Measuring Children’s Perceptions of Robots’ Social Competence: Design and Validation

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Abstract. This paper presents the design and validation of a measurement instrument for children’s perceptions of robots’ social competence. The need for a standardized validated instrument has emerged as a requisite for meta-analyses and comparisons among various studies in the field of child-robot interaction. We report on the development of the instrument and its validation, which adopted a design-based method with two iterations. We used construct validity, which was formed by divergent and convergent validity. Children’s perceptions of three different robotic platforms were examined in two empirical studies with 78 children aged 7-9 years, which was based on semi-structured interviews with qualitative thematic content analysis. The results indicated that children differentiate their perception of social competence depending on the perceived intentionality of the robot and they ascribe discrete categorizations to the robot such as a *machine*, *social artifact* and *social agent*. The findings are discussed in relation to existing literature.

Keywords: child-robot interaction, assessment, social competence

1 Introduction

Child-robot interaction (CRI) has been investigated in a variety of contexts, such as free play, open-ended activities or formal educational settings with various robotic platforms. One of the factors that influence the interaction between children and robots is the perceived social competence of the robot. The field’s interest in this is indicated by a recent systematic review of 135 studies on user-centered evaluation methods for CRI [9], which reports that 41.3% of these studies investigated children’s perceptions of their interaction with a robot after a given activity. However, most of the measurement instruments were designed only for a specific setting with a specific robotic platform and, to our knowledge, none of these instruments was validated. A validated measurement instrument would allow for cross-studies comparisons and systematic meta-analyses, replications and reviews. As a starting point, we were particularly interested in investigating the perceptions of typically developing children for the social competence of a robot. Previous research has focused on other aspects of perceived competence of robots, such as the cognitive competence (e.g. [15]). We focus on the *social* aspects, taking into consideration its importance according to recent

developmental theories, which highlight the importance of social interaction in children’s development [20], [1]. Because of the relatively unexplored field, we used a bottom up iterative design approach to develop a measurement instrument, which includes two empirical studies. The aim of this paper is dual: (i) to report the methodological process of the development and validation of the instrument and (ii) to present the results of the corresponding empirical studies.

2 Related Work

Despite the interest to measure users’ perceptions of robots, in a variety of contexts [17, 11, 16], the evaluation of young children’s perceptions remains challenging. To address this challenge, we draw on accounts of existing work on HRI and we take into consideration theories from developmental psychology.

More specifically, it seems that the assessment of the social competence of digital artifacts, such as robots, brings several challenges, because of their synthetic nature. Scholars from the field of human-robot interaction have identified several features that synthesize the perceived social competence of a robot based on aspects such as physical attributes, personality, emotion traits or animacy [8, 21], which have been investigated by validated adult-centered measurement instruments such as in [4]. However, children seem to perceive inanimate objects in slightly different way [18]; for example, they attribute human characteristics to robots and they perceive them as living entities [5, 2]. To investigate children’s perceptions, one should consider their idiosyncratic nature, the level of their developing metacognitive skills and the ways they attribute intentionality to agents or artifacts [18], which require developmentally appropriate approaches.

The scientific interest in children’s perception has resulted in the development of methods such as observations of children’s behaviours [6], questionnaires, pretend play, drawings and self-assessment methods [12]. The fact that children’s skills are very much still under development raises several additional challenges for designing questionnaires, as discussed by Borgers et al. [7]. Attempts to overcome these difficulties include indirect approaches, such as the use of pictorial tasks [12]. Borgers et al. [7] discuss the influence of cognitive development on response quality, which requires appropriate questions for children. Okita and Schwartz [17] addressed this challenge by asking the children only simple questions. However, possible oversimplification of the questions might limit the scope of the research. Pictorial tasks have been used as a basis for semi-structured interviews, using stimuli that are meaningful for children [5]. However, despite the challenges, children can provide reliable responses if questioned in a manner that they can understand and about events that are meaningful to them [14].

3 Objectives and Methodology

The main objective of this study was to develop and validate a measurement instrument to investigate children’s perception of the social competence of a robot. Based on the existing literature about children’s perceptions, we designed

the proposed instrument with an emphasis on open-ended questions with semi-structured interviews [3]. The design and validation of the assessment instrument required an iterative methodological process, with a progressive refinement of the instrument, based on the design research paradigm [13, 10]. We conducted semi-structured interviews after letting the children interact with various robotic platforms in given tasks. The interview was extended with a pictorial task. Through children’s reflections on the interaction with the robot, we expected a set of themes to emerge which we aimed to use for the construct validity of the instrument. Consequently, we chose the qualitative thematic content analysis to evaluate the convergent and the divergent validity of the instrument.

