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Technological and Interpersonal Trust in Child-Robot Interaction: An Exploratory Study

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ABSTRACT

This study aimed to explore technological and interpersonal trust in interactions between children and social robots. Specifically, we focused on whether children distinguish between these two types of trust and whether the two constitute independent constructs or interact. Using an exploratory approach, we analyzed the explanations 87 children, aged 7 to 11 years, offered for the degree to which they indicated to trust a robot with which they had just interacted. Our results suggest that children distinguished between technological and interpersonal trust in a robot. Three main categories of answers could be identified: answers relating to technological trust, those indicating the presence of interpersonal trust, and a third category in which children referred to technological properties of robots as a reason for the existence of interpersonal trust. We discuss these findings in light of the development of child-robot relationships and the design of future child-robot interaction studies.

CCS CONCEPTS

• **Human-centered computing~Empirical studies in HCI** • Human-centered computing~User studies • Human-centered computing~HCI theory, concepts and models • Human-centered computing~Field studies

KEYWORDS

Technological trust; interpersonal trust; child-robot interaction; human-robot interaction; child-robot relationship formation

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1 INTRODUCTION

Robots are becoming increasingly social, such that the establishment of social relationships is no longer confined to the domain of interpersonal interaction [e.g., 43]. Notably, children today are increasingly surrounded by social robots and are likely to form social bonds with them [17]. Controversy, however, exists about the desirability of relationship formation between children and robots. On the one hand, scholars emphasize the innocent or even beneficial nature of these social bonds [e.g., 9, 12, 27]. On the other hand, scholars have raised concerns about the deceptive, inauthentic nature and potentially negative consequences of child-robot relationships [e.g., 34, 36, 37]. Although it is currently unclear whether the benefits may outweigh adverse consequences or vice versa, child-robot relationships are likely to become more frequent in the near future [e.g., 9]. Therefore, it is generally important to understand the processes with which children establish relationships with social robots.

The literature on interpersonal relationship formation identifies trust as a central component of the development and maintenance of human-human relationships [e.g., 5]. In research on interpersonal relationships, and trust in the context of organizational behavior more specifically, affect- and cognition-based trust [21, 22] have been distinguished. Affect-based trust stems from interpersonal care and concern, whereas cognition-based trust stems from a belief in another person's reliability and dependability [22]. Similarly, Mayer et al. [25] distinguish between benevolence- and competence-related trust (next to integrity-related trust, which is not relevant to this paper). Here, benevolence-related trust indicates the existence of some degree of interpersonal attachment between the trustor and the trustee, while competence-related trust refers to domain-specific abilities that afford trust in an individual [e.g., in technical domains; 22]. Thus, trust is both domain-specific [42] and multidimensional [22].

With respect to human-robot interaction (HRI), scholars have distinguished between technological trust and interpersonal trust in a robot [41]. Technological trust can be defined as "the attitude that an agent will help [to] achieve an individual's goals in a situation characterized by uncertainty and vulnerability" [20, p. 51], or "the extent to which a user is willing to act on recommendations of a system" [23, p. 1]. Interpersonal trust respectively refers to "an individual's willingness to be vulnerable" [41, p. 3] in the presence of a robot. Thus, trust in HRI is also conceptualized as multi-dimensional, with dimensions that mirror those identified in the literature on interpersonal trust.

The multidimensional character of trust in HRI is reflected in the findings of a meta-analysis by Hancock et al. [14] on the predictors of trust in HRI. The study found that robot-related factors, such as robots' performance (e.g., their reliability, predictability, and level of automation), increased people's trust in robots. By contrast, human-related and environmental factors, such as personality traits and task type, only played a moderate role in the development of trust between humans and robots. Adults' trust in robots thus seems technology-based rather than related to interpersonal processes. In the context of child-robot interaction (CRI), however, a recent review on trust between children and robots did not reach this conclusion: Overall, the influences of robot-, human-, and environment-related factors on children's trust in robots were scarce and often inconsistent [38]. Thus, it remains unclear how findings on adults' trust in robots translate to the domain of CRI.

The review on trust in CRI proposed that one reason for the inconsistency of trust-related findings in CRI is that explicit conceptualizations and operationalizations of trust were often missing or varied between studies [38]. When studies did report conceptualizations and operationalizations of trust, they either addressed children's opinions and behaviors related to technological trust [e.g., 16, 19, 32, 33], or centered on interpersonal trust in a robot [e.g., 6, 7]. The possible interdependence of technological and interpersonal trust in CRI, however, has remained unstudied.

