## Children and social robots

*Towards a better understanding of their acceptance of a new technology*

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# General Discussion

With the spread of social robots to more naturalistic environments, children increasingly encounter these robots in their daily lives, at schools, at museums, and – with the recent developments around toy robots (see e.g., Peter et al., 2019) – even at home (Bartneck et al., 2020a). Whereas research in child-robot interaction (CRI) has, among other things, focused on the effectiveness of robots in several domains such as education, therapy and healthcare (Kory-Westlund & Breazeal, 2019; Leite et al., 2013), we know very little about the degree to which children accept a social robot. While most empirical research on CRI shows children's initial enthusiasm and willingness to interact with social robots (see e.g., Baxter et al., 2017; Cha et al., 2014; Ferraz et al., 2016; Robert & Van Den Bergh, 2014), we lack knowledge on what predicts this reaction. Moreover, we do not know what happens beyond this initial enthusiasm and how children's social robot acceptance develops over time.

In addressing these shortcomings of previous research on children's acceptance of social robots, this dissertation had four main goals. The first goal was to provide a systematic overview of the current research on children's social robot acceptance and gain more insight into the methodological and conceptual approach in the field. Second, the dissertation aimed at a more consistent approach in studying children's acceptance of social robots, notably by developing and validating a self-report measure of children's intentional acceptance of social robots. The third main aim of the dissertation was to develop a model of the predictors of children's intention to adopt social robots. The fourth and final aim was to go beyond children's initial enthusiasm for robots that is described in the literature and focus also on children's subsequent longitudinal acceptance of social robots.

With its four chapters of original research, this dissertation extends our current knowledge on children's acceptance of social robots with four substantive findings. Along with the practical implications and the recommendation for future research that can be extracted from the findings, the dissertation provides a sound basis for future research in the still novel field of CRI. Four more general findings of this dissertation deserve highlighting.

### Finding 1: Children Accept Social Robots, Initially

The main questions of this dissertation were to which degree children accept a social robot and how acceptance develops over time. Chapter 2 reviewed the literature on children's acceptance of social robots and showed that, generally, children seemed to readily accept social robots. Using an adjusted version of

the self-report measure developed in Chapter 3, Chapter 4 showed that 82% of the children intended to adopt the social robot at home, whereas the remaining children were either unsure or unwilling to adopt it. In a longitudinal follow-up study, which was based on a sub-sample of the study presented in Chapter 4, 321 children received the social robot to play with at home. The results of Chapter 5 showed that not only prior to an interaction, but also in the two weeks after the first use of the social robot, children rarely rejected it.

The findings of Chapters 4 and 5 confirm the general idea in the CRI literature that nearly all children *initially* accept social robots, that is, during the pre-adoption and adoption phase. Taken together, the findings of the two chapters also suggest that intentions to adopt the robot (in Chapter 4) may translate subsequently into actual adoption behavior (in Chapter 5). At least for children and their acceptance of social robots, there appears thus no evidence in Chapters 4 and 5 of an intention-behavior gap (Bagozzi, 2007). The notion of an intention-behavior gap emphasizes that individuals may not follow in their behavior the intentions they voiced before. Individuals may thus intend to adopt a certain technology, for example a social robot, but may abstain from doing so when they actually have the chance. For the children and the social robot studied in Chapters 4 and 5, the findings suggest that children's adoption behavior followed their previous intentions to do so closely.

The finding in Chapter 5 that only very few children rejected the robot upon initial trials during the adoption phase also suggests that there was no expectation-experience gap (Lohse, 2011), that is, a potential discrepancy between children's expectations of social robots during the pre-adoption phase and the actual experiences during the adoption phase (e.g., Fernaeus et al., 2010; Leite et al., 2013). We cannot preclude that the findings in Chapter 5 were, at least partly, affected by the set-up of the study, notably children's perception of 'having to use' the robot for the purposes of the study (for elaboration, see the limitations below). Still, the consistency across Chapters 4 and 5 in children's acceptance during the pre-adoption and adoption phase suggests that one can generally expect successful outcomes when children *initially* interact with social robots.

