The Effect of a Robot's Social Character on Children's Task Engagement: Peer Versus Tutor

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The Effect of a Robot's Social Character on Children's Task Engagement: Peer versus Tutor

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Abstract. An increasing number of applications for social robots focuses on learning and playing with children. One of the unanswered questions is what kind of social character a robot should have in order to positively engage children in a task. In this paper, we present a study on the effect of two different social characters of a robot (peer vs. tutor) on children's task engagement. We derived peer and tutor robot behaviors from the literature and we evaluated the two robot characters in a WoZ study where 10 pairs of children aged 6 to 9 played Tangram puzzles with a Nao robot. Our results show that in the peer character condition, children paid attention to the robot and the task for a longer period of time and solved the puzzles quicker and better than in the tutor character condition.

Keywords: Child-robot interaction, task engagement, robot characters, robot behaviors

1 Introduction

Social robots are envisioned as partners for children, offering companionship, tutoring and social assistance in various domains (e.g., education, therapy). Across these domains and applications, one of the main factors that contributes to initiate, sustain and maintain child-robot interaction (cHRI) is engagement. Despite the fact that children can easily make connections with robots [15], researchers and designers still face the challenge to select the appropriate set of verbal and nonverbal robot behaviors that support engagement throughout a task. The social verbal and nonverbal behaviors the robot is endowed with provide information about its '*social character*' (here defined as sets of behaviors stylized according to a precise behavioral repertoire, e.g., the robot is characterized as a friend, playmate, tutor) [17], [22], [26]. Therefore, we argue that researchers who venture into child-robot interaction also need to take this aspect into account. Firstly, because this shapes the design of the robot behaviors. Secondly because the robot character could lead to the identification of a social role (set of standards, norms and concepts held for the behaviors of an agent in a social system) [4], a key factor for successful child-robot interactions and human-robot interaction (HRI) in general [14]. In cHRI research, peer and tutor behaviors, derived from human interaction, have been explored in different task-related contexts with the ultimate goal to engage children in different types of tasks. To date, it is not clear if and how the robot character might effect children's engagement with a task, as a thorough comparison of robot social characters is missing. This paper addresses this gap and it aims at shedding light on two robot social characters that are predominant in children's task-oriented experiences, namely peers and tutors. After deriving tutoring and peer behaviors from literature, we evaluated the effect of the two robot characters on children's task engagement in a Wizard of Oz (WoZ) experiment. The exploratory study entails a triadic scenario where a humanoid robot (i.e., the Nao robot) and two same sex children (6-9 years old) perform three Tangram puzzles.

2 Children's Task Engagement

Engagement is a multifaceted phenomenon that is considered to play an important role when humans are interacting with social robots [25]. Sidner et al., defined engagement as *'the process by which two (or more) participants establish, maintain and end their perceived connection'* [24], but their definition focused on conversational engagement and as such on cognitive engagement (i.e., focus of attention during conversations). Our definition goes a step beyond Sidner's and includes insights from [7], [8], [11], [21]. Since engagement encompasses three dimensions, cognitive, behavioral and affective [8], we argue that it is necessary to take them all into account. In our study, we focused only on children's task engagement and we define it as the level of cognitive (e.g., attention to the task and the robot), affective (e.g., emotional response to the task), and behavioral attributes (e.g., performance) of engagement during the interaction. The more these attributes occur in the interaction (measured by frequency and duration), the more engaging the interaction with the task will be.