When focusing on the inconsistent findings on children's versus adults' differential trust in robots, an influence of environmental factors surfaced: The differences in whom children trusted more (i.e., a robot or an adult) appeared to depend upon the nature of the interaction task [38]. For example, children more frequently asked help from an adult than from a robot during a construction task [32], but complied more often with a robot than with a friend during a card guessing game [33]. These findings may be explained by children's specific considerations of "whom to trust when." From children's point of view, adults may know better than robots how to construct things with three-dimensional objects, whereas robots may be better at mathematical problems, such as predicting chance in a card guessing game. The above two findings may thus be related to children's domain-specific degree of technological trust in robots: In the construction task, children lacked technological trust in the robot; in the card guessing game, they had technological trust in it. Another study, in turn, found that children more often provided sensitive information about peers to a robot than to an adult [6]. This behavior suggests that children show interpersonal trust in a robot. In sum, it seems that children differentially trust robots and adults, depending on the conceptualization of trust.

Overall, then, previous research suggests that children have different types of trust in robots, depending on the scenario in which they interact with them. However, empirical evidence is lacking. At least two questions remain: First, do children actually distinguish between technological and interpersonal trust in their judgement of a robot's trustworthiness? And second, are technological and interpersonal trust independent of each other, or are there scenarios in which the two interact? In a first attempt to answer these questions, this study presents an exploratory investigation of children's verbal explanations of the degree to which they indicated to trust a robot they had just interacted with. Our aim is to advance the understanding of trust as a key component of children's tendency to bond with social robots.

2 METHOD

The data in this paper are part of a study whose main goal was to develop and validate standardized measures for CRI. These measures included a number of self-report scales that assess children's perception of a robot, their internal states during an interaction with the robot, their appreciation of the interaction with the robot, and children's cognitive development as well as personality. In the present paper, we draw on qualitative data consisting of children's explanations of the degree to which they indicated, in open-ended answers, to trust the robot in response to previously posed closed-ended questions on their trust in the robot. Ethical approval was obtained from the Ethics Review Board of the Faculty of Social and Behavioral Sciences of the University of Amsterdam before data collection.

2.1 Participants

Eighty-eight children from two Dutch elementary schools initially participated. One participant did not complete the interaction. We thus analyzed the data of 87 children (48 female, 39 male). Children's age ranged from 7 to 11 years, with an average age of 9.17 years (SD = 0.85). Our sample thus includes children from middle childhood [i.e., 6 to 12 years of age; see 3]. In that developmental period, children's friendships gradually start to increase in closeness [for an overview, see 3]. This makes the investigation of relationship formation more meaningful in this age group than in younger age groups of children. Moreover, middle childhood friendships are generally based upon more fundamental interpersonal criteria than friendships among younger children [see 8]. Most important, in middle childhood trust begins to play a significant role in children's friendships [see 2, 13, 18].

2.2 Procedure

The study was conducted at two Dutch elementary schools. Prior to conducting the study, active consent was obtained both from the two schools and from the parents of participating children. To increase children's comfort with the interaction setting [39], the study was introduced to each class before the start of the first interaction session. The female experimenter and the female interviewer introduced themselves, their roles, and the study goals and procedures. Children were shown a picture of the robot. They were informed, in age-appropriate language, that their participation was voluntary, that no personally identifiable information would be published, and that they could withdraw from the study at any point before, during, or after the interaction without giving any reasons. Finally, they were given the opportunity to pose remaining questions. Answers to questions about the robot were postponed until the debriefing to prevent an influence of the provided information on children's initial robot perception.

The interaction took place in a quiet room to minimize distractions. Children were instructed to sit down on the floor in front of the robot, at a distance they felt comfortable with. They were then asked whether they were willing to participate and reminded that they could end their participation at any point in time, without giving a reason. Once they indicated that they understood and agreed with the procedures, the experimenter started the interaction, which was videotaped if parents had given their consent. As the study relied upon a Wizard of Oz set-up, the experimenter was present during the interaction, operating the robot from a distance through a laptop. The robot was activated before the child entered and only deactivated after the child had left the room.

Upon finishing the interaction, the experimenter accompanied the child to another room in which the interviewer conducted a survey. The interviewer orally presented the children with mainly closed-ended questions on measures relevant to CRI, accompanied by some open-ended questions. Several closed-ended items addressed children's degree of trust in the robot. After answering these items, children were asked to motivate their previous trustworthiness judgements in an open question (i.e., "And how come?").