### Finding 2: Adoption Intention is Predicted by General and Hedonic Attitudes and Social Norms Towards Accepting the Robot

Besides confirming *that* children initially accept social robots, this dissertation has also provided insights into the *predictors* of this initial acceptance. In

Chapter 2, the existing literature on children's acceptance of social robots suggested that social, adaptive robot behavior, children's sex and age, and the frequency of the interaction affect children's acceptance of these robots. Overall, however, little consistent patterns emerged, and, partly due to the lack of theory-driven research, we still understand only superficially what predicts children's (initial) acceptance of social robots. Responding to this shortcoming, the fourth chapter aimed to gain more insight into the predictors of children's intention to adopt a social robot at home (i.e., at pre-adoption), relying on a model, which was based on the Theory of Planned Behavior (Ajzen, 1991). The findings showed that children's intention to adopt a social robot is mainly driven by their general conception of robots, which was mediated by hedonic attitudes and social norms.

The importance of both children's entertainment-oriented considerations and their social norms for their intention to adopt a robot resonates with earlier research on anthropomorphic social robots. Similar to previous studies, children seem to consider robots, and whether to adopt them, mainly in terms of entertainment and hedonic gratifications (De Jong et al., 2019) and beliefs (De Jong et al., 2021). Children thus appear to see robots, at least initially, as toys and place potential pleasure and fun centerstage. At the same time, children take social norms into account when intending to adopt a social robot. This merges with earlier research in which children referred to family members and family composition when rejecting the robot (De Jong et al., 2021). Together with other studies, Chapter 4 thus emphasizes the importance of hedonic and normative considerations in children's intention to adopt social robots. More specifically, the consistency in the findings suggest that children's hedonic and normative considerations should also be studied in other contexts (i.e., education) where children may encounter social robots.

Chapter 4 showed that utilitarian considerations are irrelevant for children's intention to adopt a social robot. This finding – together with the aforementioned dominance of hedonic and normative considerations – is juxtaposed to predictions from influential models of technology acceptance, such as the Technology Acceptance Model (Davis, 1989) and the Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003). Developed from an organizational perspective, these models have a utilitarian focus, with usefulness and ease of use of the technology as the central, most important predictors of acceptance (Van der Heijden, 2004). The Technology Acceptance Model (Davis, 1989) and the Unified Theory of Acceptance and Use of Technology (Venkatesh

et al., 2003) have proven to be useful in other work on technology acceptance and notably among adults. The findings of Chapter 4, however, suggest that these models may be less useful than psychological models, such as the Theory of Planned Behavior (Ajzen, 1991), in predicting children's initial acceptance of social robots. Given the need for more theory-driven research on children's acceptance of social robots, an important theoretical advancement in the field of CRI may thus be to pit predictions of the various models against each other and test their validity.

The significance of children's general conception of robots in predicting their intention to adopt social robots in the domestic environment is a straightforward finding, with a clear practical implication: If you try to predict whether children intend to adopt a social robot, find out about their general attitude to robots (for a similar finding for adults, see Katz & Halpern, 2014). Theoretically, however, this finding may be somewhat more complex than it initially seems. If general attitudes are such strong predictors of children's intention to adopt social robots, we need to understand better what shapes these attitudes. A fruitful starting point for future research may be to focus on predictors of children's general attitudes towards robots. Chapter 4 showed that, for children, concepts that are thought to influence adults' general attitudes towards robots, such as familiarity and experience with robots (Bartneck et al., 2020b), anxiety towards robots (Bartneck et al., 2020b), and exposure to media-representations of robots (Bartneck et al., 2020b; Sundar et al., 2016), did not affect children's intention to adopt social robots. However, robots are an emerging technology and undergo major, technological, developments (Kahn et al., 2013). Therefore, we need to keep in mind that, with the development and increasing presence of social robots as well as children's increasing experience with them, their general conception of robots, and consequently their intention to adopt them, may change in the coming years (see for a similar claim in HRI more generally, Bartneck et al., 2020b).

