Can Children Take Advantage of Nao Gaze-Based Hints During GamePlay?

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ABSTRACT

This paper presents a study that analyzes the effects of robots' gaze hints on children's performance in a card-matching game. We conducted a within-subjects study, in which children played a card matching game "Memory" in the presence of a robot tutor in two sessions. In one session, the robot gave hints to help the child find matching cards by looking at the correct match and, in the other session, the robot only looked at the child and did not give them any help. Children performance was measured using the number of tries and overall time used to complete the game. Our findings show that the use of gaze hints (help condition) made the matching task significantly easier and that children used significantly fewer tries than without help.

Author Keywords

Human-robot interaction, intentions, nonverbal behavior, social robotics, child-robot interaction, gaze-based interactions; attentional cues;

ACM Classification Keywords

Human-robot interaction; Gaze based interactions; Social robotics;

INTRODUCTION

Robots continue to gain popularity in areas of educational training, rehabilitation and therapeutic programs for children [3, 13]. The research in this domain has demonstrated the prospect for social robots to support children's interactions [5, 8]. For example, robots can provide appropriate personalized interactions by adapting to the cognitive and affective needs of a child, can give repetitive instructions or feedback, which may be challenging for individual teachers in classrooms. Furthermore, robots have been shown to elicit interest, which makes them useful tools for learning [10]. While there are many prospective benefits of social robots , their successful implementation requires that robots provide appropriate and intuitive interactions with human users.

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Nonverbal cues are essential in human - human interaction. Among nonverbal behaviors, gaze is a primary source of information that humans use to communicate their intentions, emotions, and their attention [2, 12]. An essential communicative property of gaze, in particular, is its ability to direct attention to objects of interest [11, 12]. Such attention directing gaze facilitates the formation of joint and shared attention, which are the foundation for child learning and development [9, 14]. Moreover, joint attention is considered to be the foundation of the theory of mind and perspective taking, which are important in early childhood social cognition. Thus, being able to understand and provide gaze cues is an important aspect in developmental robotics.

While a lot of gaze research has taken a human-centered approach to examine the ability of humans to read and perceive social cues from a robot gaze [1, 6, 7, 15], many questions remain unclear, particularly on how children perceive and respond to gaze cues, and whether they are able to attribute intentions to a robot's gaze cues during child-robot interaction. In this paper, we examine whether children read/notice gaze hints in humanoid robots; if so, whether they are able to interpret these cues appropriately and, finally, whether and under which conditions these social cues impact their performance and their cognitions about the robot. The ultimate purpose is to gain understanding of how gaze hints could be implemented as an efficient help mechanism for a robot-based tutoring system.

To answer the abovementioned questions, we designed a board game task in which a child plays "Memory" (matching card game) in the presence of a robot tutor. The robot tutor knows the positions of all the cards on the table. The aim was to examine if gaze hints provided by the tutor robot influenced the performance of the child in terms of execution: the number of tries (tries to pick a card) and the overall time the participant takes to complete the game.

Based on the non-verbal theories of gaze [11, 12], we hypothesized that gaze hints will direct the attention of the children, either implicitly or explicitly to the matching card and, thus, children will perform better with the help of the robot tutor than without help.

METHOD

Participants

Eighteen typically developing children, aged between 4 and 11 years, took part in the study; 10 of them were boys and the other 8 were girls. A picture of the child interacting with NAO can be seen in figure 1 below:-

Figure 1. Child - Robot Setup

Experiment Setup

The experimental setup, included a NAO robot, a memory game, a webcam, and a personal computer (Figure 1). NAO is a 57cm tall robot from Aldebaran robotics [18], with a moveable head and facial features that bear resemblance to those of a child. The robot tutor and the child sat across the table approximately 160 cm apart; there were fourteen (14) cards arranged in a rectangular board layout placed on a table. The arrangement of the cards on the table was informed by our prior work, where we first examined whether people can perceive gaze and head angles directed at different card locations on the board layout [16].To develop the memory game algorithm, we used the Java programming language. The algorithm was applied such that, after scanning the code of the selected card, the robot automatically executed a sequence of head movements, as follows; the head angles shifted to the position of the chosen card then to the face of the participant, and then to the location of the matching card.

