The next best friend?

How children perceive and relate to a social robot

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Chapter 7

General Discussion

Social robots have begun to enter children's everyday environment, and their presence in schools and hospitals as well as in households will likely increase in the near future (e.g., Brink & Wellman, 2019; Lutz et al., 2019). As a consequence of social robots' rather natural way of interacting with people (Breazeal et al., 2016) and children's social treatment of non-human others (Epley et al., 2007), social robots constitute a new type of entity to which children may relate socially (e.g., Kahn et al., 2013). While the body of research on child-robot relationship formation is quickly growing (see, e.g., Cañamero & Lewis, 2016; Kory Westlund & Breazeal, 2019b; Ligthart et al., 2019), several theoretical, methodological, and empirical shortcomings of the relatively young field of child-robot interaction (CRI) research hamper a thorough understanding of child-robot relationship formation (e.g., Stower et al., 2021). Against this background, this dissertation set out to extend current knowledge and facilitate future research on the emergence of social relationships between children and social robots.

The dissertation had four central aims. First, it aimed to systematize current knowledge on child-robot relationship formation by means of a literature review (chapter 2). Second, the dissertation aimed to develop and validate a set of self-report measures that can be used by future studies to assess (subcomponents of) child-robot relationship formation (chapter 3). The third aim of this dissertation was to investigate the effects of transparency about social robots' lack of human psychological capacities (chapter 4) and teleoperated working (chapter 5) on children's perception of and relationship formation with social robots. The fourth and final aim was to advance current knowledge on how three communicative processes central to the development of interpersonal relationships (i.e., self-description, self-disclosure, and question-asking) affect how children perceive and relate to a social robot (chapters 5 and 6).

The findings presented in the various chapters of this dissertation together make three contributions to research on child-robot relationship formation. In light of the ethical discussion on child-robot relationship formation as well as the development of social robots with increasingly humanlike capacities and characteristics, these contributions have important implications for both research and practice.

Contribution 1: Systematizing Empirical Research and Providing Validated Measures

Chapter 2 reviewed the literature and organized (potential) predictors, mediators, and moderating variables of child-robot relationship formation into a conceptual model. We, first, found several robot characteristics (i.e., responsiveness, role) and interaction styles (i.e., strategic, emotional) to be associated with closeness, while only responsiveness could be associated with trust. Second, robot characteristics and interaction styles generally appear to be associated with children's engagement in, and enjoyment of, interactions with robots, while their effects on children's affect and cognitive states were less consistent. Third, children appear to feel closer to friends than to robots, and closer to robots than to objects, and children's enjoyment of interactions which each follow a similar pattern. Fourth, as children grow older, they appear to become more sensitive to robots' interaction styles, less prone to anthropomorphic tendencies, and seem to enjoy interactions with robots less. Fifth and finally, boys seem to prefer robots that match their sex.

The review identified key challenges of the field and concluded with various recommendations for future research. Two of these recommendations – i.e., the need for clear conceptualizations and operationalizations of concepts relevant to child-robot relationship formation, and the need for valid and reliable measurement instruments to assess these concepts – were addressed in chapter 3. That is, chapter 3 described the development and validation of three self-report measures that can be used to assess children's closeness toward, trust in, and perceived social support from, a robot. All three scales proved to be valid and reliable and offer future research the possibility to assess child-robot relationship formation, or specific components thereof, in a relatively concise and easy-to-apply manner. The literature review in chapter 2 suggests that although initial research allows us to distill which concepts may play a role in child-robot relationship formation, much remains to be ascertained regarding the relationships between them. Chapter 3, in turn, demonstrates that this can be done using self-report measures.

While scholars have discussed both positive and negative consequences of child-robot relationship formation, Jones (2016, p. 89) has argued that "there is insufficient empirical evidence for substantiating either position." In line with his statement, we argue that the current lack of comprehensive insights into the emergence of child-robot relationships hampers the discussion about its consequences. Without a solid answer to the question when and how child-robot relationships emerge,

it is difficult to evaluate whether attempts to encourage their development are justified and to estimate how relationships with robots may affect children's social development. Therefore, the first part of this dissertation systematized the empirical literature on child-robot relationships, offered recommendations regarding research practices, and presented self-report measures through which child-robot relationship formation can be assessed among children in middle childhood. In doing so, the dissertation paves the way for cumulative research on child-robot relationship formation to develop answers to the questions when, how, and with what consequences children relate to social robots.