### Finding 3: Children's Acceptance of Social Robots Decreases Over Time

As mentioned before, the dissertation has confirmed that children *initially* accept social robots. This picture, however, changes considerably when subsequent stages of children's acceptance of social robots are studied. Whereas Chapter 5 showed that children rarely rejected a social robot during the first two weeks (i.e., the adoption phase), it also demonstrated that acceptance strongly dropped during the following two weeks (i.e., after two to four weeks of use),

to remain stable after six weeks. Only a little less than 30% of the children used the robot consistently across the eight weeks of the study. The majority of children discontinued the use of the robot, that is, they stopped using it after initially having adopted it. Another substantive group of children alternated between using and not using the robot (and are therefore called 'resumers'). Overall, the findings in Chapter 5 thus suggest that most children decide to discontinue using the social robot during the adaptation phase, contradicting their earlier adoption decision. Moreover, the majority of children do not seem to integrate the technology in their daily life (De Graaf et al., 2018) and do not reach the final phases of robot acceptance.

Chapter 2 already suggested that cross-sectional research may not give full insight into children's social robot acceptance, which is substantiated by the findings in Chapter 5. The fact that cross-sectional research may provide an overly positive impression of children's acceptance of social robots may be partly due to the novelty of the robots. The novelty of an entity *to its user* – experiential novelty, that is (Smedegaard, 2019) – is not unique to social robots and can also exist, for example, when a child gets a new toy. Ontological novelty, in contrast, refers to the novelty of social robots *as an entity* (i.e., social robots are novel in itself; Smedegaard, 2019) and is central to social robots. Consequently, children may be overly enthusiastic about initially interacting with social robots, regardless of whether it concerns encounters in a domestic or a research context. Given the far-reaching implications of this problem for our understanding of children's robot acceptance, but also for CRI more generally, it thus seems essential to not only center on initial interactions between the user and the entity, but to also study these interactions over time.

The findings in Chapter 5 are inevitably linked to the duration of the study, which was only eight weeks. As a result, it may be that the children in the study may have needed more time to eventually integrate the robot into their lives. While this possibility cannot be precluded, it seems unlikely. The patterns of discontinuing and resuming occurred too early to suggest that children would have changed radically after eight weeks. Instead, a theoretical and a practical conclusion can be drawn from the general decrease of children's robot acceptance in this dissertation.

The theoretical conclusion is that, in conjunction with children's strong emphasis of hedonic aspects of social robots, scholars need to more strongly conceptualize social robots, and notably those made for domestic use, as toys and see children's

use of social robots as a type of play. This conclusion is most strongly supported by the identification of the group of resumers, that is, children who alternated between using and not using the robot. As suggested by Fernaeus et al. (2010), robots – as toys – follow the general life cycle of toys in which children have changing interests across time and consequently play with, and alternate between, different toys. Because robots are technologically more advanced and more demanding to produce than many other toys, a notion of 'robot exceptionalism' seems to pervade, at least implicitly, the field of CRI and robotics more generally. Regarding domestic social robots, this notion is called into question. For the children, robots are toys that they may like initially, explore, and then drop, or re-use only occasionally – similar to many other toys they have. The focus on the toy character of social robots and its play function may therefor offer fruitful perspectives for future research and important new perspectives on how to conceptualize CRI more broadly.

A practical, more applied conclusion from the findings notably in Chapter 5 is that current domestic social robots still have a long way to go to rival other advanced technologies, such as games consoles, in children's play environment. Some researchers have argued that entertainment robots, such as pet and toy robots, are easier to establish in the consumer market as they generally require less advanced functions (Bartneck et al., 2020a). However, based on the findings in this dissertation, it also seems that they are particularly difficult to keep in the market. Anki Robotics, the producer of the Cozmo robot used in this study, went bankrupt and many new robot companies disappear as quickly as they appeared (International Federation of Robotics, 2021). This dissertation suggests that the key in a social robot's success lies in increasing its longitudinal acceptance. Although this is more easily said than done, the robot community may be well advised to pay more attention to this somewhat neglected aspect of CRI.