3 Related Work and Hypotheses

Studies have shown that an expressive behavioral repertoire, that conveys a robot social character is one of the factors that affects children's engagement with a task [10], [26]. In a field study, Kanda et al. [16] revealed that sharing common ground with a peer robot contributes to an enhanced level of engagement with a task. Also Okita et al. [22] illustrated how a peer-like cooperative style of interaction supported affective task engagement. In a similar vein, Leite et al. [18] suggested that a set of emphatic behaviors, exhibited by a robot companion during a game, may encourage the child to identify the robot as a peer enhancing the endurability of the task. A related indication emerges from the work of Belpaeme et al. [3]: a robot perceived as a peer, during a game appeared to be more likely to support engagement. Hence, our first hypothesis **(H1)** is that a peer-like character will enhance **(H1a)** affective and **(H1b)** behavioral (i.e. performance) children's task engagement. Our expectation is that this effect will be more prominent than for the tutor-like character as implied by the education literature [9]. On the other hand, the attention to the task could be enhanced by a tutor-like character [17], who is focused on guiding in a scaffolding fashion [28]. As a result, our second hypothesis **(H2)** is that a tutor-like character will enhance the focus of attention on the task and the robot more than the peer-like character.

4 Method

Our independent variable, the robot social character, was manipulated between-subjects. In order to address the above mentioned hypotheses, we devised two conditions, namely *peer-like character* ***(PC)*** and *tutor-like character* ***(TC)***. In the study, dyads of same gender, same age children performed three tasks in either the PC or the TC condition. The three tasks consisted of three Tangram puzzles of increasing difficulty. The children first solved a puzzle missing three pieces, then two puzzles missing six pieces. The first puzzle consisted of a simple outline of an animal shape with orientation lines, i.e., the lines defining the Tangram piece perimeter, partially completed. The second and the third puzzles consisted of geometric outlines to be completed. The puzzle pieces were divided between the children, who could collaborate to accomplish the task. We used the Nao robot [1] which was remotely controlled by a Python script operated by a researcher (See Figure 1).

4.1 Robot Character Design

The social character is conveyed by behaviors based on peer collaboration [9] for the PC condition and instructional scaffolding [6] for the TC condition. We designed eleven verbal and nonverbal behaviors both for the PC condition and for the TC condition, in such a way that their functions, interaction modalities, number of actions and speech remained the same across the two conditions. The behaviors were designed to (i) regulate the phases of the task, (ii) provide information about the state of the task, (iii) support the attention of the participants, (iv) provide reinforcement and support, and (v) provide reward.

The only difference between the designs was the style of interaction. In other words, the way the behavior was expressed through gestures, speech, and postures was designed either with peer or tutor characteristics. From literature on teachers' multimodal expressions and on peer collaboration [6], [20], we identified distinctive features of speech [23], [27], gestures [1], [12], [28], positioning and posture [19] for each condition. The set of behaviors were organized in a task-dependent flow, which was strictly followed by who controlled the robot. Table 1 presents the above cited interaction modalities and the manipulations applied to convey the peer and tutor character. Figure 2 depicts examples of the robot gestures in PC and TC conditions.

Before the user study took place, we video-recorded all behaviors following the task-dependent flow. We showed the two videos to three Montessori teachers

[1] https://www.aldebaran.com/en/humanoid-robot/nao-robot

Fig. 1. The figure presents children working in dyads on the tasks in (a) the tutor condition (TC) and (b) in the peer condition (PC).

Table 1. Interaction modalities and elements that were manipulated in the peer (PC) and the tutor condition (TC).

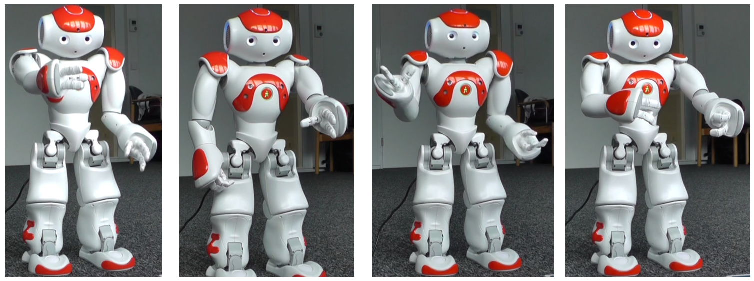
Modalities	Elements	Peer	Tutor
speech	pitch	high	low
speech	style	direct, emphatic	maieutic, interrogative
body	postural	sitting	standing
gestures	deictic	indication, sweeping	pointing, tracing
gestures	emphatic	exultation, surprise	head nods
gestures	representational	grasping	presenting

