interaction. Children like robots, are more forgiving when robots make mistakes and are quicker to ascribe human characteristics to robots [4]. In many applications of robot-child interaction, such as a robot as teacher, this interaction will take place for a longer period of time. Research has shown that for persistent interaction between robot and child, the child has to establish a social bond with the robot [18], and that it is certainly possible for such a bond to exist [29]. Forming a social bond is a complicated process, in which several aspects play a role. One aspect is expressive behaviour, which is important in showing internal states to an interaction partner. Two concrete examples of expressive behaviour are showing emotion and gesturing. Humans show their emotions in various ways and gesture while they speak to clarify their meaning. These expressions are very important in interactions and the forming of social relationships [6, 24]. Research in robotics shows that these processes also hold for human-robot interaction. People react differently to robots depending on their expressions [14]. [22] show that empathy facilitates interaction in robot-child interaction, indicating that human-based expressions can be successfully implemented by robots.

Although much work has been done on expressive behaviour, few studies have integrated both emotional behaviour and gesturing. Moreover, research which takes into account the emotional state of the interaction partner is sparse, especially when taking into account the important role contagion plays in human interaction [23]. This paper presents a study of the role of the adaptive expression of gestures and emotion in robot-child interaction, based on the emotions of the interaction partner and relevant occurrences to the robot. In order to study this issue, the expressions first needed to be developed for the Nao robot. Based on previous research, a model of the adaptive expression of emotion and gestures for the humanoid Nao was designed and implemented. In this paper, we present the results of an experiment using a Wizard of Oz design which was done using this model, where we studied the influence of the expressions on the interaction behaviour and opinions of children.

2. MODEL

The Nao is a 57 cm tall humanoid robot, developed by Aldebaran¹. It has 25 degrees of freedom in its body, but

¹<http://www.aldebaran-robotics.com/>

does not have movable facial features. The Nao is very suitable for robot-child interaction because of its size, appearance, and because it is capable of many different bodily expressions, which also makes it a good platform for expressive behaviour.

2.1 Previous Research

In emotion research, two approaches exist. The first approach distinguishes several basic universal emotions, such as happiness and sadness [13]. The other approach considers each emotion to be a specific combination of arousal, or how exciting the emotion is, and valence, how positive the emotion is [26]. This is also the approach taken in this paper, as the combined use of arousal and valence allows us to design complex emotional states and smooth transitions between the basic emotions.

In order to design human-like expressive behaviour for a robot, it is first important to know how humans express themselves in interactions. We can distinguish three ways in which people express their emotion, namely through facial features, through body movement and through voice. As the Nao robot cannot display facial features, this was not considered. People can recognize emotions from body pose alone, especially the emotions happiness, anger and sadness [11]. These poses have also been implemented in the Nao robot, and were well recognized by both children and adults [2, 3]. When considering body movement, trunk position especially is related to the valence of the emotion felt [12], while head position has a strong influence on both perceived valence and arousal [2]. Both adults and children can also recognize emotion from vocal cues alone [20]. The fundamental frequency of voice, speech rate and speech volume of the voice all seem to be related to the arousal of the emotion felt [1].

Aside from considering how people show emotion, it is also important to look at when they show them. This is crucial as people show emotion tailored to the context and reacting to their interaction partner. They mimic the emotions of others, smile when they smile, frown when they frown [15]. People are also influenced by the emotions of others, emotions are contagious [23]. Although the exact link between mimicking and emotional contagion is not quite clear, both processes clearly exist in human interaction.

Most gestures used by people in interactions are classified as spontaneous gestures, as they are made without conscious thought. Four different types of gestures can be distinguished. Iconic gestures refer to concrete events and are closely related to the semantic content of the utterance. Metaphoric gestures are pictorial like iconic gestures, but represent abstract ideas. Beat gestures are related to the rhythm of speech and deictic gestures are pointing gestures. Not all types of gestures occur equally often, beat and iconic gestures being the most common. Which kind of gesture occurs is also related to the type of clause they occur with. Narratives are subject to sequential constraints, extranarratives are not. Iconic and deictic gestures occur most with narrative clauses, metaphoric gestures most with extranarrative clauses [24].