Experiment Procedure and Conditions

In the beginning, the cards were laid face down on the board, and the child was required to find matching pairs of cards by turning the first one and then guess of the matching one. The cards contained pictures of black dog 'silhouettes' that varied slightly in **shape. If** the two cards turned face up were identical (a pair), the child continued to a new try. Otherwise, the child turned the cards face down and made a new try/move. The game ended when the child found all the matching pairs.

Each child played the game in the presence of the robot tutor in two conditions. In the **Help condition**, the robot tutor provided gaze hints to help the child find the matching cards, when the child turned up the card; the robot tutor looked at the flipped card, then the face of the child and continued to look at the matching card. In the **No_Help condition,** the robot tutor only looked at the participant and did not provide any help. In the Help condition, the robot tutor added the following statement while giving the instructions"“I know the positions of all the cards on the table; I am going to help you.” However, the tutor did not disclose the modality they were going to use to help; we wanted to see if this statement would trigger a search for help clues from the robot and if children would notice the robot was using gaze to help them. The order of conditions was counterbalanced across trials.

The experiment was conducted in the social robotics lab at the university. Both the experimenter and the researcher were present in the room during each session. Before the game session with the robot, the experimenter welcomed and introduced the child to the robot and detailed the task they were expected to perform. The whole task took approximately 25 minutes.

Measurements

To evaluate the effects of gaze hints on children's performance, we identified two measures that are notably used to measure performance in memory game:-

(1) **Duration:** the time it takes the children to find all pairs of matching cards on the table; and (2)**Tries:** the number of tries required to find all matching cards. A try consists of choosing two cards. All sessions were video-recorded to facilitate the analysis of these measures. The goal of the game was to get all the cards flipped face up (i.e., find all the matching card pairs) in the least number of tries and in the shortest time possible.

RESULTS

For this analysis, we considered a total of 15 children (age 6 -11; Mean Age= 7.6), for a total of 15 trials in the Help condition and 15 trials in the No_Help conditions. We excluded three (3) children from this analysis, one of the children declined to participate in the second session and the other two were very young (below age 5) and needed a lot of help from the experimenter to play the game. From the post-experiment interview, eight (8; approximately 53%) out of the fifteen (15) children said they noticed the help hints from the tutor, while the others (7: 47%) stated that they did not see the help gaze cues.

Effect of Help on performance:-To evaluate the effect of Help on performance, we conducted a repeated measures ANOVA, with Help_Type (Help vs. No_Help) as the within_subject factor.

	Help		No_Help	
Measures	Mean	SD	Mean	SD
Duration (s)	167.87	75.70	169	79.18
Number of tries	14.07	4.90	17	3.65

Table 1: Performance Measures; Mean Duration and Number of tries

Duration:- There was no significant difference in duration of the game between the Help and No_Help condition (Help = 167.87s; No_Help =169.6s; F (1, 14) =0.015, p=0.905).Furthermore, there was no significant correlation between noticing gaze and the duration the children took to play the game (p=0. 530, two-tailed), thus there was no significant difference in time taken to find all the matching pairs between those who noticed gaze hints and those who did not notice the gaze hints.

Number of tries: - There was a significant difference in the number of tries of the game between the Help and No_Help condition (Help = 14.07 tries; No_Help =17 tries; F (1, 14) =5.331, p=0.03). Further analysis shows a significant correlation between noticing gaze hints and the number of tries (p=0.001, two-tailed). This shows that the children who noticed the gaze hints performed significantly better, measured by the number of tries, than those who did not notice the gaze hints.