Following the approach taken by former CRI studies [e.g., 31, 40], children were debriefed at class-level. Immediate, individual debriefing seemed unnecessary as this is only required when the interaction likely causes distress or negative self-reflections [e.g., 11], which was not the case in the present study. Moreover, the debriefing at class-level allowed children to hear the answers to other children's questions. In that way, they obtained information that they may have missed otherwise. During a ten-minute presentation, children were informed about the nature and working of the robot. The Wizard of Oz paradigm was revealed and it was emphasized that the interaction was fully scripted. To finish, some differences between humans and robots were pointed out, and children were allowed to pose any remaining questions. At the end of the debriefing, they received a little present to thank them for their participation.

2.3 Interaction task

Each child engaged in an interaction with a Nao robot (SoftBank). On average, the interaction lasted about 8 minutes. The interaction included four stages. First, the female experimenter introduced the child to the robot. Second, the robot engaged the child in small talk by asking a couple of questions. Third, the experimenter suggested that the child and the robot play a guessing game together. During the game, the robot made a series of assertions (e.g., "I love to eat fries") and the child had to guess whether they were true or false. To prevent deception [10], the robot never claimed or implied to have truly human capabilities (e.g., feelings, consciousness). After each guess, the robot provided the child with the correct answer and some additional explanation (e.g., "Like toys and computers, robots do not eat; instead they need electricity to function."). Throughout the game, the robot asked the child several personal questions (e.g. "What is your favorite color?") and engaged in small talk to decrease repetition. Fourth, the robot and child said goodbye and the child was led to the interview room.

2.4 Data analysis

We read through children's explanation of the degree to which they indicated to trust the robot using a 'template analysis style' [24]. In the 'template analysis style,' the data are coded into predefined, theory-based categories. In our case, these are technological and interpersonal trust, which we defined above. Motivations (not) to trust a robot were categorized based on their indication of the presence or absence of either technological or interpersonal trust. Subcategories of these two types of trust were inductively defined, in line with procedures in qualitatively oriented research.

3 RESULTS

When analyzing the data, three general findings regarding trust judgments emerged. First, certain children did not provide an explanation for their level of trust in the robot (N = 14). Thus, we eventually analyzed 73 explanations. Second, expressions of interpersonal trust were more prevalent than expressions of technological trust. Third, in addition to the two predefined categories of technological and interpersonal trust, a third category of trust judgments was inductively identified. Based on existing literature, it was not possible to anticipate this category and define it theoretically before. This third category contained answers that express interpersonal trust while referring to technological properties of the robot.

3.1 Technological trust

Several children's motivations for (not) trusting the robot can be linked to technological trust, which concerns people's willingness to rely on the capacities of a device or system (e.g., robot), as defined above. Responses that referred to technological trust could be grouped into two subcategories that related to the robot's technological sophistication or to its technological limitations respectively.

In the first subcategory, we grouped responses of children who indicated to trust the robot because of its sophistication. Children were willing to rely on the robot because, in their view, its technology is advanced enough to think of the robot as a competent other, which justifies a certain degree of trust. For instance, children referred to the robot's memory and intelligence: *"Robots have a memory, they are smart, and usually do the right thing"* (participant [pp] 53) or *"Robots are smart, can remember things, and see everything with their brains"* (pp 65). This subcategory also contained answers that convey children's awareness of 'the man behind the machine.' Instead of simply pointing to the robot's capacities, children provided reasons for trust which were based upon their knowledge that robots are technological products made and controlled by humans. This awareness was illustrated, for example, by the answer of a child who explained to trust the robot because *"you can program a robot to be reliable"* (pp 33). Another child argued that *"it is a robot and people have worked on it for a very long time, it seems very real"* (pp 69).

In contrast to the first subcategory of answers, a second group of motivations within the category of technological trust referred to the limitations in robots' technology rather than to its sophistication. For instance, children explained that *"it is a robot that can break, and then it cannot do what I tell it to do"* (pp 34), and that *"a robot does not remember very much"* (pp 73). In this subcategory, we also included answers that refer to the robot's artificial, non-human nature. Albeit less directly, these answers also pointed to robots' lack of certain capacities (i.e., robots' limited sophistication as compared to humans). Examples of explanations offered by children were: *"It is not really a human being"* (pp 06), and *"It is not a human"* (pp 76).

3.2 Interpersonal trust

Another, much bigger group of children explained their degree of trust in the robot by referring to elements of interpersonal trust or the readiness to be vulnerable toward the robot. Within this category, two subcategories of answers could be distinguished: those that made a comparison between Nao and other actors, and those that expressed how children felt about the conversation they had with Nao.