Gestures serve several purposes, including that they show us what the speaker finds relevant [8]. Related to this is that gestures can tell something about the speaker. In robotics, gestures also serve to make a robot more life-like, as people almost always use gestures when speaking. Most systems

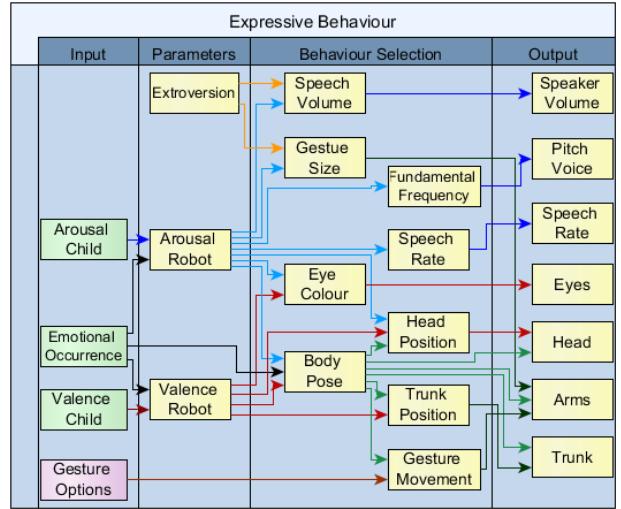


Figure 1: Model for expressive behaviour of the Nao robot

which generate gestures for robots rely on a textual analysis to generate their gestures [9]. The effects of a robot gesturing on the opinions of their human interaction partners is not quite clear. Although some studies find that gesturing is always positive, no matter if it is semantically congruent [27], other results indicate that a robot gesturing might create a cognitive overload [21].

Aside from emotions felt and text spoken, personality also influences how we express ourselves. Extroversion in particular is a trait which influences speech and movement. Extrovert people have a stronger voice, smile more, move quicker and move more than introvert people [5]. Personality is very relevant for robotics, a study using extrovert and introvert robots has shown that people tend to like robots with a personality comparable to their own [17].

There are several ways to implement emotions and gestures in a robot. The most important design choice here is to have either a functional or a biological inspired robot. If the robot reacts directly to input from the environment it is functional, if it reacts according to its internal state, which in turn is influenced by input from the environment the robot is biological inspired. Some studies use a functional approach, such as [28], who employ a state-machine. Most current systems are biologically inspired, however, as the existence of an internal state makes for a more insightful model and can help a robot with long-term interaction and decision making. [7], for instance, use a stimulation model strongly inspired by emotion theory. [16] have developed an architecture based on motives, emotional state, habits of interaction and percepts of interaction.

2.2 Adaptive Emotion Expression

Based on the knowledge from previous studies, it is possible to design a model for the adaptive expression of emotion and gestures for the Nao robot. The full model is presented in Figure 1. It consists of four phases, an input phase, adapting the internal parameters based on this input, reasoning about the correct behaviour and the output to the Nao robot. In this section, all phases will be discussed in more detail.

The model needs *input* from its environment in order to decide on the correct emotional and gesture behaviour. The first kind of input is information about emotional occurrences. The emotions of people are influenced by their environment, so the same should be the case for the robot. For this reason, it is important to know when things take place which influence the emotions. An example is the robot winning a game. The second kind of input is the emotion of the child. As seen in the previous section, people are influenced by the emotions of our interaction partners, so the robot needs to have information about the emotion of the child. The third kind of input are the possible gestures. Based on the text which the robot will speak, several possible gestures can be derived. This will happen outside of this model and is hardcoded in this study.

The model has three *internal parameters*, namely its extroversion, its arousal and its valence. Extroversion of the robot will be based on the extroversion of the child as we have evidence that people like a robot similar in personality. The arousal and valence of the robot are represented on a scale from -1 to 1 and will be influenced by both emotional occurrences and the emotions of the child. Whenever an emotional occurrence takes place, the emotions of the robot will move in the direction of the occurrence. For instance, if a happy occurrence takes place with arousal 0.8 and valence 0.9, the arousal of the robot will move halfway to 0.8 and the valence halfway to 0.9. When no such occurrence takes place, the robot is influenced by the emotions of the child. In this way emotional contagion is considered. The emotions of the child will influence the robot in the same way as emotional occurrences, with the exception of the situation where the emotion of the child becomes too extreme. Whenever the valence or arousal of the child drops too low, or the arousal rises too high, the robot will compensate. This should exclude situations such as the child being very sad and becoming even sadder because the robot is very sad.

Based on the literature, several aspects of *behaviour* have been incorporated in this model. Emotions will be shown by the robot through full body poses as developed and validated by [2, 10] and Aldebaran². These poses will only be executed when emotional occurrences take place, as it is impossible for the robot to constantly use them. The happy pose, for instance, has raised arms, which would make playing a game with a child very difficult. The head position of the robot will be influenced by both arousal and valence, the higher these values the higher the head position. The trunk position will be similarly influenced, but only by valence. The robot also has the possibility of changing its eye colours. Red colours will be associated with high arousal emotions, blue colours with low arousal emotions [19]. The voice of the robot will be influenced by its arousal. The higher arousal, the louder the robot will speak, the higher pitched its voice will be and the higher the speech rate. Speech volume is also influenced by extroversion, the higher the extroversion, the louder the voice. Finally, gesture movement will be chosen based on the type of narrative the gesture relates to and the type of gesture. Knowing how often people use specific kinds of gestures, the model will choose between the options reflecting this. The size of the gesture movement will be influenced by both arousal and extroversion [32].