Age & Gender: - We found no correlation between gender and noticing help (p=0. 483, two-tailed). However, in our observation, we noticed age had an influence on the capacity of children to read help from gaze with older children being more aware of the tutor intent and behaving accordingly while younger children were not able to interpret the robot was helping them despite noticing the cues. This can be explained by social cognition developmental theories of children including the theory of mind [4].

DISCUSSION & CONCLUSION

In this study, we examined whether robot gaze hints can improve the performance of children in a matching card game. We compared two performance measures (time and number of tries) in two conditions, one in which the robot provided gaze hints to help the child find matching cards, and one in which the robot did not provide help to the children. We analyzed the data of 15 children, who were between the ages of 6 and 11. In the following paragraphs, we discuss our performance measures results based on our observations during the study and the answers from children in the post-experiment interview.

In our first hypothesis, we projected that children would perform better with help (gaze hints) from the tutor than without help. Analysis of the number of tries supported this assumption. We found overall that children performed better with gaze hints from the tutor than without gaze hints. However, we found no significant time difference between the two conditions of Help and No_Help.

Eight out of the fifteen children said they noticed the robot hints during the game, while the other children stated that they did not notice the help hints. The majority of the children who did not notice the gaze hints said they noted the head movements of the robot tutor but did not understand that the robot was using gaze to help them, so they were unable to interpret the head movements as gestures pointing to the matching card.

We further found that children who noticed the help gaze hints from the robot performed significantly better with significantly fewer attempts than those who did not see the help. However, we found no difference in duration between those who noticed the gaze hints and those who did not. Thus, based on the findings, we can conclude that most of the children who noticed the gaze hints were able to interpret them and attribute meaning to accept them as help cues. From the subjective feedback we got from the post-experiment interview, children who noticed the help from the robot regarded the robot as friendly giving it terms such as “cool” and were engaged longer during the interaction with the robot.

We found no significant difference in durations during the No_help and Help condition. Moreover, there was no significant correlation between noticing gaze and the duration. There are several possible explanations for this. Firstly, as soon as the children noticed that the robot tutor was helping them with gaze hints, they waited until the robot showed them the matching card, even when they had an idea of where the matching card was. Secondly, the novelty effect of the robot, which is supported by the larger duration for the robot even when the number of tries was less, indicates that the children who noticed gaze probably spent more time looking at the robot. Another probable reason is the duration of head motions during attention shifts from the flipped card to the face of the participant and then to the matching card. Lastly, a few of the children spent some time asking the experimenter questions during the game either due to confusion, or when they saw the robot movement and could not interpret what it was doing

The results from this study compare with our previous study with adult participants using a similar setting on performance. In the adult setting, we found that the participants performed better when the tutor was helping than without help [17]. However, from our observations, we can highlight notable differences on how children perceive and interpret gaze cues from the robot.

For example, in the child experiment, we observed a few children who proceeded to select different cards despite noticing that the robot tutor was looking at a particular card, which was not the case for the adult participants. This could be attributed to social cognitive theories of development [5, 19], which are fascinating to study with robots. This could be attributed to social cognitive theories of development –such as perspective taking and agency attribution- which are fascinating to study with robots. This work provides initial findings on the ability of children to read, perceive and attribute intentions to a robot gaze.

Also, in both settings for the adult and children, most indicated that they expected verbal help from the tutor. We assume the design of the robot behavior may have led participants to expect verbal help from the tutor since, in the beginning, the robot verbally gave instructions to the participant but remained silent during the entire interaction only giving gaze clues. In future works, it would be interesting to vary levels of nonverbal cues -such as a quick glance-, and introducing the fairness of the tutor as a study variable on performance and subjective experience.

Currently, we are carrying out an observational analysis of the child-robot interaction videos recorded to examine child-robot dyad gaze behavior during the game (such as patterns of joint attention and eye contact), the level of engagement and the emotions expressed throughout the game - flow. Our future work involves as well examining the temporal aspects of gaze in human–human interactions to build more realistic interactive robot gaze behaviors, and study interactive gaze behavior with robots with articulated eyes.

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