Within the first subcategory of assertions related to interpersonal trust, several children determined their interpersonal trust in the robot by comparing it to other entities, either robotic or human. Their judgement of Nao's trustworthiness thus depended on their view of Nao's behavior as compared to that of other actors. The following answers illustrate this: *"With a friend, you are never entirely sure that she does not pass on your secrets, but with a robot you are"* (pp 10) or *"You can't trust all robots, because some are secretly dangerous, but Nao is cute and nice and kind and if you get to know him you learn that you can trust him"* (pp 32). Similarly, another child emphasized that *"it is not an aggressive robot, this one is sweet, I could just stop at any point and he would never think that was stupid"* (pp 45).

In addition to answers that compared Nao to other actors, a second subcategory emerged in which children explained their interpersonal trust in the robot by pointing to how it talked to them and treated them during the interaction. In doing so, they sometimes referred to Nao's conversational style, for example by saying *"because he talked with me in a familiar way"* (pp 39). Other children pointed to their own level of comfort with the robot, as in *"because I can really speak with him"* (pp 62), or compared the robot to how they relate to other people. For instance, a child replied: *"Because he was very nice, and I trust nice people really quickly, because trust is one of the most important things"* (pp 70).

3.3 Interpersonal trust based on technological properties

Several children motivated their degree of trust in the robot by referring to technological properties of the robot in combination with aspects of interpersonal trust. In these cases, the robot's technological properties thus seemed to figure as a precursor of interpersonal trust. Three subcategories of answers could be distinguished. They refer, on the one hand, to the robot's technological sophistication and, on the other hand, to two types of technological limitations: physical and cognitive ones.

The responses that pointed to Nao's technological sophistication resemble the examples provided in the similar subcategory of technological trust (see 3.1). However, in contrast to the motivations presented earlier, the explanations here center on interpersonal trust by explicitly mentioning the robot's advanced technology as an underlying reason for trust. Examples of such responses are: *"A robot can remember everything, and if it is a secret, he will not tell it, only if his friend allows him to"* (pp 15), and *"Robots can be kind of smart, and will not pass anything on if you do not want them to"* (pp 63). In this subcategory, we also included children's assertions about the robot's preprogrammed, manufactured nature, such as *"I think that robots will not just pass something on. I think most children got the same interaction with Nao as I did and he did not tell a secret so far"* (pp 18), and *"He's a robot, and robots are mostly built to be sweet"* (pp 24).

Among explanations that relate technological limitations to interpersonal (dis)trust in the robot, we found two main subthemes. First, several children referred to the robot's physical incapacities as a reason for (dis)trusting the robot on an interpersonal level. For instance, one child pointed out Nao's limited moving capacities: *"Nao says he can do many dances, but he only showed one, so is that really true? A robot cannot move its arms and legs very well because they are made of iron"* (pp 01). Others referred to its inability to truly hear and speak: *"He does not pass anything on because he cannot hear anything"* (pp 29) or *"Robots cannot really talk themselves, so they also cannot pass anything on"* (pp 74). Another child also made a more general assertion regarding its physical capacities: *"A robot will not pass anything on, but will not always be able to help me"* (pp 44).

A second group of children motivated their interpersonal (dis)trust in the robot by pointing to its various cognitive inabilities. Similar to some explanations provided in the category of technological trust (see 3.1), they related, amongst other things, to the robot's limited memory capacities and intelligence: *"He was little and a robot, so he cannot remember that much and so he also cannot pass on much"* (pp 09) or *"Because it is a robot, and robots almost never get angry, but sometimes they do not understand something"* (pp 16). One child remarked that *"he is very trustable and kind, but the downside is that robots can often say something that was supposed to remain secret"* (pp 51).

4 DISCUSSION

This study explored the emergence of technological and interpersonal trust in CRI. Our data tentatively suggest that children aged 7 to 11 years differentiate between technological and interpersonal trust in their reasoning about a robot's trustworthiness. Thus, the multi-dimensionality of trust seems to manifest itself in children's assessments of trust in robots, which reflect categories previously identified in research on HRI and interpersonal trust. Answers that pointed to the presence of technological trust referred either to the robot's technological sophistication or to its limitations. Children who motivated their trust levels with statements about interpersonal trust compared the robot to other actors or explained why the robot can be trusted by referring to its social behavior. Overall, answers related to interpersonal trust were much more prevalent than references to technological trust.