Contribution 2: Clarifying the Effects of Transparency about Social Robots

Based on the insights and measures generated in chapters 2 and 3, chapter 4 studied how transparency about a social robot's lack of human psychological capacities influences children's perception of and relationship formation with a social robot. Previous research on the topic has suggested that transparency about robots' technological nature and working is ineffective (i.e., Bumby & Dautenhahn, 1999; Kory Westlund et al., 2016; Turkle et al., 2006). In contrast to these findings, chapter 4 shows that informing children about a social robot's lack of intelligence, self-consciousness, emotionality, identity construction, and social cognition (see Hubbard, 2011, after Dennett, 1988) decreases children's perception of the robot's animacy, anthropomorphism, social presence and similarity to themselves, as well as relationship formation in terms of trust. However, in accordance with earlier research (i.e., Bumby & Dautenhahn, 1999; Kory Westlund et al., 2016; Turkle et al., 2006), children's sense of closeness toward the robot remained intact.

Subsequently, chapter 5 investigated whether and how revealing the WOZ paradigm, in which a robot is being remotely controlled, affects how children perceive and relate to a social robot. Previous studies have obtained mixed findings that also do not provide detailed insight into children's perception of, and relationship formation with social robots (e.g., Cameron et al., 2017; de Haas et al., 2016; Tozadore et al., 2017; Turkle et al., 2006). Chapter 5 demonstrated that revealing the WOZ paradigm before children interacted with a social robot decreased their perception of the robot's autonomy and anthropomorphism, while no effects were found on children's perception of the robot's animacy, social presence, and similarity to themselves, and child-robot relationship formation in terms of closeness and trust.

Together, chapters 4 and 5 provide experimental evidence that shows that being transparent to children about a social robot is useful but does not prevent the emergence of child-robot relationships altogether, as children continued to consider the robot a (potential) friend. Still, both chapters show that transparency can evoke a shift in children's perception of a robot. Kahn et al. (2013) proposed that children may be unable to make clear judgements about, among others, social robots' aliveness and social otherness because they conceptualize social robots as a new ontological category that defies traditional distinctions between, for instance, the inanimate and the animate. Our findings, however, suggest that transparency about social robots can increase children's understanding of a robot's characteristics, thus contradicting the idea that children, per definition, find questions about these characteristics "puzzling and answer each of them 'yes and no'" (Kahn et al., 2013, p. 35). At the same time, children remained somewhat hesitant about social robots' overall similarity to humans, animals, and machines even when their perception of particular robot characteristics became more pronounced (chapter 4). Transparency thus has the potential to alter children's conceptualization of social robots in terms of specific characteristics and, to some extent, influence their (still hybrid) ontological classification of robots more generally.

In terms of relationship formation, it is conceivable that changes in children's robot perception led them to imagine the robot to be a different *kind* of friend in transparent interaction contexts – thus shifting children's notion of relationships with robots. This idea receives support from the finding that children's level of trust in the robot decreased when they were informed about the robot's lack of human psychological capacities (chapter 4). It currently remains unclear to what extent children's social relationships with robots resemble their relationships with people, animals, and objects (e.g., Kory Westlund et al., 2018). However, our findings initially suggest that the way we interpret child-robot relationships may depend on the way social robots are introduced to children. This implies that child-robot relationship formation is not something entirely beyond control, but a process that, at least to some extent, can be influenced by transparency about social robots' machine nature and corresponding (lack of) capacities.

The findings about transparency (chapters 4 and 5) have two important implications for future research on children's interactions and relationship formation with social robots as well as the use of social robots in societal applications. First, the finding that transparency can alter children's perception of, and to some extent their relationship formation with, social robots importantly provides initial empirical support for criticisms against not being

open to children about social robots' machine status (e.g., Sharkey & Sharkey, 2020). Second, the finding that transparency does not prevent children from conceiving of social robots as potential friends implies that being open to children about robots' technological nature and limitations does not stand in the way of effective societal robot applications. That is, the development of social relationships between children and robots appears to be conducive to the use of social robots for, among others, education and healthcare purposes (e.g., Kory Westlund & Breazeal, 2019a; Sinoo et al., 2018). Accordingly, CRI studies often focus on the question of how social relationships between children and robots can be intensified (e.g., Cañamero & Lewis, 2016; Kory Westlund & Breazeal, 2019b). Our findings, however, indicate that children may develop feelings of friendship toward a robot even when they are made aware of its technological, machinelike character. Thus, desired outcomes of children's interactions with robots may be achieved without presenting social robots to children in deceptive ways.

