See Where I am Looking at: Perceiving Gaze Cues with a NAO Robot

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ABSTRACT
Gaze is an important nonverbal cue in human - human communication, for example, in communicating direction of attention. Therefore, presumably being able to understand and provide gaze cues is an important aspect in robot's interactive behavior. While there is considerable progress, as regards the design of social gaze cues for robots, there is little that has been done to examine the ability of humans to read and accept help signals from a robot's gaze. In this study, we examine how people perceive gaze cues and head angles directed towards different target positions on a table when human and NAO robot are sitting against each other as in board game scenarios. From the results, we show that when the head pitch angle is higher (24±2) and the depth is less, approximately 20 cm from the robot, participants detected the positions with good accuracy. Unexpectedly, the locations on the left of the robot were detected with lower accuracy. In conclusion, we discuss the implications of this research for design of interaction settings between human and a robot that is intended for social and educational support.

Author Keywords
Gaze based interactions; gaze perception; serious games for social robots; directed attention; facial orientation

ACM Classification Keywords
H.5.m. Information interfaces and presentation; Design, Human factors.

INTRODUCTION
Nowadays, robots are showing more potential to be effectively incorporated into many social settings, for example in educational and therapeutic facilities for children and nursing homes for the elderly [1]. Accordingly, the design of intuitive human-robot interaction in these settings is becoming crucial. Providing nonverbal cues in an intuitive manner is crucial for the successful application of robots in these settings. Gaze, in particular, is an important nonverbal cue. Gaze facilitates a number of functions in social interaction such as turn-taking activities, communicating direction of attention [2, 3, 4]. Importantly, gaze reading and attending to gaze direction or head orientation cues of another person facilitates the formation of joint visual attention to objects in the surrounding and subsequently helps to create shared attention [5]. Prior work showed that gaze improves interactions with robots and thus being able to understand and provide gaze cues is an important aspect of human-robot interaction [6].

While human-robot interaction research has made considerable progress in finding out how to provide social gaze cues with robots [6, 7, 8, 9], studies are yet to explore the ability of humans to read, and accept help cues from a robot's gaze. In addition, robots capabilities differ significantly from those of humans, and hence their ability to communicate gaze information. Therefore to increase the effectiveness of robot gaze behaviors, it is important, to establish how people perceive gaze cues while interacting with a robot. For this experiment we use NAO robot platform from Aldebaran [10]. NAO has minimal facial features with static mouth and eyes, and its face bear a resemblance to a child's face. Due to its minimalistic design and perception capabilities, NAO robot has been adopted widely for research focused on interactions with children with autism spectrum disorders, either for therapeutic or for general educational/pedagogical purposes. Because NAO lacks movable eyes and therefore has to turn its entire head to look at something, it is necessary, to establish how people perceive gaze cues while interacting with the robot.

The overall aim of our research is to examine how different timing strategies of gaze influence human behavior, particularly in the context of children to robot interactions. As a step toward this goal, we have developed an experimental task, using a board game where a human

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participant plays a matching card game in the presence of either a human or a robot tutor. The general idea is that the tutor provides gaze clues to help the participant find a matching card.

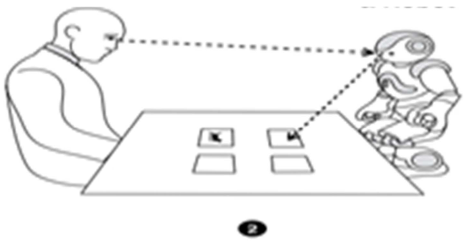

Figure 1: Experimental setting. The interaction flow is as follows: participant (left) turns over a card, tutor (right) gazes at the matching card, participant gazes at the tutor, participant's gazes at the matching card, participant turns the matching card.

Adopting the perspective of human - human communication on gaze behavior and nonverbal cues, we hypothesize that, gaze social cues (facial orientation; head orientation) from the tutor will help focus participant's attention to the matching card and subsequently influence the choice of the participant. Accordingly to determine the above, and to establish whether the gaze cues from the robot will communicate card location, we prepared a design to examine if people perceive accurately the gaze and head direction displayed by NAO robot towards different card positions on the table.

In related work, researchers in [11] measured the region of eye contact with NAO robot. A study in [12] also addresses the ability of individuals to read the gaze direction when presented with various forms of displays. Our motivation is that, many settings used for therapeutic training and for educational purposes are implemented in the form of board games. Therefore it is necessary to investigate gaze perception in such settings, which we further use to build human-centered applications.

