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Getting Acquainted for a Long-Term Child-Robot Interaction

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Abstract. We are developing a social robot that should autonomously interact long-term with pediatric oncology patients. The child and the robot need to get acquainted with one another before a long-term interaction can take place. We designed five interaction design patterns and two sets of robot behaviors to structure a getting acquainted interaction. We discuss the results of a user study (N = 75, 8–11 y.o.) evaluating these patterns and robot behaviors. Specifically, we are exploring whether the children successfully got acquainted with the robot and to what extent the children bonded with the robot.

Results show that children effectively picked up how to talk to the robot. This is important, because the better the performance the more comfortable the children are, the more socially attractive the robot is, and the more intimate the conversation gets. The evaluation furthermore revealed that it is important for children, in order to get familiar with the robot, to have shared interests with the robot. Finally, most children did initiate a bond with the robot.

Keywords: Child-robot interaction · Getting acquainted · Bonding

1 Introduction

We are developing a social robot companion for children with cancer. The goal is to reduce medical traumatic stress. The robot can offer event-oriented support, in the form of a concrete intervention during a potential traumatic event. However, our primary research focus lies on providing *prolonged social support*. The goal

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is not only to keep up the effectiveness of an intervention after the novelty effect wears off. It's also about offering consistent social support throughout the whole treatment process. By being there, especially when parents cannot (e.g. during radiation therapy), and forming a bond, the robot can potentially achieve those goals.

However, we are not there yet. First the robot needs to be able to form and maintain a bond with a child. In this paper we focus on the very beginning, the child and the robot getting acquainted. Not only does the child gets familiar with the robot during this first encounter. It is also the first opportunity for the robot to learn things about the child that it can use in future interactions. Finally, like with people, first impressions matter. It is also the moment that determines if, and to what extend, a bond is formed.

We designed five interaction design patterns and two sets of robot behaviors to structure the getting acquainted interaction. We evaluated the performance of the interaction design with a user study (N = 75 school children, 8–11 y.o.) on three aspects. The robot getting acquainted with the child, the child getting acquainted with the robot, and the bonding between the child and the robot. In past work we discussed whether the robot got acquainted with the child. Results show that the interaction design effectively allowed the robot to elicit children to self-disclose and process those self-disclosures to form a user model of the children [12]. In this paper we evaluate whether the child got acquainted with the robot as well and whether a child-robot bond is initiated.

2 Related Work

Enabling robots to engage long-term and repeatedly with the same user is one of the main challenges within HRI research. Although we are not quite there yet, there is an increasing body of work that gives us insights into how to design and evaluate these long-term interactions [10].

2.1 Long-Term Bonding

In order for the social robot companion to bond with the children it at least needs to safeguard the continuity of the interaction [3,4], personalize the interaction [10], and deepen the bond [4]. Safeguarding the continuity is mostly about recognizing, recalling, and referring to relevant information about the child, previous conversations, and shared activities. Personalizing is about adapting the robot's behavior and interaction content to the child's preferences and interests [13]. Deepening the bond is about presenting novel interaction content over time [3,10] and adapting the intimacy level accordingly [5].

2.2 Getting Acquainted

Before the robot can personalize or safeguard the continuity of the interaction the robot needs to get enough information about the child. And before a bond can be deepened it must be formed first. In other words, a getting acquainted interaction needs to happen before anything else.

When people get acquainted they typically engage in an unstructured conversation where various topics are seemingly discussed freely [8]. However, under the surface there are a lot of implicit social norms and mechanisms that shape the relationship formation process [14]. Sharing personal information, a process often referred to as 'self-disclosure', is one important mechanism [1,16]. Getting acquainted, and forming a bond, does not work if the partner does not self-disclose as well [6]. Research shows that reciprocity is not only important between people, but also between people and artificial agents [5].

The discussed research forms the foundation for our interaction design. The goal is not to imitate how people get acquainted, but to facilitate this process to the best of the robot's ability. In the next section the interaction design is discussed in more detail.