²<http://www.aldebaran-robotics.com/>

Finally, the model has an *output* module in which the behaviours will be translated into specific voice characteristics and joint values for the Nao robot.

2.3 Implementation

The model was implemented for the Nao robot in the Prolog-based BDI-Agent language GOAL³. A GOAL program consists of a knowledge base with static facts, a belief base with changeable beliefs, a goal base with changeable goals, an action base specifying the actions to the environment, a program module specifying which actions to perform and which beliefs to change in which circumstance and an event base which processes the input from the environment. In the implementation of this model, the knowledge base was used to represent the dependencies between specific behaviours and the internal parameters. These parameters, along with information about the environment, were stored in the belief base. The program module specified when to adapt behaviours. Due to technical constraints, it was not practically possible to make gesture and speech perfectly synchronized in the Nao robot. We chose to still work with these imperfect gestures, as research has revealed that incongruent gesturing might still be perceived as more positive than no gesturing at all [27].

3. EXPERIMENT

In order to test the effect of the adaptive expression of emotion and gestures in robot-child interaction, an experiment was done. In this experiment, children played a quiz with a robot that shows the model-based adaptive expressive behaviour and a robot without such a model. We wished to know what the influence of the adaptive expression of emotion and gestures was on the opinions of the children about the robot and on the expressiveness of the children.

3.1 Experimental Method

Experimental Design

We applied a within-subjects design with a two-level independent variable: the adaptive expressive behaviour of the robot. One robot displayed adaptive expressions of emotion, the other did not. Two separate robots were used. From this point, we will call these robots the *affective robot* and the *non-affective robot*. The affective robot adapted its emotions and showed these through voice, body movement, body pose and gesture. The non-affective robot only showed small randomized body movements not related to emotion, such as swaying in the hips and slightly moving the arms. The two dependent variables in this experiment are the opinions of the children and the expressive behaviour of the children when interacting with the robot. During the experiment we also looked at the interpersonal synchrony between the emotions of child and robot, but as these results were of secondary importance, we have chosen to leave them out of this paper. Full results can be found in [30].

Participants and robot settings

All participants were children from the primary school Dalton Lange Voren in Barneveld (group 5 and 6). 18 children participated, mean age was 8.89, SD 0.81. 9 boys and 9 girls participated. The mean extroversion of the children was 69, SD 10. During the interaction, the robot will adopt the ex-

³<http://mmi.tudelft.nl/trac/goal>



Figure 2: A child playing the quiz with the robot using the tablet and seesaw

troversion of the child as its own. In order to determine the extroversion of the child, the corresponding questions from the BFQ-C questionnaire were used. This questionnaire is validated for children [25] and will give an insight to the extroversion of the children in the form of a score between 0 and 100.

Task

In order to test the effect of the adaptive expression of emotion in robot-child interaction, the child and robot need to interact in a meaningful way. In this experiment the children were told to play a quiz with the robot. In this activity the child and robot are seated across from each other, with a tablet on a seesaw between them projecting the quiz questions as seen in Figure 2. The game starts with the robot asking the child a question and then showing the child the question. The child then has to answer the question, getting two tries. Once an answer is given the turn goes to the robot. A new question will appear on the tablet, including the possible answers, which the child reads to the robot. The robot will then try to answer the question. This procedure is repeated until the quiz stops after 12 questions, 6 posed by each player. All questions are multiple choice with four possible answers. The robot has a 75% chance of answering the question correctly. The quiz questions were either trivia or on health subjects.

Before and after playing the quiz, the robot will have a short conversation with the child. It will first introduce itself, ask the child about its interests, such as hobbies and tell something about itself. At the end of the quiz, the robot will tell the child who has won the quiz, express that it liked playing and say goodbye. The entire experiment was conducted in Dutch.

Measures

A common problem with experiments testing children's opinions on robots is a ceiling effect. Children like all robots so much that it becomes impossible to distinguish between conditions. For this reason, two kind of measures were used in this experiment, video analysis to study the expressive behaviour of the children and questionnaires to get to know their opinions. We have added the video analysis in the hope of getting a better understanding of the unconscious opinions of the children, as conveyed by their behaviour. In order to study this behaviour, all interactions were filmed and the behaviour was analysed. The videos were annotated