working at an elementary school in the Netherlands. The teachers filled in a form with one closed question ('*Do you think that the robot behaved like: a.peer b.tutor*') and two open questions to discuss the robot character design (*'What did the robot do to make you think it was more like a peer or a tutor?', Do you have other comments on the behaviors?'*). The teachers correctly recognized the behaviors as belonging to the respective two robot social characters and they made comments consistent with the behavior design.

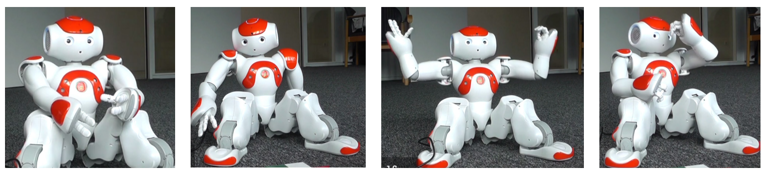
4.2 Setup, Procedure and Participants

Setup. We conducted the study at a Montessori school in The Netherlands. We divided their gym room in three areas: an experimental, a WoZ and a questionnaire area. The WoZ area was only entered by the researchers. From there, the robot was remotely controlled. Although the researcher was sitting in the same room, his role was hidden from the children. The sessions were recorded with three cameras, one recording the central view and two for the side views.

Procedure. A facilitator escorted the participants to the experimental area and provided an introduction to the robot in order to allow the children to familiarize



a)



b)

Fig. 2. The figure presents some pictures of the behaviors designed for a) tutor condition (TC) b) peer condition (PC). In a) examples of deictic, emphatic and representational gestures (pointing, tracing, presenting and head nods). In b) examples of deictic, emphatic and representational gestures (indication, grasping, exultation and surprise).

themselves with it. Thereafter, the facilitator placed the puzzle outlines and the Tangram pieces in front of the children. The robot was placed opposite of the participants, outside the play-mat at a safe distance. After everything was in place, the facilitator asked the children to complete the puzzle with the robot. As soon as the facilitator left the area, the researcher who controlled the robot started the behaviors following the task-dependent flow. After the interaction with the robot, the facilitator escorted the participants to the questionnaire area where the questionnaires were administered.

Participants. Twenty children ($N = 20$) belonging to one Montessori class (this includes children from 6 to to 9 years old) participated in the study. They were divided into six male and four female couples matched by ages. Five couples were assigned to the PC condition ($N = 10$, age: $M = 7.1$, $SD = 1.10$) and the other five to TC condition ($N = 10$, age: $M = 7.0$, $SD = 0.66$).

4.3 Measures

We measured children's task engagement via behavioral observations and a questionnaire. To account for the *cognitive attributes* of task engagement, we investigated the focus of attention, namely the gaze behaviors of the participants directed to the robot and to the task. To get a complete overview of the gaze behaviors of the children in the interaction we also measured gaze to the other child and gaze elsewhere. In order to account for the *affective attributes* of task engagement i.e., enjoyment, we designed a questionnaire based on the subscale enjoyment from the Intrinsic motivation inventory (IMI)[2]. We translated it to Dutch as this was the language of the study. We used a 5-point Likert *Smileyometer* scale anchored from *"Strongly disagree"* to *"Strongly agree"* and we avoided reversed items. To account for the *behavioral attributes* of task engagement, i.e., task performance, we rated the degree of completion of the tasks per dyad i.e., how many pieces were put into the puzzle correctly, with 3 being the maximum for the first task and 6 for the second and the third. We also analyzed task duration.