We acknowledge that even when children are provided with transparent information about social robots, the design of such robots often inherently encourages the formation of social relationships. For instance, robots with a child-like appearance may "encourage people to switch on their baby-scheme and treat it as a cute creature in need of protection and care" (Breazeal & Foerst, 1999, p. 377). Lacey and Caudwell (2019) are critical toward the 'cute' design of social robots, which according to them "establishes ideal conditions for the creation of social and emotional intimacy" (p. 377) by decreasing people's agency and deceiving them about social robots' potential to take on the roles of companions. Based on similar concerns, Scheutz (2012) suggests that a social robot's appearance *and* behavior may need to continuously signal that the robot "is a machine, that it does not have emotions, [and] that it cannot reciprocate […]" (p. 218).

At the same time, when presented with technological artifacts that exhibit even minimal social cues, people automatically attribute humanlike traits to these artifacts and respond to them as they would respond to humanlike others, as research in the Computers as Social Actors paradigm has shown (see Reeves & Nass, 1996). Thus, as admitted also by Scheutz (2012), *preventing* people – and especially children – from relating to robots may be unrealistic. It may be possible, however, to influence how the development of a child-robot relationship unfolds and, by consequence, what kind of relationship emerges. Similarly, Lacey and Caudwell (2019, p. 379) propose that cute robots provoke "quick and easy" yet meaningless affections. In contrast, emotionally more durable relationships with robots might be less acute and intense, but may eventually more positively affect

people by, for instance, encouraging them to engage in meaningful activities (Caudwell et al., 2019). In sum, then, transparency about social robots may allow children to gain a better understanding of what robots are and may evoke more realistic expectations of their relationships with robots. As a consequence, child-robot relationships may emerge that are a less deceptive but equally effective in reaching the desired outcomes of CRI applications.

Contribution 3: Showing CRI Does Not (Have to) Mirror Interpersonal Communication

Next to the effects of transparency about the WOZ paradigm, chapter 5 set out to investigate the effects of a social robot's self-description (i.e., sharing of factual self-related information from a first-person perspective) on children's perception of and relationship formation with a social robot. Although previous CRI studies have suggested that self-description fosters the emergence of a child-robot relationship (i.e., Kanda et al., 2007; Ligthart et al., 2020, 2019; Shiomi et al., 2015; van der Drift et al., 2014), causal evidence for this claim is lacking. We found no influence of self-description on children's perception of the robot's animacy, autonomy, anthropomorphism, and social presence, and their feelings of closeness toward and trust in the robot. Self-description had an adverse effect on children's perception of the robot's similarity to themselves, possibly because the robot's provision of transparent information about itself in the first rather than the third person may have emphasized to children how *this* robot was, in fact, *unlike* them in many ways.

Finally, chapter 6 investigated whether and how a social robot's self-disclosure (i.e., sharing of personal, as opposed to factual, self-related information) and question-asking influence children's perception of and relationship formation with a social robot. Previous studies have suggested that robots' self-disclosure increases child-robot relationship formation (e.g., Gallego Pérez et al., 2019; Kory Westlund & Breazeal, 2019b), yet it remained unclear how the content of the disclosed information affects this process. Likewise, the effects of a robot's engagement in question-asking required further investigation (see Ceha et al., 2019; Kruijff-Korbayova et al., 2014, for two studies on the topic). Chapter 6 found self-disclosure to have an adverse effect on children's perception of the robot's ability to understand their affective perspective, leaving children's perception of the robot's cognitive perspective taking abilities and social presence, as well as their feelings of closeness toward and trust in the robot, unaffected. The robot's

question-asking increased children's belief in the robot's ability to take their cognitive perspective as well as children's trust in the robot, without affecting the remaining variables.