3.1 Construct validity

The construct validity was based on two studies that provided us the data to build (i) divergent validity, which is demonstrated by using the same method to measure two different constructs, and (ii) convergent validity, which is demonstrated by using two different methods to measure the same construct. In this way we aimed to generalize from our observations to children’s conceptualizations in the form of the construct [19].

3.2 Design of the measurement instrument

The initial design of the measurement instrument was theory driven. We decided to adopt a bottom-up approach by letting the themes emerge through children’s responses. To triangulate the results from the interviews we designed a pictorial task in order to explore the same construct with a different instrument.

The set of questions A robot’s sociability refers to the features and behaviours of the robot that are seen as social by the human [8]. We designed the first prototype by defining the main themes for investigation, starting with generic questions and narrowing down to robot-related ones, as shown in Table 1. The first set of questions (Theme I) aims to give the children the opportunity to familiarize themselves with the process of interview and recall the context of the activity. The questions were open-ended and allowed the child to refer to the most prevalent events of their experience without restrictions. The second set (Theme II) aimed to trigger the child to focus on the robot. This set of questions was meant to ascertain the possibility for the children to ascribe several characteristics to the robot such as theory of mind. The third set of questions (Theme III) probed the children to talk specifically about the *social* competence of the robot. Table 1 shows the final set of questions, designed to (i) satisfy the themes, (ii) be relevant to the provided tasks and (iii) be generic enough in order to be used across different robotic platforms. Questions that trigger a “yes” or “no” answer were always followed by a “WHY” question. In this way we ensured that the child had the opportunity to explain / develop a rationale for their choices.

<i>Number</i>	<i>Theme</i>	<i>Question</i>
1	I	Warm up question
2	I	Did you enjoy it?
3	I	What did you like most?
4	II	Can you tell me something about the robot / tablet?
5	II	How would you describe the robot to friends/at home?
6	III	Could the robot be your friend? Why?
7	III	Do you think that the robot would like to be your friend? Why?
8	II	How would you describe the robot at home / parents/ siblings?
9	III	Could the robot see you? Why?
10	III	Could the robot hear you? Why?
11	II	Did the robot help you or did you help the robot? Why?
12	II	Would you like to have a robot? Why?
13	III	Do you think that the robot would like to have a lot of friends? Why?
14	III	Could the robot be able to harm anybody? Why?
15	II	Is the robot able to help you with the school assignments? Does the robot know everything?

Table 1. Semi-structured interview: Themes for investigation and Set of Questions

Fig. 1. Picture task: Not presented in a particular order

The pictorial task In order to construct convergent validity, we designed a pictorial task (see Figure 1). First, children were asked to identify the objects on the pictures. Then they were asked to select the picture that in their opinion *did* and *did not* fit the robot and to elaborate on their choice. This gave them the opportunity to associate their perceptions of the social abilities of the robot with familiar notions. Pictorial tasks have been previously used in the field of developmental psychology to measure children’s perceptions in a developmentally appropriate way [12]. The *car* represents a technological tool that can be used by humans; the *notebook* represents a non-technological tool; the *laptop* represents a digital tool; the *teddy bear* represents a toy; the *dog* represents a pet: something alive but not the same as a human; the *children* represent friends; and the *teacher* represents someone who instructs.

4 Validation Process

For the examination of divergent and convergent validity we designed activities which would allow the examination of the sharpness and accuracy of the proposed instrument. In the first iteration we compared a humanoid robot with a tablet. For the second iteration we used three different robotic platforms varying in

social competence, embedded in different tasks. All the methods were piloted with children of the same age group and were revised or expanded accordingly.

4.1 Iteration 1: Robot versus tablet

Procedure and participants Children engaged in an inquiry learning activity which was supported either by the Zeno R25 robot or a Nexus tablet. After the completion of the task the facilitator proceeded with the initial version of the semi-structured interview and the pictorial task. The evaluation of the set of questions from the first iteration informed the construction of the final set of questions, which was refined and used for the second iteration. Participants of this study included 49 children between aged 7-9 years. 24 children participated in the activity with the robot and 25 children in the activity with the tablet.

Results: Semi-structured interview All interviews were transcribed. Three experienced researchers conducted qualitative thematic content analysis, resulting in the emergence of annotation themes as follows: (i) *Enjoyable experience*: Without any exception children talked positively about the task and their interaction with the system; (ii) *Technical / design features of the system*: Children referred to specific characteristics of the system such as “he can really move his mouth”. These descriptions focused on technical and design aspects without referring to social competence; (iii) *Task-related descriptions*: Most of the children described the task as a learning activity. The children that interacted with the tablet focused mainly on the learning process while the children that interacted with the robot focused on their impressions about the robot; (iv) *Human-like features*: 19 out of the 24 children in the robot condition and 12 out of 25 children in the tablet condition believed that the system could see them; in both cases, the responses related to technical aspects such as “I think he (the robot) has a camera in his eyes”; and (v) *Interaction with the robot*: Most children perceived the interaction as a collaborative activity in which they helped each other which was related to their perception of the cognitive competence of the robot.