We also investigated whether technological and interpersonal trust are independent of each other or whether there are scenarios in which the two interact. We found that children motivated their interpersonal trust in the robot by mentioning the sophistication or limitations of its technology. No specific references to both technological and interpersonal trust emerged and it would thus be premature to conclude that the two interact. Still, children's interpersonal trust in a robot seems to depend, at least partly, on their considerations of the robot's technological properties: The children related the technological properties of robots causally to interpersonal trust by explaining why certain technological features led to (dis)trust in the robot on an interpersonal level.

While answers referring to interpersonal trust included references to the robot's technological *properties*, children did not explicitly mention technological *trust* in their explanations of interpersonal trust. Such reasoning patterns may be absent simply because, from children's point of view, technological trust may not precede interpersonal trust although they seem to associate interpersonal trust with precursors of technological trust. Moreover, as children's causal reasoning becomes more advanced and complex only in the course of middle childhood [29, 30], the majority of the children may also have lacked the cognitive skills necessary to provide such complex explanations. Finally, the concept of trust may be elusive to children, as illustrated by the fact that some children did not provide an explanation of their level of trust in the robot.

Taken together, our results imply that children's relationship formation with social robots should be approached in a different way than the establishment of human friendships, at least when it comes to the development of trust. It seems necessary to look, next to interpersonal processes, also into the emergence of technological trust to better understand children's overall level of trust in a robot. Accordingly, the ongoing discussion about child-robot relationship formation [9, 12, 27, 34, 36, 37] may benefit from broadening its focus beyond interpersonal features of child-robot trust and relationships. As technological properties of social robots may predict children's (technological and/or interpersonal) trust in them, a more comprehensive approach may be required to map the full range of causes and consequences of child-robot relationship formation.

A limitation of the current paper is that the data we analyzed were not the central part of the study in which they were collected. Consequently, the corpus of answers that we could use was small. Moreover, statements about technological trust and the relevance of technological properties in interpersonal trust judgements were not as prevalent as statements exclusively referring to interpersonal trust. Therefore, the provided evidence in the categories of technological trust and interpersonal trust based on technological properties should not be over-interpreted. The more frequent mentioning of interpersonal trust may have been triggered by the content of our closed-ended trust items, which focused on the assessment of interpersonal processes. However, even in this context, references to technological trust and/or technological properties of the robot were made and were distinguishable from answers that purely addressed interpersonal trust.

Another limitation is that children's assessment of technological trust may, at least partly, have been affected by the Wizard of Oz set-up of our study. With that set-up, we made sure that the interaction between child and robot worked smoothly and reliably. However, notably in CRI in the wild, children may encounter malfunctioning robots, which in turn may influence their technological trust.

Several suggestions for future research can be derived from our findings. First, to advance our knowledge of the role of trust in CRI, future research should distinguish between the emergence of technological and interpersonal trust. Second, investigating technological and interpersonal trust in a CRI scenario that focuses also on technological trust would present a more encompassing picture of the frequency with which children refer to interpersonal and technological trust respectively. Third, to build upon the exploratory evidence presented here, the occurrence and possible interdependence of technological and interpersonal trust in CRI should be studied with larger, preferably representative samples of children. This would not only allow for a broader generalization of findings, but also for the investigation of individual differences in children's trust judgments. For instance, studying trust in robots with older children or adolescents, who are capable of more complex causal reasoning [29, 30], may further clarify how technological trust, or technological robot properties, and interpersonal trust are related.

Fourth, the similar categories of trust that we found in both interpersonal interaction and CRI suggest that it might be worthwhile to investigate further similarities between interpersonal and child-robot relationship formation. For instance, the attribution of interpersonal trust seems to vary with people's attachment styles [e.g., 26], which may also apply to children's trust in robots [for a detailed discussion of attachment styles, see 1]. Fifth and finally, previous CRI studies suggest that individual differences between children may affect how they interact with robots. For instance, boys and girls differ in their perceptions of robots [35] and in their estimation of a robot's (trust-related) abilities [15]. Thus, future studies could compare the emergence of different types of trust across biological sexes. In addition, based on prior findings on children's beliefs about robots' intellectual, psychological, and biological characteristics [4], it is possible that individual differences in technological interest and experience with high-tech toys influence the prominence of technological or interpersonal considerations in children's trust-related behavior, which could be disentangled by future research.

To conclude, the present study provides tentative, exploratory evidence for the idea that both interpersonal and technological trust, as well as their possible interrelatedness, should be considered when investigating the emergence of child-robot trust. Our suggestions may guide scholars who aim to further elucidate questions about children's reliance on, and relationship formation with, social robots.

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