Chapters 5 and 6 suggest that communication processes may sometimes manifest themselves differently in CRI than can be expected based on the literature on human-human communication. That is, the absence of several expected findings shows that some processes established in research on interpersonal communication may be ineffective – or perhaps even counterproductive – when used by a robot. Possibly, this finding signals that children may not always expect social robots to communicate like people. In addition, social robots are still limited in their capacity to adequately follow the conventions of interpersonal interactions in their conversations with children (e.g., van den Berghe et al., 2019). As a consequence, the use of interpersonal processes in interactions with robots might miss intended effects (see also Fox & Gambino, 2021). Although much research still needs to be done on that issue, an important implication of our findings is that social robots may not always have to live up to interpersonal standards in order to achieve envisioned goals. Our findings may thus initially challenge the commonly made assumption that "humans prefer to interact with machines in the same way that they interact with other people" (Fong et al., 2003, pp. 145–146).

At a more general level, the findings also question whether humanizing the interaction capacities of social robots necessarily results in more natural interactions with better outcomes (see Giger et al., 2019, for a critical discussion). As people will not abandon interpersonal communication principles altogether when interacting with robots (see Krämer et al., 2011), communication science presents a useful starting point for studying and designing (children's) interactions with social robots (see also Edwards et al., 2019). However, people will become increasingly used to interactions with technological entities, such that their expectations of interactions with robots may not always mirror interpersonal expectations (Fox & Gambino, 2021). This may especially be true for children who may grow up surrounded by social robots and for whom interactions with robots may be a normal element of life (e.g., de Graaf, 2017).

Against this background, we should carefully investigate which communicative processes may truly be beneficial to children's interactions and relationship formation with robots, and which may not (see also Kennedy et al., 2015; Stower et al., 2021). Our findings also suggest that even relatively basic elements of robots' interaction (e.g., asking questions, saying "I") may affect children's

responses to social robots. Such features may easily be overlooked but deserve the same consideration as more complex robot behaviors (e.g., self-disclosure) in the investigation of children's perceptions of, and relationship formation with social robots.

In sum, this dissertation shows that similarities between interpersonal communication and interactions with robots should be investigated rather than assumed, and that differences between the two deserve more research attention. As Zhao (2006, p. 412, emphasis added), summarizes it, "humanoid social robots are designed to interact with, for *and as humans*." However, it should be kept in mind that social robots "are not humanlike enough at this time to meet the fundamental assumptions and claims of key interpersonal theories, and it is unclear when, or if, they ever will be" (Fox & Gambino, 2021, p. 4).

Looking Back: Limitations

When interpreting the findings of this dissertation, four main limitations should be taken into account. First, we conducted all of our experimental studies with children who were 7 to 10 years old, because children in this age range (i.e., middle childhood; Cole et al., 2005) begin to develop increasingly close friendships that are based upon fundamental interpersonal criteria (e.g., Bernath & Feshbach, 1995; Cole et al., 2005). In addition, they increasingly develop a sensitivity to social conventions and discourse elements as well as the ability to discern what is real from what is not (e.g., Stafford, 2004). Therefore, middle childhood is a developmental period in which we could meaningfully study the effects of transparency about social robots, as well as of a robot's use of communicative processes, on children's perception of and relationship formation with a social robot. However, it remains to be ascertained to what degree our conclusions apply to younger and older children's interactions with social robots. Younger children may more readily trust (e.g., Di Dio et al., 2020) and anthropomorphize (e.g., Cameron et al., 2015; Kim et al., 2018; Manzi et al., 2020) social robots. In contrast, adolescents may less readily consider robots to be social, mental, and moral others (Kahn et al., 2012) and may have different expectations and desires of their interactions with social robots (e.g., Björling et al., 2020). In sum, children's perception of, and relationship formation with, social robots may change with children's age, and the effects of transparency and interpersonal processes may vary accordingly.