### Finding 4: Competition of Other Toys and Devices and a Lack of Motivation to Interact with the Robot Explain Children's Non-Acceptance

In extending the research focus on children's non-acceptance of social robots, this dissertation has produced some first insights into the reasons for why children may choose not to accept a social robot. To date, the CRI literature has consistently referred to disappearing novelty (e.g., Baxter et al., 2017; Leite et al., 2013) and the expectation-experience gap (e.g., Fernaeus et al., 2010; Leite et al., 2013) as children's reasons for not accepting a robot. These two reasons also surfaced in this dissertation but seem less prominent for children than other reasons for not

accepting a social robot. In contrast to what the extant literature suggests, the competition of other toys and devices seems to be the most important reason for children's non-acceptance of social robots. A general lack of motivation to play with the robot also emerged as another important reason for non-acceptance. These results not only deepen our understanding of why children do not accept a robot, but they also offer new perspectives on what social robots mean to children.

The competition of other toys and devices as a reason for non-acceptance merges with the aforementioned finding on children's hedonic orientation when it comes to their intention to adopt social robots. Because children view current domestic social robots mainly as a toy, social robots need to compete with other toys and devices in the household. In this context, an interesting point to consider is that robots may be differently accepted depending on the extent to which they fit into the "existing 'eco-system' of toys and resources in the homes" (Fernaeus et al., 2010, p. 45). When a social robot fits into the eco-system of toys and resources in a home, it may more easily be accepted than when this is not the case. Future research should look more strongly into children's existing eco-system of toys and resources to deepen this point.

The finding that children do not accept social robots because they are not motivated to play with them is probably the most disappointing from a practical point of view and the least satisfying from a theoretical point of view. However, the result may be explained by the technological impediments of current domestic social robots (see e.g., Barco et al., 2018). Generally speaking, technology is often designed to make life easier and more pleasurable or to engage in specific tasks. Social robots, in contrast, are not specifically designed to fulfill a certain task (for a justification with robotic pets see Kaplan, 2000), but rather to interact socially with its users (Jung & Hinds, 2018). Currently, however, only very few of these robots can engage in meaningful interactions with children (Barco et al., 2018): They are often unable to function (well) autonomously, like NAO, or need to be controlled through an app, like Cozmo. Moreover, essential aspects that contribute to a meaningful interaction, such as the ability to engage in a conversation, are often missing or are under-developed, partly due to the demands of implementing multiple complex technologies into current social robots (e.g., Kennedy et al., 2017), while keeping prices attractive to potential users. Against that background, children still need to invest a lot of effort in interacting with social robots, whereas they do not get a lot in return,

at least over time. Albeit speculative, these shortcomings may explain not only children's general lack of motivation to interact with the social robot in our study (Cozmo), but also their preference to play with other toys and devices.

## Limitations

Whereas this dissertation provides several valuable insights into children's acceptance of social robots, it also has at least four more general limitations. First, the social robot that we focused on in Chapters 4 and 5 of this dissertation, the Cozmo robot (Anki), is a toy-like, caricatured robot (Akimana et al., 2017). It can be used for teaching children basic programming, but it is mainly designed to play with it. Consequently, children may have different expectations of, and experiences with, this robot than with an anthropomorphic robot, such as the NAO robot (used in Chapter 3), which is often employed in an educational or therapy setting, or a zoomorphic robot, such as the Pleo robot (Innvo Labs), which is a more expensive, toy-like robot. An exploratory study on the effect of robot morphology on children's perceptions of the robot, has suggested that an anthropomorphic robot (NAO) is perceived similarly as a caricatured robot (Cozmo), but differently than a zoomorphic robot (Pleo) (Barco et al., 2020). Moreover, a study with the NAO robot on children's beliefs for intending to adopt or reject a social robot at home (De Jong et al., 2021), showed that similar considerations surfaced for its adoption intention as in Chapter 4 of this dissertation, in which Cozmo was used. Other research thus suggests that the current findings may also apply to anthropomorphic robots. Still, future researchers should not prematurely generalize the findings of this dissertation and instead look systematically into the effects of different robot morphologies and different robot functions on children's acceptance of social robots.