METHOD

Experimental Setup

The proposed experimental setup is as follows: The participant and NAO sit on the two sides of a table facing each other. The table is approximately 80 cm in width and the height of the table is 72 cm. A board grid with the card positions resembling a memory game is fixed on the table. The layout has 18 squares (8*8cm) organized in six (6) columns and three (3) rows. The 18 squares correspond to the 18 card positions for the game. The squares are 10 cm apart in depth (y-axis) and 6 cm apart on the width (x-axis). The layout is 600 mm in width and 900 mm long

To measure the angles, we placed NAO on a small desk 56 cm in height at "Stand in "pose (0, 0), and at a distance of 5 cm from the table. The design grid has six squares in the x - direction, which is from left to right side of (NAO), and three squares in the y direction which is the depth direction of the (NAO The distance between NAO and the closest square position is approximately 20 cm away, and the furthest at the corner is about 60 cm. We attached a laser beamer on the mid-section of NAO head and adjusted it to point at the middle of the layout, using the "look at" module in Choregraph program. We estimated the head pitch and head yaw angles for all the target positions using the motion screen on Choregraph.

Position= {HeadYawAngleVal, HeadPitchAngleVal}

NAO coordinate system is as shown in Figure 2; left. The HeadYawAngleVal of NAO gaze direction is defined as the angle between the positive y-axis and a line drawn from the center to a fixated position. The yaw angle of the y-axis is 0, and a positive head yaw angle value is on the left side of NAO. NAO head yaw angles range from -119 to 119 degrees. The HeadPitchAngle of NAO gaze direction is the angle between the *xy* plane and a line drawn from NAO head location to a target square. The pitch (head joint front and back) angle increases from 0 to 29.5. For the setup, the highest angle pitch value used is 24± degrees, for the two middle positions in the first row. The highest yaw angle is 48± for position 1 and -48± for position 6. On the second row, the angle pitch decreases to 10±1 for the middle positions. The pitch angle decreases with increase in yaw angle for the positions on the sides.

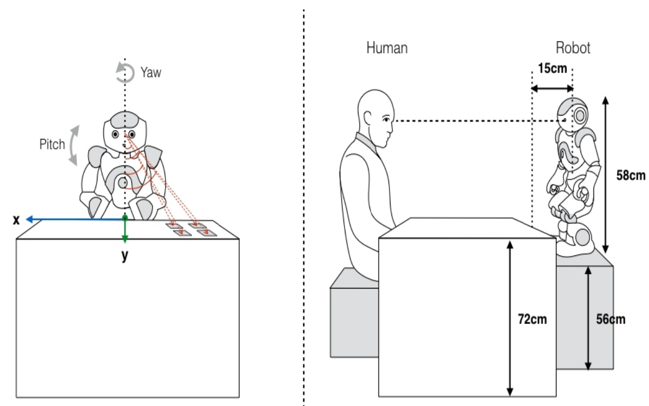

Figure 2: left; Experimental setting; human robot test; side view

Participants and Procedure

Six students from the University College participated in the study. Three were female and three males. The robot was placed on a small table 56 cm tall at (0, 0) with its face directed to the face of the person .The participant sat on a chair which was adjusted to give an eye - height position with the robot. The distance between the robot and the participant was approximately 110 cm. The experimenter informed the participants of their role and gave them instructions regarding the experiment. We implemented a Java algorithm to turn NAO head randomly to the 18 positions on the layout. Each participant interacted with the robot only in one trial. When the robot moved its head to a certain location, the participant wrote a number between 1