4.4 Data Analysis

Video data. In total, 125 minutes and 41 seconds of video material were analyzed: 60 minutes and 47 seconds in the PC condition and 64 minutes and 54 seconds in the TC condition. The videos were manually coded in Elan[3] following an annotation scheme developed for the analysis, including focus of attention, task performance, and task duration. The annotations were analyzed using a Matlab toolbox called SALEM [13]. The annotations of focus of attention were analyzed for counts and duration. As the recorded interactions differ in lengths, we normalized the results providing seconds per minute of gaze and counts per minute of gaze (i.e., the rate) We compared the results across conditions (PC vs. TC) with two-tailed independent sample t-tests. Also the results of the degree of completion were compared across conditions (PC vs. TC) with two-tailed independent sample t-tests. To investigate the difference between the duration of task performances between the conditions, a Mann-Whitney U test was carried out. For both focus of attention and task performance we calculated inter-rater reliability for about 10% of the data (11':42") which showed acceptable agreement (Cohen's kappa; focus of attention $\kappa = .730$, $p = .003$, task completion $\kappa = .750$, $p < .001$).

Questionnaire data. The internal reliability of the IMI/ Enjoyment scale was 0.851 (Cronbach's alpha). Unfortunately, the general polarization of the children's answers toward the positive anchor did not allow to find any difference between conditions. Hence, the questionnaire results are not included.

5 Results

Cognitive attributes of task engagement: focus of attention. The gaze to the robot rate was significantly higher in the PC condition ($M = 3.44$, $SD = 0.67$) than in the TC condition ($M = 2.36$, $SD = 0.92$; $t(18) = 2.97$, $p = .008$). Moreover, the participants looked at the robot significantly longer (i.e., gaze seconds/per minute) in the PC condition ($M = 19.30$, $SD = 3.11$) than in the TC condition ($M = 12.71$, $SD = 3.21$; $t(18) = 4.66$, $p < .001$.). As for the gaze

[2] //www.selfdeterminationtheory.org/intrinsic-motivation-inventory/
[3] https://tla.mpi.nl/tools/tla-tools/elan/

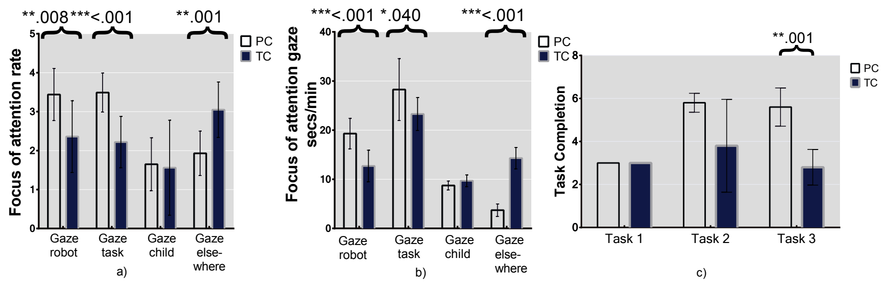


Fig. 3. Difference in focus of attention (robot, task, child, elsewhere) and task completion between peer condition (PC) and tutor condition (TC). Figure 2 a): focus of attention rate results. Figure 2 b): focus of attention results in gaze seconds per minute. Figure 2 c): task completion results. * indicates significance at the 0.05 level, ** 0.01 level, *** < .001 level. Error bars show standard deviations.

on the task, the rate was significantly higher in the PC condition (M = 3.49, SD = 0.50) than in the TC condition (M = 2.22, SD = 0.66; $t(18) = 4.86$, $p < .001$). The average amount of gaze seconds per minute on the task was also significantly different in the two conditions and more in PC. (PC: M = 28.26, SD = 6.30; TC: M = 23.29, SD = 3.26; $t(18) = 2.21$, $p = .040$). We found no significant difference in the rate (PC: M = 1.65, SD = 0.68; TC: M = 1.56, SD = 1.22) and gaze seconds per minute (PC: M = 8.73, SD = 0.90; TC: M = 9.70, SD = 1.20) to the other child, but the rate and gaze seconds per minute elsewhere are significantly higher in TC (PC: M = 1.93, SD = 0.57; TC: M = 3.05, SD = 0.71; $t(18) = 3.84$, $p = .001$; gaze secs/min elsewhere: PC: M = 3.71, SD = 1.27; TC: M = 14.30, SD = 2.18; $t(18) = 13.28$, $p < .001$ see Figure 3 a, b).