Second, the studies in Chapter 4 and 5 focused on acceptance of a social robot in a domestic environment. As a result, different, more hedonically oriented considerations may have been at play than for a social robot in a more goal-oriented setting, such as education or therapy. In a domestic environment, children may also interact with the robot more freely than in an educational or therapy setting, where an interaction may be less flexible and more rule-based. The review in Chapter 2 showed that the latter type of interactions generally seems to result in less variation in children's acceptance compared to "free" interactions. Consequently, we may expect children to be more accepting of social robots in non-domestic contexts, but systematic research is necessary to test this expectation.

Third, Chapter 5 was based on an in-home study in which families were given a Cozmo robot to play with. Although this study set-up is more ecologically valid than many other CRI studies and the voluntariness of using the robot was continuously stressed, it is subject to artefactual findings because children knew that they had to fill in a survey about their robot use several times over the course of eight weeks. We thus cannot rule out that the study set-up created demand characteristics that affected children's robot acceptance and/or reporting of it. Simply put, it may be that children felt obliged, at least initially, to reciprocate being given a robot and used it more often than they would have done otherwise. Over the course of the study, the set-up of the study may have elicited socially desirable behavior in children. Because they knew that they would be asked about their robot acceptance, they may have adjusted their answers to what they thought the researchers would expect. The discrepancy between self-reported and observational acceptance in Chapter 5 points to this possibility. That said, the basic pattern of findings was rather comparable for both self-report and observational measures and overall acceptance was, over time, generally low. If the set-up of the study created artefacts, the scope of it seems limited.

A fourth and final limitation of this dissertation is related to both Chapters 4 and 5. The study whose data are used in both chapters aimed at closely simulating the acceptance process with all its stages, and children were unaware at pre-adoption that they could actually receive a robot to play with at home. Still, the set-up of the study may have resulted in different considerations for children's intention to adopt the social robot to emerge compared to when families would have bought the robot themselves. A study on children's beliefs about intending to adopt or reject a social robot at home showed that, albeit not prominent, the costs of the robot surfaced as a reason for children to not adopt the robot (De Jong et al., 2021). As Chapter 4 also demonstrated that children consider their parents' opinion when it comes to their intention to adopt a social robot, future research should look more into the family context when studying children's acceptance of social robots in their homes.

## Concluding Remarks

This dissertation gave an answer to an essential question in CRI which had rarely been asked before, namely to what extent do children accept a social robot. It provided theoretical as well as practical insights into children's acceptance of social robots over time. These insights have been partly positive – children are initially enthusiastic about social robots – and partly somewhat negative – many children do not accept a social robot over time. For robot developers, the findings in this dissertation mean that they have to focus on the current technological shortcomings of social robots, especially over time. For robot researchers, these findings mean that they need to deal more strongly with children's disappointment about robots, robot failure, and how robots relate to children's existing play practices. For practitioners, the findings mean that social robots are currently most suitable for short-term interaction with children, whereas longitudinal interactions may be less successful.

In any case, the findings of this dissertation are timely. Social robots, at least those made mainly for entertainment and targeted at children, face fierce competition from other advanced technologies. The latest developments in augmented and virtual reality applications and their intended embedding in a new form of three-dimensional internet ('metaverse') along with the progress in digital assistants should therefore be carefully observed by anybody interested in children's acceptance of social robots. Only if we deal more strongly with children's acceptance of social robots and concurrently consider it in the broader technological and social context will we be able to understand how a promising and potentially beneficial technology can eventually be integrated into children's daily lives.

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