3 The Getting Acquainted Interaction

We have formulated three goals for the getting acquainted interaction. The robot needs to get acquainted with the child, the child must be able to get acquainted with the robot, and the bonding process needs to be initiated.

3.1 The Robot Gets Acquainted with the Child

What we mean with "the robot gets acquainted with the child" is enabling the robot to collect enough information about the child to facilitate a long-term interaction. We have designed robot behaviors that on the one hand elicit children to self-disclose, but on the other hand keep that process manageable for the robot to process it autonomously [12]. All our designs and evaluations do not rely on the Wizard-of-Oz approach.

The main interaction modality is speech. To keep it feasible we apply quite some structure to the conversation. The challenge is to keep the conversation from feeling too restrictive. In our interaction design the robot has the initiative, controls the turn-taking, and asks the children questions about their hobbies and interests.

Children are first prompted to give a concise answer by using closed-ended questions. For example, "would you rather dance or play football?". These constrained questions are followed by an open question that allows children to elaborate themselves. For example, "why is France your favorite holiday destination?". This keeps the conversation from turning into an interrogation. Note that the robot only processes the closed-ended questions. For the open questions, the robot only uses speech activity detection to take the turn back when the child finished answering.

Children have two speech attempts to get their answer across. If the second attempt fails as well, the robot switches to the touch modality. The robot lists all answers possibilities and the child can press a button on the robot's feet to lock in an answer (see Fig. 1). Although children do not have the opportunity to ask questions, the robot shares fictional anecdotes about itself and its own hobbies and interests to reciprocate the self-disclosures of children.

Besides conversational elements we also designed two behavior profiles for the robot. The profiles are relatively less and more energetic in nature. Details can be found in Ligthart et al. [12]. Originally these profiles were meant to result in a matching effect, and stimulate self-disclosure elicitation, for introvert and extravert children respectively. Results show however that all children self-disclosed more to a robot with the less energetic behavior profile [12].

3.2 The Child Gets Acquainted with the Robot

A second goal is the child getting acquainted with the robot. This goal is achieved when three sub-goals are met. Firstly, the child needs to learn how to effectively communicate with the robot. At the start of the getting acquainted interaction the robot demonstrates to the child how to talk to it and offers a practise question. We are interested in the performance of the children making themselves understood by the robot, what and why mistakes were made, and what the influence is of those mistakes are on the outcome of the interaction.

The second sub-goal is managing the expectations of the children. Research shows that inappropriate expectations can reduce the effectiveness of the social support offered by the robot [11]. The design did not include explicit behaviors to manage the expectations. The getting acquainted interaction as a whole is meant to be an accurate representation of what children can expect from future interactions.

The third sub-goal is that the child gets familiar with the robot [9]. This means that the child knows something about the robot and its interests after the interaction. The robot disclosed several personal anecdotes about its hobbies and interests. We are interested in what the children can remember about the robot.

3.3 Child-Robot Bonding

For this last goal we follow the steps taken by Vittengl and Holt (2000) closely. They studied bonding between dyads of children during a short getting acquainted interaction [16]. In their study they followed Baumeister and Leary's work on relationship formation, who established that an increase of positive affect is indicative of bonding [2]. In their study, Vittengl and Holt, established that positive affect increase also occurs when children form a bond. They furthermore found that self-disclosure and social attraction between partners was predictive of the positive affect change [16]. We replicated their set-up, but instead, study child-robot dyads.

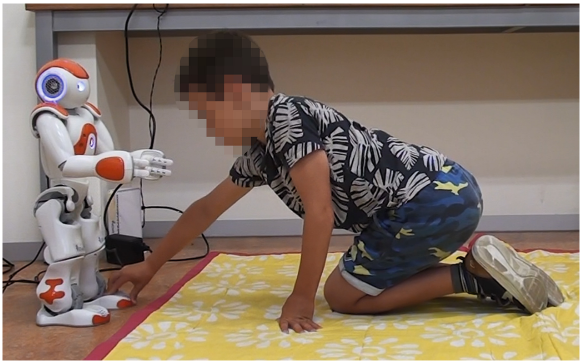


Fig. 1. Child getting acquainted with the Nao robot.