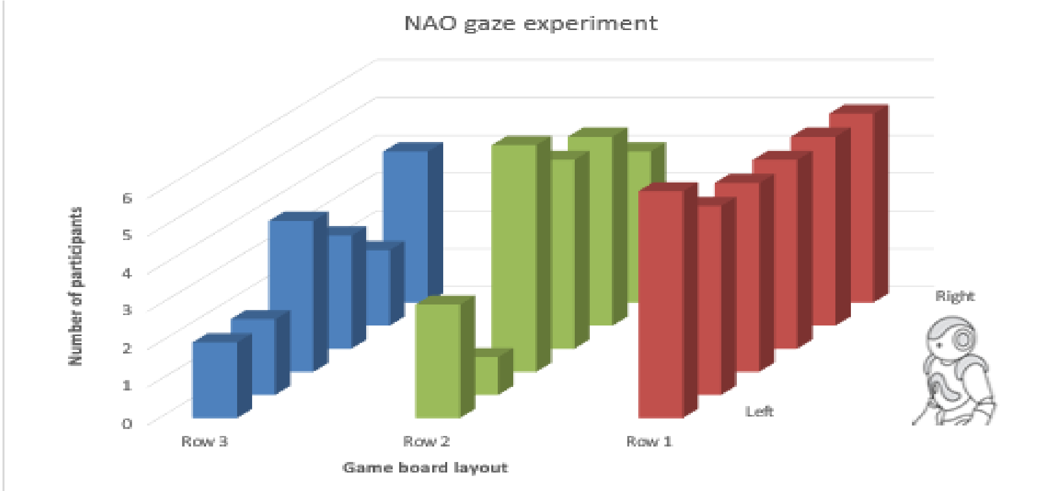

Figure 3. Gaze perception results; the number of participants who perceived the robot gaze correctly for each card location. Row 1; Row 2; Row 3.

and 18 on a post-it and placed it where they perceived the robot was looking on the layout. Each trial lasted for about 5 minutes.

RESULTS

We recorded the number of correct perceptions for each card location. The count of correct perceptions included all the post-its placed inside the square position and those surrounding in a distance less than or equal to 1cm. For the post-its that were placed more than 1cm from the intended card locations, these were regarded as wrong perceptions. Figure 3 shows the results of the gaze perception experiment, on how human observers judged where NAO was looking and the intended card locations. From the graph it is clear that people are better able to perceive correctly the square positions more for the card locations that are in the row that is closest to NAO i.e. when the head pitch angle is higher (24±2); less depth in the y direction) which is approximately 20 cm from NAO. The ability to perceive seems to lessen with the increase in depth. For example, the number of participants who perceived the gaze correctly decreases rapidly when the rows are far from (NAO). The number of correct perceptions is lower in Row 2 compared to Row 1 and continues to lessen for the third row, which is approximately 60 cm away from NAO for this layout

An interesting observation from the result is when NAO robot is looking at positions on its right the participants are better able to perceive more than when the robot is gazing at the locations on its left. Observers were also able correctly to perceive the positions in the middle of the layout more. Observations also show that participants understand head yaw angles quite better as opposed to head pitch angles for this robot. However, with the increase in depth, the perception of yaw information seems to lessen. A study in [13] indicates that the perception of pitch gaze component directions depends on the communicative method, however, the yaw component does not rely on the communication method

CONCLUSION

Being able to understand and provide gaze cues is an important aspect especially for robots intended for educational and developmental support. In this report, we present a preliminary study conducted to examine how human observers perceive where NAO is looking. Our goal was to find out if gaze cues provided by a robot can direct the attention and influence the choices of the human partner. In this initial experiment, we tested whether gaze cues from the robot tutor communicate accurately enough card location in a card board game.

From the results: it is clear that people can follow the orientation of NAO head and its movements to judge gaze direction. Thus, head orientation has a significant influence on gaze direction perception especially with a robot such as NAO, which has fixed eyes. However, it's hard to use head angles alone to distinguish objects on the table if they are very close. Since human observers can clearly perceive NAO gaze cues when the depth is less; it is, therefore, effective to place the objects closer to NAO, for example, reduce the number of rows or increase the spacing between objects for the distant rows from the robot. Consequently, this will improve the accuracy of perception and the overall effectiveness of the use of a social robot in these settings. Unexpectedly, we found that the locations on the left of the robot (right of the human participants) were detected with lower accuracy by the participants. This finding needs to be further investigated in follow-up experiments.

Future work involves examining the temporal aspects of gaze in human–human interactions to build more realistic interactive robot gaze behaviors. Moreover, using human studies is a promising approach as the robots are intended for interaction with humans. Further analysis of head movement's impact on gaze perception with a robot is necessary. In future, we also plan to combine NAO head-directions behaviors, other social cues such as body posture derived from Time and Flow Effort of Laban Movement Analysis [14]. In our future experiments, we will include more human-like eyes, to explore how more articulated eyes will improve interactions in social settings.

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