Table 1: Expressions and their definitions

Expression	Properties
Smiles	All instances where the mouth of the child angles upwards. As we only count instances and not duration, this was only counted when there was a change. So only when the mouth angles rose upwards.
Laughter	All cases in which the child laughed. Laughter is here classified as those smiles which are accompanied by sound or movement of the chest related to the happy feelings.
Excited bouncing	All cases in which the child either bounced up and down out of obvious excitement, or in which the child made a large excited gesture. An example of the latter is raising both arms, and other such gestures of success.
Positive vocalization	Every positive exclamation not directly related to the dialogue. Common words are <i>yay</i> or <i>yes</i> .
Frowns	All facial expressions obviously related to thinking, concentrating or misunderstanding. Also all facial expressions where the eyebrows are lowered.
Shrugging & Sighing	Raising the shoulders and dropping them again, or audibly letting out air. These two expressions are seen as signs of boredom
Startle	All signs of involuntary fright from the child, such as it being startled by sudden movement.
Negative vocalization	All negative exclamations not directly related to the dialogue, such as <i>nou zeg</i> or <i>jammer</i> .

on several specific behaviours, such as smiles and frowns. A full list of the behaviours can be found in Table 1. From these behaviours, we can calculate two measures. The first is the weighed frequency of the expressions of the children, which is calculated by taking the frequency scores of the behaviours and adding them up, counting smiles, frowns and startles once and laughter, bouncing, positive vocalization, shrugging, sighing and negative vocalization double. The second measure is the valence of the expressions, which is calculated by taking the frequency of positive expressions (counting stronger expressions twice) and subtracting the frequency of negative expressions. The corresponding formula is as follows:

$$\text{Valence expressions} = \text{Smiles} + 2x(\text{Laughter} + \text{Bouncing} + \text{PosVocalization}) - (\text{Startle} + \text{NegVocalization}) - 2x(\text{Shrugging} \& \text{Sighing})$$

Aside from the behaviour of the children, we also measured their subjective opinions through questionnaires. Although previous work has shown a ceiling effect with questionnaires, we still added them in hopes of being able to compare results between different studies. Two types of questionnaires were used, one questionnaire about an individual robot and one forced-choice questionnaire in which children had to choose between the two robots. Both questionnaires had questions on the same subjects. Table 2 shows the topics of the questions and the number of questions per questionnaire.

Table 2: Topics of questions in questionnaires

Subject	Nr. of questions individual robot	Nr. of questions forced choice
Fun	9	1
Acceptance	3	1
Empathy	3	1
Trust	3	1
Emotions	3	1
Preference	0	1

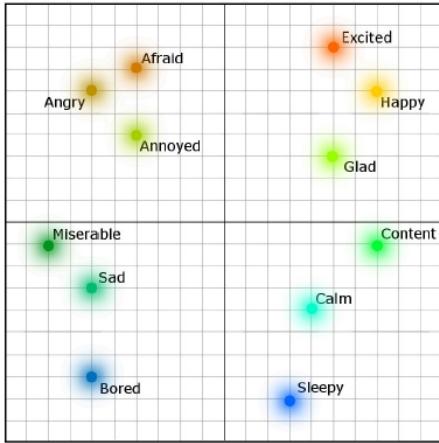


Figure 3: The interface via which the experimenter provided information about the arousal and valence of the child. The horizontal axis represents the valence of the child, the vertical axis the arousal. The coloured dots reference specific emotions as context.

Wizard of Oz

As described in the implementation section, the GOAL language was used to implement the model for the adaptive expression of emotion and gestures. For this experiment, however, a final step was necessary as the model relies on input. In the current experiment, an experimenter provided this information via a Wizard of Oz (WoOz) program. This interface allowed the experimenter to provide the valence and arousal of the child, giving guidelines in the form of specific emotions. Figure 3 shows this WoOz interface. The experimenter also performed the dialogue selection for the robot, all pieces of dialogue were scripted. The emotional occurrences were scripted into the dialogue, as the robot will always say something reacting to these occurrences. For instance, when the robot wins a game it will say *Yay! I've won!*. With selecting this dialogue, the experimenter sends the corresponding input to the model, which will automatically adapt the emotions of the robot accordingly and send a happy pose to the robot. The gesture input was scripted in a similar manner. Whenever a piece of dialogue was selected by the experimenter, the model received input on the possible gestures to display. The model automatically chooses which gesture is actually displayed. During the experiment, the experimenter operating the WoOz was sitting in the same room as the children, as it was necessary to see the child's face to interpret the emotions and the location did not allow for a video set-up.

Materials

The list of materials for this experiment can be divided into two categories, the technical devices and the computer programs. When it comes to the technical devices, two Nao robots were used, a video camera, a Dell laptop and one Samsung Galaxy tablet on a seesaw. The laptop was used by the WoOz and ran the WoOz interface program through which the dialog was managed, the quiz operated and the emotional state of the child communicated to the robot. It also ran the GOAL program which made the decisions on which behaviour to display in the way described in section 2.2. Because the two robots used are identical in appearance, both wore a different little shirt. One robot had a plain orange shirt, the other a striped white and orange shirt. These shirts were used to make sure that the children understood that there were two different robots and help them to keep the robots apart. In addition to keeping the robots apart, it was important that the children remember the names of the robots, as the questionnaires refer to them by the names *Charlie* and *Robin*.