Second, all of our studies were conducted with the humanoid Nao robot (Softbank). As Softbank writes on their website, "Nao easily create[s an] empathic link with kids", among other things due to its humanlikeness (Softbank Robotics, n.d.). Although the ability to verbally communicate with children was a prerequisite for our studies, using a social robot with a less humanlike appearance might have resulted in different findings (see also Stower et al., 2021). For instance, Manzi and colleagues (2020) found that children anthropomorphized the Nao robot more strongly than the more mechanical-looking humanoid robot Robovie (Hiroshi Ishiguro Laboratories, Advanced Telecommunications Research Institute International, Japan). In addition, Tung (2016) found that the anthropomorphism of social robots' appearance affects children's social attraction toward robots – robots like Nao being considered most attractive. Moreover, the findings of chapter 2 indicated that the presentation of social robots to children as creatures that are younger and less capable than the children themselves may encourage child-robot relationship formation. Nao is rather small and children who participated in our studies often told us they thought it was cute. Our finding that children felt close to the robot no matter what may thus partly be influenced by the type of robot we used.

Third, our studies were cross-sectional, one-interaction-only studies and it remains to be further ascertained how children's perception of, and relationship formation with social robots unfolds longitudinally, beyond their initial encounter, and after multiple interactions. Children's first impressions of a social robot are important and determine whether a child-robot relationship will be initiated (Ligthart et al., 2019). However, once the novelty effect wears off and children's initial excitement about a social robot diminishes (see, e.g., Leite et al., 2014), their belief in the robot's friendship potential may decrease. Moreover, the effects of interpersonal processes and transparency may change over children's repeated encounters with a social robot. Interpersonal processes that seem to foster the initial emergence of a child-robot relationship may, over time, need to be complemented with more complex communicative processes to sustain the relationship (Baxter et al., 2011; Kanda et al., 2007). Conversely, processes that may not be central to the initiation of child-robot relationships may still play a role in their maintenance (see also Oh & Kim, 2010, on the growing importance of social attributes over time).

It is also unclear how transparency about social robots will affect children's perception of a robot and their sense of relationship with it when transparent information is provided to children repeatedly over multiple child-robot encounters. One possibility is that, when a robot's novelty wears off, children's

increasingly critical stance toward the robot will make them more receptive to information about its limitations. Alternatively, when children's sense of closeness to a robot increases over encounters, they may start to care *less* about the robot's limitations – such that transparency about social robots may become less effective in the long run. Furthermore, we do not know how long transparent information will sustain its influence on children's perception of, and sense of relationship with, a social robot. For transparency about social robots to remain effective, an ongoing effort may be required to continuously remind children of the inherent limitations of 'robotic friends.'

Fourth and finally, although we conducted our experiments in schools and museums, we used controlled, rather laboratory-like set-ups. Because of the measures we took to ensure children would be able to focus on the interaction and to maximize the comparability of the interaction sessions, these set-ups were quite different from the social contexts in which children may encounter robots in the future. While controlling any variation other than the experimental manipulation is a precondition to the conclusive power of experimental studies, it remains to be ascertained how our findings transfer to less controlled interaction settings (see Jung & Hinds, 2018; Salter et al., 2010, on interactions with robots "in the wild"). For instance, children may respond to a social robot differently when they choose freely when and for how long they will interact with it (see De Jong et al., 2019). Moreover, children's spontaneous interactions with robots will be less structured and more prone to robot malfunctioning (Serholt et al., 2020), which may all affect how children perceive and relate to a social robot (see also Geiskkovitch & Young, 2020).

Looking Forward: Future Directions

Apart from the suggestions for future research that follow from the limitations of this dissertation as discussed above, three more general directions for future research can be distilled from the findings presented in this dissertation. First, we call for research on child-robot relationship formation to aim for knowledge accumulation by more strongly building upon existing research and theory (see also the recommendations of Eyssel, 2017 for social robotics research). The establishment of a coherent understanding of relevant concepts and the systematical, experimental investigation of their role in the emergence of child-robot relationships could advance the maturation of the research field (see also Stower et al., 2021). The investigation of more elaborate arrangements of variables could eventually allow for model- and theory-building and more encompassing

explanations of the emergence of child-robot relationships (see also Fox & Gambino, 2021, on human-robot relationships). Although this dissertation took initial steps into this direction, it raised at least as many questions as it could resolve. For instance, we did not investigate the potential interdependence of children's perceptions of, and relationship formation with, social robots, because the direct effects of transparency and interpersonal processes on each needed to be clarified first. We encourage future research to continue our efforts, as only a thorough understanding of child-robot relationship formation will allow us to anticipate the consequences of social robots' increasing presence in children's lives.

