***Section.* Method**

This research is aimed at answering the research question of how design of gaze behaviors from a humanoid robot affect a human’s natural perception of the robot’s state of whether it is receiving command from him/her or not when robot is fully conducting a task. This question is one of the core HRI problems of Information Exchange defined in [1]. Gaze can be used to establish participant role in conversation [2], the main independent variable is gaze manipulation.

The independent variables are:

**1) Robot gaze behavior**. **2) Robot’s actual state:** a. receiving command, b. not receiving command.

The conditions are: **1) Gaze orientation,** which can be a visual cue showing attentiveness towards a human [3]: a. towards the commander, b. not towards the commander. **2) Eye luminous intensity orientation**: a. from weak to strong, b. from strong to weak. **3) Eye blinking**: a. blinking, b. not blinking. **4) Eye circling**: a. circling, b. not circling.

The dependent variables are: **1)** Human’s perception of a robot’s state. **2)** Accuracy of confirming human’s perceptions of a robot’s state in the correct timing. **3)** Time when participant confirms his/her perception of a robot’s state. **4)** How natural people think each condition of the behavior of gaze cues express robot’s state.

***Subsection.* Hypotheses**

Hypothesis 1: People will think that a humanoid robot is more likely to be receiving command when its gaze orientation is towards themselves than elsewhere.

Hypothesis 2: People will think that a humanoid robot is more likely to be receiving command when its eye luminous intensity increases from zero to high than high to zero.

Hypothesis 3: People will think that a humanoid robot is more likely to be receiving command when its eye is blinking than not blinking.

Hypothesis 4: People will think that a humanoid robot is more likely to be receiving command when its eye is circling than not circling.

***Subsection.* Experimental Design**

In order to explore how the design of gaze cues affect human’s perceptions of robot’s state, a within-participants study was conducted. Each participant went through 4 conditions, which were randomly assigned. A long table (2m x 1m) was used. During the experiment, a humanoid robot of NAO sat in the middle back of the table, using both hands drawing on the paper in front of it with eyes looking down at the picture. Participants were in the other side opposite to the robot. Three laptops were located in the left, middle and right of the table from the same side of participants.

***Subsection.* Experimental Task**

Throughout the experiment, the robot NAO always used its both hands to draw a picture. Participants were asked to give command to the robot. Each participant’s goal was to identify whether the robot is receiving command or not based on his/her perception of the robot. These tasks are aimed at representing the real world situation when robot is focusing on performing a task and a human is attempting to interact with it and give command to the robot, thus during the experiment, the robot NAO is always drawing with both hands.

***Subsection.* Experimental Procedure**

Each participant had to finish 80 tasks with 4 conditions - each condition equally contained 20 tasks. All 80 tasks were randomly assigned during the experiment which was implemented by a research application. A task started with a laptop making sound to notify the user to interact with that laptop. Then a command description was shown on the screen on the laptop. User had to give the command provided from the laptop to the robot by voice command while the robot was drawing. The robot would conduct some actions as a response to participant’s command. After each task the notification of the laptop would always come from one of the other two laptops such that when the robot performed the gaze orientation, it had to move from elsewhere towards the participant.

***Subsection.* Measurements**

Before the experiment, each participant was given an informed consent to sign along with a pre-survey asking participant’s basic information. Two types of measurements were involved in terms of the dependent variables.

*Objective -* After participants giving command to the robot, when the participant thought that the robot was receiving command, he/she should pressed the “1” button, otherwise pressed “2” button. Critical times were recorded, including the start of participant’s giving command to the robot, the start and end of the real robot’s state of receiving command, the start and end of robot’s response actions and the button the participant pressed to confirm his/her perceptions of the robot’s state.

*Subjective -* Participant’s perceptions of robot’s state. After each experiment, a post-survey was given to participants describing their experience with the robot via 7-point likert scales.

***Subsection.* Participants**

A within-participants study was conducted with 30 participants (15 males and 15 females) in total, age ranging from 18 to 27. All the participants were recruited from the University of Colorado Boulder. No prior experience of interacting with humanoid robot was required to avoid the prior-knowledge bias of gaze interactions.

***Section.* References**

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