Procedure

The experiment was conducted in two sessions, an introduction session and an experimental session. The introduction session was the same for all participants and took the form of a short classical lesson with the robots. In this lesson, one robot was introduced to the children in order to make them more familiar with robots and to hopefully lessen the ceiling effect where robots are considered so cool that there would be no discrimination between conditions. The robot used in the introduction did not wear a shirt and was given a different name than the robots used in the experimental sessions. After the introductions, all children filled in the BFQ-C questionnaire.

In the experimental session, the first robot was always named Charlie and always used the same dialogue and questions, while the second robot was always named Robin and also always used the same dialogue and questions (different from the first robot, of course). Which robot displayed the adaptive expressions of emotion and gestures was counterbalanced, half of the children played the first quiz with the affective robot, half with the non-affective robot. The children were shown into the room and the experimenter first explained the quiz. In all sessions the first robot started with introducing itself to the child. After a short conversation about their interests, the robot asked if the child still understood the quiz and explained again when necessary. Next, the child and the robot played the quiz. After 12 questions (about 10 minutes), the robot ended the quiz and the interaction. The children were then presented with the questionnaire about the first robot. The first robot was then taken away, but kept in sight, and the second robot was brought to the child. The reason both robots were kept in sight is to ensure that the child viewed the robots as two different entities. The procedure described was repeated, the second robot introduced itself and had a short conversation with the child. The quiz was played for 10 minutes after which the robot ended the interaction and the same questionnaire as before was presented. After this, one more questionnaire about the differences between the robots was presented. The session ended with the possibility for the child to take a picture with one of the robots.

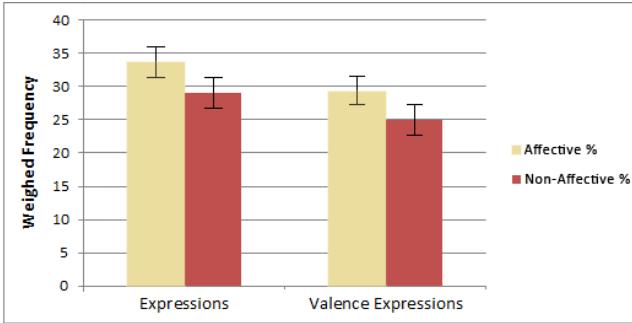


Figure 4: The weighed frequency of the expressions of the children, as well as the valence of their expressions.

3.2 Results

Expressions

The first set of results are those representing the expressions of the children during the interaction. In one session there was a technical problem with the camera, meaning that for one subject no video was available for analysis. The expressions were scored as described in the Measures section, by the experimenter. In order to ensure the objectivity of this scoring method, two children were also scored by a second experimenter. These results show that the differences between conditions are comparable. For instance, experimenter 1 counted 30 smiles with the affective and 14 with the non-affective robot, while the second experimenter counted 24 versus 11 smiles. All other expressions also showed only minor deviations or were identical. Figure 4 shows the weighed frequency scores of expressions of the children when interacting with the affective and the non-affective robot. The results for the expressions of the child for the affective robot ($M=33.59$, $SE=17.34$) are significantly higher than for the non-affective robot ($M=29.06$, $SE=13.53$), $(t)(16)=2.156$, $p<0.05$, $(r)= 0.47$ (one-tailed). Of course it is important to also consider the valence of the expressions of the children. We would like to know if children react more positively or negatively to the affective robot. These results show that the children had a significantly higher valence in their expressions with the affective robot ($M=29.24$, $SD=16.75$) than with the non-affective robot ($M=24.94$, $SD=13.89$) $(t)(16)= 2.251$, $p<0.05$, $(r)= 0.54$ (one-tailed).

Questionnaires

Figure 5 shows the results from the first questionnaire, about the individual robots. The questions were asked on a scale from 1 to 5, meaning that a score of 100% corresponds to the most positive answer given to every question and a score of 0% to the most negative answer given to every question. Both robots scored very high, the difference between the affective and the non-affective robot is not significant for any of the question topics.