Second, issues being raised in the ethical discussion about child-robot relationship formation deserve a more prominent position on the CRI research agenda (see also, e.g., Grinbaum et al., 2017; Jones, 2016; Pearson & Borenstein, 2014; Sharkey & Sharkey, 2020). To date, a rather rigid distinction persists between scholars who voice ethical concerns about the emergence of child-robot relationships on the one hand (e.g., Sharkey & Sharkey, 2020; Turkle, 2007) and empirical research on the encouragement of child-robot relationship formation on the other (e.g., in healthcare contexts; Cañamero & Lewis, 2016; Díaz et al., 2011; Sinoo et al., 2018). Accordingly, we call for empirical research that takes a critical stance toward the emergence of children's social relationships with robots and investigates how undesirable consequences of child-robot relationship formation could be accounted for. A recent research proposal by Geiskkovitch and Young (2020) takes a notable step in this direction, outlining studies on the possibility to decrease children's overtrust in social robots by intentionally having robots make errors (see also Wortham & Theodorou, 2017, for a proposal on trust and transparency in the broader context of human-robot interaction). More generally, we encourage scholars to study how social robots can be presented to children in accordance with existing guidelines for responsible robotics (i.e., Boden et al., 2017); what effects such a 'responsible approach' has on children's responses to social robots; and how this could inform and advance the ethical discussion on the (un)desirability of child-robot relationships (see also Tolksdorf et al., 2020, who call for research on robot literacy).

Third, future research needs to advance our knowledge about the applicability of theories of interpersonal communication and relationship formation to children's interactions and relationship formation with social robots (see Fox & Gambino, 2021; Westerman et al., 2020, for similar calls in the broader context of human-robot interaction). As concluded in chapter 2, the effects of specific, isolated features of CRI – such as characteristics of social robots' interaction style

– require further investigation. Chapters 5 and 6 followed up on this conclusion, and we call on future research to do the same. In doing so, it is important to avoid biased expectations of CRI outcomes by reminding ourselves that "robots are not people" (Dautenhahn, 2007, p. 104) and "children are not just small adults" (Belpaeme et al., 2013, p. 453). As illustrated in chapter 5 and the findings on self-description, interpersonal principles may less seamlessly apply to CRI when the differences between robots and humans are openly acknowledged to children. As current social robots may, in addition, remain unable to adequately use certain communication processes for some time to come (see Fox & Gambino, 2021), it seems important to investigate how children perceive and relate to robots whose behavior more closely reflects social robots' actual capacities.

In this context, chapter 4 and 5 show that children need not believe in a robot's human psychological capacities and autonomous working to consider it a potential friend. Moreover, an exploratory study on children's motivations (not) to trust a robot suggested that children's trust in social robots may be based on both interpersonal and technological considerations (van Straten et al., 2018). Thus, children's relationships with social robots may differ from their relationships with people. Reasoning from children's hybrid ontological classification of social robots (see Kahn et al., 2012, 2013), child-robot relationships may challenge our traditional notion of relationships and overlap conceptually with children's relationships with humans, animals, and objects. If so, the terms and conditions of child-robot relationships may differ from those of interpersonal ones. To advance our understanding of the consequences of child-robot relationship formation, future studies should investigate what kind of relationship children may experience with robots under which conditions.

Concluding Remarks

Interactions and social relationships between children and robots will become more common in the upcoming years. This dissertation provides theoretical insight into current knowledge about child-robot relationship formation as well as methodological equipment to expand it. In addition, it offers empirical evidence that speaks for being open to children about social robots' machine status and capacities and demonstrates that differences between humans and social robots should be taken into account when designing or investigating social robots' communicative behavior. Children will form social relationships with robots regardless of our stance toward this new kind of social bond. But *how* children perceive and relate to social robots appears to partially depend on

how we prepare both children and robots for their interactions with each other. We may consider whether the kind of friendship that emerges when children experience a social connection with a robot despite having realistic expectations of it might suffice for social robots to support hospitalized children, function as educational assistants in schools, or otherwise figure in children's everyday lives. Instead of asking how social robots can be turned into humanlike peers, we may ask ourselves how little is required for children to consider social robots as (potential) friends.

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