4 Method

4.1 Participants and Experimental Design

75 children (45 girls and 30 boys), between 8 and 11 years old, completed the experiment. The experiment had a 2×2 between-subject design with the personality of the children (introverts vs. extraverts) and the two robot behavioral (lower vs. higher energy) as independent variables. However, the evaluation discussed in this paper was done across all child-robot dyads independent of condition.

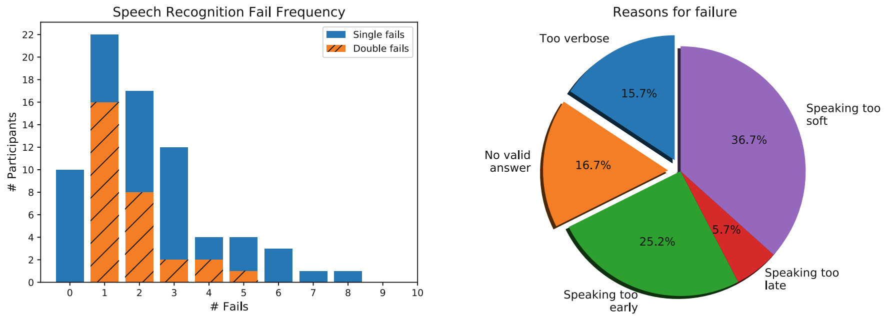
4.2 Set-Up, Procedure, and Materials

The experiment was approved by the ethics review board of our institution. Children interacted one-by-one with the robot for 15 min in an empty classroom at their school (see Fig. 1). Each interaction was recorded on video. After the interaction the children filled in a questionnaire and were interviewed in a separate room.

A Nao robot (see Fig. 1) was used in the experiment. The robot was controlled by a rule-based artificial cognitive agent implemented in the cognitive agent programming language GOAL [7]. The rules were based on the interaction design pattern defined in Ligthart et al. [12]. The agent followed a predefined conversation script, containing the following topics: sports, leisure activities, books, pets, seasons, colors, holidays, and television.

4.3 Measures and Instruments

Each speech recognition error was logged together with the most probable cause. We investigated the relationship between all speech recognition errors and the outcome of the interaction. The included outcome measures are the amount and



(a) Speech recognition fails (b) Reasons for speech recognition fails

Fig. 2. How much trouble do children have talking to the robot and why?

intimacy of children's self-disclosures, the perceived comfort, social attraction, and positive affect change.

All conversations between participant and robot were transcribed to text. Using the transcripts of the open questions we calculated the *amount* of statements self-disclosed by the children and how *intimate* those self-disclosures where. See Ligthart et al. for a detailed discussion of these measures [12]. Perceived comfort was measured using a custom-made 3-item 5-point Likert-scale. Social attraction and positive affect change are introduced below.

To assess whether children got familiar with the robot we asked them during the exit-interview to recall the topics they discussed with the robots and whether they could recall the favorite tv-series of the robot. We also asked them if they shared interests with the robot.

For researching bond formation we have used the same measures for self-disclosure, social attraction, and affect as Vittengl and Holt [16]. The only difference is that we used the Dutch version of the measures. To measure *perceived self-disclosure* participants were asked to indicate how much they disclosed about 10 different topics. *Social attraction* is a self-report measure used to capture the social attraction of the participants towards the robot. It is heavily based on the social attraction subscale of the Interpersonal Attraction Scale. The Positive and Negative Affect Schedule (PANAS) was used to measure *positive affect* before and after the interaction with the robot.