Figure 6 shows the results from the second questionnaire, comparing the robots. Some data were excluded from this dataset, based on the motivations of the answers given. A preference for a robot motivated clearly by reasons which can be contributed to un-planned circumstances was not taken into account. One example is a child disliking one robot because it was slow to answer questions, which was caused by a crash of the program. When considering Figure 6, note

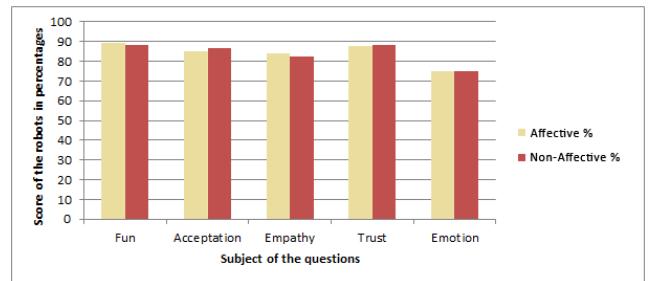


Figure 5: Opinions of the children on both the affective and the non-affective robot on several subjects.

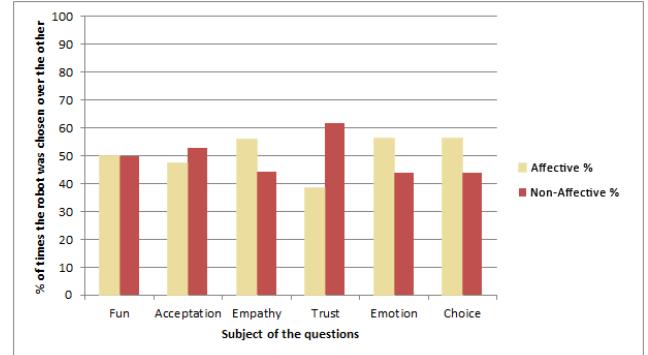


Figure 6: Forced choice between the two robots on several subjects.

that the children had to choose between the robots, meaning that the scores for any subject will add up to 100%. All these scores are based on a single question. Although some differences can be seen, none are statistically significant.

Aside from asking the children about their preference, the final questionnaire also asked for motivations. These motivations can be classified into different categories. Figure 7 shows the number of times that each kind of motivation was given for each robot. This figure also shows how often a child who gave a certain motivation eventually chose the affective robot or the non-affective robot in the final question of the forced-choice questionnaire. This question was which robot they preferred most, so the coordinate gives an indication of the influence of the motivation for the final preference. The most noticeable motivations are clearly that the non-affective robot was more understandable, while the affective robot was preferred most often because it showed emotions.

4. DISCUSSION AND CONCLUSION

Behaviour of the children

When looking at expressiveness scores for children in Figure 4 we can clearly see that children show more expressions when interacting with an affective robot than with a non-affective robot. Moreover, we also see that children behave more positively in their expressions with an affective robot than with a non-affective robot. We can therefore state that when a robot displays adaptive expressions of emotion and gesture, children will also show more, and more positive expressions. Although there are very large differences in weighed expression frequencies between children, the affective robot tends to incite more smiles, more laughs, etc. from children. We already know that expressions from one interaction partner elicit expressions from the other in

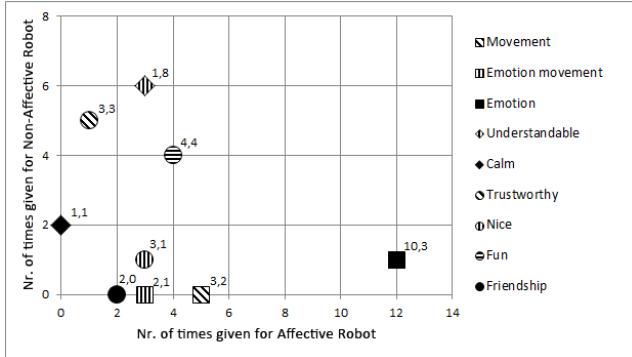


Figure 7: The number of times certain arguments were given as reason to choose one of the robots over the other. The coordinates represent the number of times an argument was given by a child who eventually chose the affective robot (X), or the non-affective robot (Y) as overall preferred.

human-human interaction [15, 23]. From the fact that children show more expressions with a robot showing adaptive emotions than with a non-affective robot, we can conclude that this is also the case in robot-child interaction. This is relevant as it suggests that children interpret robot emotion in the same way as human emotions. It also means that it is possible to influence the behaviour of children by adapting the behaviour of the robot they interact with. As children showed more positive expressions with an affective robot, we can also state that children enjoy themselves more with a robot which shows adaptive emotion expressions and gestures than with a robot which does not.