Results: Pictorial task Table 2 provides an overview of the chosen pictures. In both conditions most children chose the laptop as the picture that fits best with the technology they interacted with. The picture with two children was chosen by 20.8% of the participants in the robot condition and by none in the tablet condition. Data analyses of their reasoning revealed that children focused mainly on the technology. In the tablet condition, 28% of the children talked about the function or tool-related characteristics compared to only 2.5% in the robot condition. Furthermore, 20% of the children in the robot condition (vs. none in the tablet condition) discussed about social characteristics of the robot.

4.2 Iteration 2: Three robotic platforms

	Robot		Tablet	
	<i>1st Choice</i>	<i>2nd Choice</i>	<i>1st Choice</i>	<i>2nd Choice</i>
Car	12.5%	8.7%	0.0%	30.4%
Children	20.8%	21.7%	0.0%	0.0%
Dog	0.0%	0.0%	4.0%	4.3%
Laptop	50.0%	26.1%	80.0%	0.0%
Book	0.0%	0.0%	8.0%	26.1%
Teacher	16.7%	39.1%	8.0%	34.8%
Teddy	0.0%	4.3%	0.0%	4.3%

Table 2. Iteration 1 - Pictorial task - Summary of chosen pictures that fit the robot or tablet

	<i>Tech/design</i>	<i>Tool/function</i>	<i>Social characteristics</i>	<i>I learned</i>	<i>I taught</i>
Zeno	45.0%	2.5%	20.0%	12.5%	20.0%
Tablet	48.0%	28.0%	0.0%	24.0%	0.0%

Table 3. Iteration 1 - Pictorial task - Summaries of explanations used for choosing a certain picture that fits with the robot or tablet

Fig. 2. Robotic platforms used in the various tasks

Procedure and participants During the second iteration, children interacted with three different robots, illustrated in figure 2. With the Dash robot, the children were given the opportunity to develop elements of computational thinking by programming it for a collaborative problem solving activity. The anthropomorphic Zeno robot had the role of a learning companion for an inquiry learning activity. With the Robotino robot, children were engaged in the analysis and design of expressive behaviors for the robot. After each session, we conducted individual semi-structured interviews followed by a pictorial task for the measurement of the perceived social competence of each robot (see Table 1 for the questions used in the second iteration). Participants included 32 English speaking children (8-9 years old, even number of boys and girls). Each child or pair of children took part in one activity. In total, 8 children worked with Robotino, 14 with Dash, and 10 with Zeno.

<i>Robot</i>	<i>Task-related</i>	<i>Tech/design</i>	<i>Role</i>	<i>Interaction</i>	<i>ToM</i>
Dash	28.6%	42.9%	7.9%	11.1%	9.5%
Zeno	10.0%	16.7%	13.3%	36.7%	23.3%
Robotino	8.1%	46.0%	16.2%	8.1%	21.6%

Table 4. Iteration 2 - Theme II: Percentage of answers per category

<i>Robot</i>	<i>Machine</i>	<i>Social artifact</i>	<i>Social agent</i>
Dash	47.4%	23.5%	29.0%
Zeno	40.0%	13.3%	46.7%
Robotino	48.0%	16.0%	36.0%

Table 5. Iteration 2 - Theme III: Percentage of answers per category

Results: Semi-structured interview The interviews were transcribed for thematic content analysis. We used the annotation scheme that emerged in the first iteration, while being open for more themes to emerge.

Theme I: warm-up / recall activity The division between responses about the task or the (interaction with the) robot varied. With the Dash robot, 71.4% of children talked about the task. For the same set of questions, 87.5% of children that interacted with the Robotino talked about the task, while 12.5% focused on both the interaction with the robot and the task. In contrast, for Zeno, 40.0% of children talked about the interaction with the robot and 20.0% about the task.

Theme II: Open-ended perceptions of the interaction Five categories of answers emerged from the data analysis (see Table 4). The majority of children who interacted (i) with the Dash discussed about the technology/design of the robot (42.9%); (ii) with Zeno, they focused on the interaction (36.7%); and (iii) with the Robotino, focused on the technology/design (46.0%).

Theme III: Robot-related perception For these questions three categories were emerged: answers in which children discussed about the robot (i) as a machine, (ii) as a social artifact, and (iii) as a social agent. Table 5 shows that children who interacted with the Dash mainly talked about it as if it were a machine (47.4%); with Zeno mainly as a social agent (46.7%); and with Robotino mainly as if it were a machine (48.0%) and as a social agent (36.0%).