5 Results

5.1 Child Getting Acquainted with Robot

There were 986 speech recognition attempts. 266 times (27%) the attempt failed. We assigned a reason to each failed attempt. 80% of the fails were due to something the participant did (see Fig. 2b). For example, speaking too soft. In the remaining 20% of the cases the participants followed protocol, but the speech recognition failed nonetheless.

The robot asked ten questions. In Fig. 2a the frequency of participants who failed with zero or more questions are displayed by the blue non-hatched bars. Each participant had two speech attempts before switching to the touch modality. The orange hatched bars show the frequency of participants that failed two speech attempts on one or multiple occasions.

To assess whether there is a relationship between the failed speech recognition attempts (regardless of cause) and the outcome of the interaction a Pearson's product-moment correlation was run. The included outcome measures are the amount and intimacy of self-disclosures, perceived comfort, social attraction, and positive affect change. The results are shown in Table 1.

Table 1. Pearson's correlation results of failed speech recognition attempts with several interaction outcome measures.

Amount of SD	Intimacy of SD	Perceived comfort	Social attraction	Positive affect
−.063	−.303**	−.298**	−.241*	−.077

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

The robot and the child discussed 8 different topics. On average children recalled 3 ± 1 topics with a maximum of 4 topics. 33 (40%) children mentioned they had similar interests as the robot. A Mann-Whitney U test was run to determine if there were differences in amount of topics recalled by the children between those we felt had similar interests and those who did not. Median topic recall scores were not significantly different between both groups (3.00 vs. 3.00), $U = 637$, $z = -.101$, $p = .920$.

37 (49%) children recalled the favorite tv-program of the robot (Pokemon). 21 (.68) children who felt had similar interests as the robot correctly recalled it's favorite tv-program, compared to 16 (.36) children who felt no similarity. A chi-square test of homogeneity showed that these proportions where statistically significantly different, $p = .007$.

5.2 Child-Robot Bonding

The positive affect scores from before and after the interaction were compared. Of the 72 included[1] participants, 48 reported a higher positive affect afterwards, 19 reported a lower positive affect, and 5 reported no difference. A Wilcoxon signed-rank test determined that there was a statistically significant median increase (.35) in positive affect from before (3.40) to after (3.75) the interaction with the robot, $z = 4.55$, $p < .0005$.

A number of things stood out while exploring as to why a smaller, but sizable, portion of the participants had a decrease in positive effect. No statistical differences for positive affect change were observed for age, extraversion, and robot

[1] 3 participants showed signs of an extremity bias, where they maxed out every rating. These data points were deemed unreliable and were excluded.

behavior where observed. This was different for gender. An independent t-test was run to determine if there were differences in positive affect change between boys and girls. Girls (.35 ± .40) have a statistically higher positive affect change than boys (.15 ± .45), $t(70) = 2.00$, $p = .049$, $d = .48$. The 19 cases of decreased positive affect represents 1/3 of the boys in the sample, compared to 1/5 of the girls. The top 90-percentile contains 10 girls versus 3 boys.

Finally, a multiple regression analysis was run to predict a positive affect change from self-disclosure and the social attractiveness of the robot. The multiple regression model statistically significantly predicted a positive affect change, $F(2, 74) = 4.340, p = .017, adjR^2 = .108$. Only the perceived degree of self-disclosure added statistically significantly to the prediction, $p = .022$.

6 Discussion

6.1 Child Getting Acquainted with Robot

Knowing how to communicate with the robot is a first step for starting a relationship. The robot offered a tutorial at the start of the getting acquainted interaction. Results show that the majority of children (86%) make no to only two mistakes.

Because this part of the study was not in the form of a controlled experiment, we cannot make causal claims about the effect of the tutorial on the mistakes. However, we did observe a high amount of self-correcting behavior among the participants. For example, when the Nao starts listening it beeps and when children spoke before the beep (too early) they would repeat their answer after the beep. This behavior prevented a lot of mistakes. Furthermore, when asked to explain how to talk to the robot, almost all the children mentioned they had to speak loud and clear. This makes it likely that the tutorial had a positive effect on the performance of the children.