Opinions of the children

The second dependent variable tested were the subjective opinions of the children. Through questionnaires, we tested if a robot adaptively expressing emotions and gestures elicits different opinions from children than a robot which does not. Looking at the results, we first see that the children are very positive about both robots, they clearly enjoy playing with robots. When asking the children for their opinions of each robot, no significant differences can be found between the robot using the model for adaptive emotion and gesture expression and the robot which did not. One of the possible reasons for this result is that there was a ceiling effect, indicated by the high opinions the children had of both robots. It is possible to make some suggestions about preferences when combining the data from the final questionnaire with the motivations given to the answers. Interesting from Figure 6 is that although the affective robot scores higher on empathy, emotion and general preference, the non-affective scores higher in acceptance and trust. Figure 7 shows an overview of the motivations for choosing either the affective or the non-affective robot over the other, for any of the questions. Looking at these reasons, we see that children particularly like the fact that the affective robot showed its emotions and that it moved more. They also thought this robot was fun and nice and they felt friendship. These reasons are given most often for the questions about fun, empathy and emotion. For the non-affective robot, the strongest argument for choosing it was that it was easier to understand. This can be explained by the fact that this robot had not fluctuations in the pitch of its voice. The fact that

this robot moved less might also have contributed, as this leads to less signals to be processed by the child. The children also noted that they found this robot more trustworthy. Additionally, they liked that it was calm, and thought it was fun. All these reasons were given most to the questions about fun, acceptance and trust. We can take these motivations as evidence that the fact that the affective robot scored higher on empathy and emotion and the non-affective robot higher on acceptance and trust is not entirely due to chance. It seems there is some reason to believe that an affective robot increases empathy, but decreases acceptance and trust. Looking at the coordinates for the motivation of emotion, we see that 10 out of 13 children who gave the emotion argument also preferred the affective robot in the end. When asked which robot they thought nicer, one girl motivated her choice for the affective robot with *She showed her feelings and because of this I felt a stronger friendship*. This motivation gives a very clear statement of the positive effect showing emotion can have on robot-child interaction. There is also a downside to the expressive behaviour, however. Especially the voice of the affective robot has proven to make the speech of the robot harder to understand. The questionnaires show that it is very important for children to have a robot which they can understand well. Considering the coordinates with the motivation of understandability, we see that 8 out of 9 children who gave *easier to understand* as reason to choose a robot preferred the non-affective robot in the end. We can conclude that intelligibility is more important to children than emotion when it comes to a robot's voice. Noticeable is that a recent study using the same voice adaptations found no effect on understandability. [31]. As the only difference with this study was that the voice of the robot was constant, we can conclude that the fluctuations in voice might be a bigger problem than that the voice was too high or fast.

Conclusion

In an experiment with children we have shown that children display more expressions when interacting with a robot which displays emotion and adapts its expressions to the child than with a robot which does not. From this, we can conclude that we can influence the expressive behaviour of children by adapting the expressive behaviour of their robotic interaction partner. Moreover, as children showed more positive expressions with an affective robot, we can also state that children enjoy themselves more with a robot which shows adaptive emotion expressions and gestures than with a robot which does not. Data also shows that children particularly like it if a robot shows emotion through movement, while showing emotion through voice has the negative effect of reducing intelligibility. One thing which will have to be explored further in the future is the exact effect of adaptability in the expression of emotion. Because this experiment compared an adaptive affective robot with a non-affective robot, we do not know what part of the results was because of adaptability, and what part because of affect. We believe, however, this work provides a first insight into the relation between adaptive emotion expression and the bond between robot and child.