Results: Pictorial task Table 6 provides an overview of the pictures children chose as representative for the robot they interacted with. The majority of the participants who interacted with the Dash chose the picture of a car (50,0%); 75.0% of the children that interacted with the Zeno chose the picture with the laptop; and the majority of the participants who interacted with the Robotino chose the picture with the two children (37.5%). Table 7 provides an overview of the annotation labels that emerged in the analysis of children’s explanations. In the conditions with the Dash and the Zeno, children mainly explained their choices based on the technology/design of the robot (54.2% and 46.6% respectively) while children who interacted with the Robotino talked about the social characteristics (54.5%).

	Dash		Zeno		Robotino	
	<i>1st</i>	<i>2nd</i>	<i>1st</i>	<i>2nd</i>	<i>1st</i>	<i>2nd</i>
	<i>Choice</i>	<i>Choice</i>	<i>Choice</i>	<i>Choice</i>	<i>Choice</i>	<i>Choice</i>
Car	50.0%	9.0%	0.0%	25.0%	0.0%	25.0%
Children	8.3%	9.0%	25.0%	0.0%	37.5%	0.0%
Dog	0.0%	18.2%	0.0%	0.0%	12.5%	0.0%
Laptop	41.7%	36.4%	75.0%	12.5%	25.0%	37.5%
Notebook	0.0%	0.0%	0.0%	12.5%	12.5%	0.0%
Teacher	0.0%	9.0%	0.0%	37.5%	0.0%	12.5%
Teddy	0.0%	18.2%	0.0%	12.5%	12.5%	25.0%

Table 6. Iteration 2 - Pictorial task - Summary of chosen pictures that fit the robot

	<i>Tech/design</i>	<i>Tool/function</i>	<i>Social characteristics</i>	<i>I learned</i>	<i>I taught</i>
Dash	54.2%	20.8%	20.8%	4.2%	0.0%
Zeno	46.6%	6.7%	20.0%	13.3%	13.3%
Robotino	27.3%	9.1%	54.5%	9.1%	0.0%

Table 7. Iteration 2 - Pictorial task - Summaries of explanations used for choosing a certain picture that fits with the robot

4.3 Construct validity

The instrument was validated for different robotic platforms, to examine divergent validity. Calculation of correlation coefficient provided indications of low correlation between a humanoid and a non-humanoid robot ($r=.27$) and strong correlation between two non-humanoid robots ($r=.78$). It was also validated against a pictorial task for its convergent validity. We calculated the correlation coefficient among the pictorial task and children’s explanations, regarding the characterization of each robot as a machine, social artifact or social agent. Results demonstrated strong correlation for the Dash and the Robotino ($r=.92$ and $r=.78$ respectively) and moderate correlation for the Zeno robot ($r=.61$), which supports the convergent validity. Consequently, our results support the construct validity of the instrument. The proposed instrument is sensitive enough to capture the expected differences in children’s perceptions among different robots. It depicts children’s perceptions of the robot with humanoid characteristics as a social agent, while the non-humanoid robots were perceived as machines or social artifacts. However, this needs further elaboration to capture even more detailed nuances among different robotic platforms.

5 Discussion

Research has demonstrated that children perceive robots in multiple ways depending on the design of their appearance and behaviour and the situation in which they are embedded. However, in the field of CRI, existing measurement instruments for children’s perceptions are usually designed for specific cases or

robotic platforms without having previously been validated. The main contribution of this paper is the development and initial steps of validation of a measurement instrument designed for the assessment of children's perceptions of the social competence of a robot to be used for children aged 7 to 9 years by taking into consideration the developmental characteristics of the specific age group. Previous research has indicated that humanoid characteristics which are related to the appearance or the behaviour of a robot affect the way children perceive its social competence [21]. In the same direction, our results indicated that the humanoid platform with the anthropomorphic characteristics was perceived as socially competent. Most importantly, the behavioural accounts of the robot and the way in which it is embedded to a specific task seemed to be a prevalent element that affected children's perceptions. Although the children were aware that the robot is a machine, they ascribed social agency to it, which was mainly related to the exhibition of intentionality of the robot. Future work includes further validation of the proposed instrument in a longitudinal study by examining children's perceptions of the same platform overtime by taking into consideration the characteristics of the constantly developing child.

6 Conclusion

This study is the first step towards the validation of our interview and pictorial-based measurement instrument, which aims to capture the perceived social competence of a robot in CRI. We demonstrated the process of a design-based iterative methodological approach aiming to promote the construction of validated instruments for the idiosyncratic field of CRI. We emphasized on open-ended questions with qualitative content analysis. This instrument can be considered as a starting point for further development in the ongoing process of construct validation and it can be used during the design process for CRI to further understand and actively include the perceptions of the end-users, in this case the developing child.

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