Behavioral attributes of task engagement: completion. Task 1 was completed by all the participants in both conditions. Task 2 was fully completed by 80% of the participants (4 out of 5 dyads) in the PC condition and by just 20% of the participants (1 out of 5 dyads) in the TC condition. The task performance in Task 2 is better in the PC condition (M = 5.80, SD = 0.44) than in the TC condition (M = 3.60, SD = 2.40), but no statistically significant difference was found. Likewise, Task 3 was completed by 80% of the participants in the PC condition and by only 20% of participants in the TC condition. The task performance was better in PC (M = 5.60, SD = 0.89) than in TC (M = 2.80, SD = 0.83) and a statistically significant difference was found ($t(8) = 5.11$; $p = .001$, see Figure 3 c).

Behavioral attribute of task engagement: task duration. The participants in the TC condition took more time to perform the tasks than the participants in the PC condition. A Mann-Whitney U test conducted on the total performance duration i.e., all three tasks, confirmed that the participants in the TC condition (mean rank = 18.50) took significantly more time (U = 154, Z = 2.13, p = .033) to perform the task than the participants in the PC condition (mean rank =11.73).

6 Discussion

In this paper we presented a study on the effect of two robot social characters, peer-like and tutor-like, on children's task engagement. Our results showed that the children performed significantly better in the more difficult task and were faster when working with a peer-like robot character. These results support H1b (a peer-like character will enhance behavioral task engagement). However, the questionnaire results do not allow us to say anything about children's enjoyment, thus H1a (a peer-like character will enhance affective task engagement) cannot be addressed.

We believe that this outcome suggests the potential inappropriateness of using questionnaires for this user group [5]. Another explanation is the *suggestibility effect* [29], i.e., the desire to please the researchers. Nevertheless, our findings also show that the peer-like character appears to have a positive effect on the focus of attention of the children. In fact, the peer character triggered significantly more attention towards the robot and the task than a tutor-like character. Moreover, in the tutor character condition, the participants looked more elsewhere and this can be an indication that the tutor character could be less effective in sustaining attention to the task. These results contradict H2 (a tutor-like robot social character will enhance the focus of attention on the task and the robot), but they highlight that the behavioral repertoire of a peer might be able to enhance children's cognitive engagement with a task and the robot. Overall, our results suggest that embedding a peer-like repertoire of engagement-seeking robot behaviors might represent a good strategy in task-related child-robot interactions.

7 Limitations and Future Work

Our exploratory study is a very first step towards understanding the effect of a robot's social character on children's task engagement. As such, it has some limitations, which will be addressed in future work. We are aware that our findings cannot provide a comprehensive account on the effect of the peer robot character on the task performance results, as they do not account for children's prior level of ability on the task. In our experimental design, we tried to overcome possible discrepancies in the children's cognitive development matching the gender and the age of the participants. Nevertheless, future work needs to take children's task abilities (prior and post interaction) into account. Also, our forthcoming research should provide a complete overview of the dyads/groups dynamics in a more sequential way (i.e., how does the interaction change over time). In addition, we will address children's expectations towards robot behaviors to have a better picture of the effect of a robot character on children's task engagement.

Building upon our promising findings and significant results, we will proceed with bottom-up investigations to discern low-level engaging behaviors and interaction style features of a peer's behavioral repertoire, while investigating if and how a social role can emerge from a social character.

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