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6. REFERENCES

- [1] R. Banse and K. Scherer. Acoustic profiles in vocal emotion expression. *Journal of Personality and Social Psychology*, 70(3):614–636, 1996.
- [2] A. Beck, L. Canamero, and K. Bard. Towards an affect space for robots to display emotional body language. In *IEEE RoMan Conference*, 2010.
- [3] A. Beck, L. Canamero, L. Damiano, G. Sommavilla, F. Tesser, and P. Cosi. Children interpretation of emotional body language displayed by a robot. In *ICSR 2011*, 2011.
- [4] T. Beran, A. Ramirez-Serrano, R. Kuzyk, M. Fior, and S. Nugent. Understanding how children understand robots: Perceived animism in child-robot interaction. *International Journal of Human-Computer Studies*, 69:539–550, 2011.
- [5] P. Borkenau and A. Liebler. Trait inferences: Sources of validity at zero acquaintance. *Journal of Personality and Social Psychology*, 62(4):645–657, 1992.
- [6] E. Butler, B. Egloff, F. Wilhelm, N. Smith, E. Erickson, and J. Gross. The social consequences of expressive suppression. *Emotion*, 3(1):48–67, 2003.
- [7] L. Canamero and J. Fredslund. I show you how I like you-can you read it in my face? *IEEE Transactions on Systems MAN and Cybernetics*, 31(5):454–459, 2001.
- [8] J. Cassell. *Nudge Nudge Wink Wink: Elements of Face-to-Face Conversation for Embodied Conversational Agents*, chapter Introduction, pages 29–63. MIT Press, 2000.
- [9] J. Cassell, H. H. Vilhjálmsson, and T. Bickmore. Beat: the behavior expression animation toolkit. In *SIGGRAPH 2001*, 2001.
- [10] I. Cohen, R. Looije, and M. Neerincx. Child’s recognition of emotions in robots’ face and body. In *Proc. 6th Int. Conference on Human Robot Interaction 2011*, pages 123–124. ACM, 2011.
- [11] M. Coulson. Attributing emotion to static body postures: Recognition accuracy, confusions and viewpoint dependance. *Journal of Nonverbal Behavior*, 28:117–139, 2004.
- [12] M. De Meijer. The contribution of general features of body movement to the attribution of emotions. *Journal of Nonverbal Behavior*, 13:247–268, 1989.
- [13] P. Ekman. Facial expressions of emotion. *American Psychologist*, 48:384–392, 1993.
- [14] R. Gockley, J. Forlizzi, and R. Simmons. Interactions with a moody robot. In *Proc. Conference on Human-Robot Interaction*, 2006.
- [15] U. Hess and S. Blairy. Facial mimicry and emotional contagion to dynamic emotional facial expressions and their influence on decoding accuracy. *International Journal of Psychophysiology*, 40(2):129–141, 2001.
- [16] J. Hirth, N. Schmitz, and K. Berns. Towards social robots: Designing an emotion-based architecture. *International Journal of Social Robotics*, 3:273–290, 2011.
- [17] S. Jung, H. taek Lim, S. Kwak, and F. Biocca. Personality and facial expressions in human-robot interaction. In *Proc. 7th ACM/IEEE Int. conference on Human-Robot Interaction*, 2012.
- [18] T. Kanda, R. Sato, N. Saiwaki, and H. Ishiguro. A two-month field trial in an elementary school for long-term human-robot interaction. *IEEE Transactions on Robotics*, 23:962–971, 2007.
- [19] N. Kaya and H. Epps. Relationship between color and emotion: a study of college students. *College Student Journal*, 38(3):396–405, 2004.
- [20] J. Kessens, M. Neerincx, R. Looije, M. Kroes, and G. Bloethoof. Facial and vocal emotion expression of a personal computer assistant to engage, educate and motivate children. In *3rd IEEE Int. Conference on Affective Computing and Intelligent Interaction*, Amsterdam, the Netherlands, September 2009.
- [21] A. Kim, H. Kum, O. Roh, S. You, and S. Lee. Robot gesture and user acceptance of information in human-robot interaction. In *Proc. 7th ACM/IEEE Int. conference on Human-Robot Interaction*, pages 279–280, New York, NY, USA, 2012. ACM.
- [22] I. Leite, G. Castellano, A. Pereira, C. Martinho, and A. Paiva. Modelling empathic behaviour in a robotic game companion for children: an ethnographic study in real-world settings. In *Proceedings of the seventh annual ACM/IEEE International conference on Human-Robot Interaction*, pages 367–374, New York, NY, USA, 2012. ACM.
- [23] G. McHugo, J. Lanzetta, D. Sullivan, R. Masters, and B. Englis. Emotional reactions to a political leader’s expressive displays. *Journal of Personality and Social Psychology*, 49(6):1513–1529, 1985.
- [24] D. McNeill. *Hand and Mind*. The University of Chicago Press, 1992.
- [25] P. Muris, C. Meesters, and R. Diederen. Psychometric properties of the big five questionnaire for children (bfq-c) in a dutch sample of young adolescents. *Personality and individual differences*, 38(8):1757 – 1769, 2005.
- [26] J. Russell. A circumplex model of affect. *Journal of Personality & Social Psychology*, 39(6):1161–1178, 1980.
- [27] M. Salem, S. Kopp, I. Wachsmuth, K. Rohlffing, and F. Joublin. Generation and evaluation of communicative robot gesture. *International Journal of Social Robotics*, 4:201–217, 2012.
- [28] J. Schulte, C. Rosenberg, and S. Thrun. Spontaneous, short-term interaction with mobile robots. In *Proc. Int. Conference on Robotics and Automation*, 1999.
- [29] F. Tanaka, A. Cicourel, and J. Movellan. Socialization between toddlers and robots at an early childhood education center. *Proc. of the National Academy of Sciences*, 104(46):17954–17958, 2007.
- [30] M. Tielman. Expressive behaviour in robot-child interaction. Master’s thesis, Utrecht University, 2013.
- [31] I. Van Dam. Meet my new robot best friend: an exploration of the effects of personality traits in a robot on enhancing friendship. Master’s thesis, Universiteit Utrecht, 2013.
- [32] J. Xu, J. Broekens, K. Hindriks, and M. Neerincx. Mood expression through parameterized functional behavior of robots. In *22nd IEEE RO-MAN*, 2013.