Although the overall performance was good, mistakes were made, and some children consistently made the same mistakes. The most prominent mistake was speaking too softly, followed by speaking before the robot was ready. These mistakes can probably be reduced by using a more state-of-the-art speech recognition system. Children being too verbose or saying unexpected things are more tricky to deal with. Improving the conversation management could support the children even more. For example, when the robot detects a verbose answer it could give the child the feedback to be more concise.

These improvements are necessary because the results show that there is a negative relationship between the amount of recognition errors and how comfortable the children feel in the conversation and how socially attractive the robot is. It is plausible that children either blame themselves or the robot (or both) for the mistakes. Furthermore, a negative relationship was found between the amount of errors and how intimate the children's self-disclosures were. No significant relationship was found with the amount of self-disclosures and positive affect change. This suggests that on the short term it does not prevent the robot from getting acquainted with the child and children forming a bond. However, it might have consequences on the long-term, because children initiate a more shallow relationship.

Finally, we also evaluated whether the children got familiar with the robot. We did this by asking what children could recall from their conversation with the robot. Children seem to recall at most four different conversational topics. Experiencing a shared interest with the robot did not influence their recall ability for topics. However, it did influence their ability to remember specific details. Children who felt they shared interests with the robot were more successful in recalling its favorite TV-show. It is important to note that this analysis was done for only one topic.

6.2 Child-Robot Bonding

In our user study we have studied child-robot bonding in a similar fashion as Vittengl and Holt, who studied bonding within child-child dyads [16]. The results first of all show a positive affect increase for most children. This is indicative of forming a bond [2]. More importantly, the results show the same mechanism as with child-child bond formation, namely mutual self-disclosure [16], is steering the bonding process. However, in contrast with Vittengl and Holt's study, we did not find that social attraction was of influence. A novelty effect might have affected the scoring of social attraction.

Most participants took the first step to initiate a bond with the robot. There is however a smaller, but sizable, portion of the participant that did not bond with the robot. The results show a medium sized effect of gender on positive affect change. The majority of the stronger 'bonders' with the robot are girls and a larger part of those who do not seem to bond with the robot are boys. This could be because girls have been found to be more accepting of human-like social robots [15].

7 Conclusion

We have designed robot behaviors meant to facilitate a getting acquainted interaction between children and the robot. We have run a user study (N = 75, 8–11 y.o.) to evaluate that design. We explored whether the children got acquainted with the robot by investigating whether children learned how to communicate with the robot and whether they got more familiar with the robot. By including a 'how to communicate with me' tutorial, children seem to efficiently pick up on how to communicate with the robot. The recurrency of mistakes is low and the children self-correct themselves often preventing speech recognition failures.

Improvements in speech recognition technology and conversation management will lower recognition failures even further, and eventually pave the way for a less restrictive conversation. Improvements are beneficial, because the lower the amount of failures, the more comfortable and intimate the conversation gets and the more socially attractive the robot is.

Preliminary results show that having shared interests is beneficial for recalling specific details about the robot. To find common ground the robot should explore a diverse range of interests, hobbies, and other topics, during the getting acquainted interaction. It is also a useful personalization strategy for future interactions.

We, furthermore, explored whether children bonded with the robot by investigating the changes in positive affect. For most children a bond was initiated with the robot. Just like with other children, mutual self-disclosure is an important factor for bonding with a robot. It were mostly girls who showed the strongest increases in positive affect. On the other end, a larger portion of the boys showed a decrease in positive affect, inhibiting bonding. This reinforces the importance of further personalization.

In this explorative evaluation we establish that our interaction design for an autonomous social robot is on the right track for facilitating a getting acquainted interaction. More importantly, we identified a number of clear leads to improve our design. The next steps are to improve, extend (e.g. hold multiple conversations), and properly validate the interaction design, so that the robot can truly contribute to the social support of pediatric oncology patients.

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