Evaluating the Effectiveness of Nonverbal Communication in Human-Robot Interaction

Waqar Ali
wali@ku.edu
University of Kansas
Lawrence, KS, USA

Andrew B. Williams
andrew.williams@ku.edu
University of Kansas
Lawrence, KS, USA

ABSTRACT

We evaluate the effectiveness of the type of directions given by a robot in a joint-activity task. The joint-activity task we focus on involves a humanoid robot giving directions to a human subject in exploring an unknown environment and finding objects hidden in certain locations inside the environment. The experiment is conducted in the form of a between-group study with 8 participants in which one group is provided directions by the robot verbally and the other group is given nonverbal directions in the form of hand gestures and gaze direction. Our findings show that the type of directions given by the robot do have a noticeable impact on the performance of the human subjects in the experiment. Specifically, the group which is given nonverbal directions by the robot is on average ~70% quicker in finding all the hidden objects than the group which is given verbal directions. We evaluate the hypothesis from prior research that the reason for this discrepancy is correlated with the reduced perceived mental workload of the activity by the human subjects when the robot provides nonverbal directions, with the help of post-experiment survey responses provided by the participants of our study groups.

CCS CONCEPTS

• **Computer systems organization** → Robotics; • **Human-centered computing** → Human computer interaction (HCI); Empirical studies in collaborative and social computing.

KEYWORDS

nonverbal cues; kinesics; joint-activity; guide robot

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Figure 1: Test environment showing the position of the robot, the human subject and the location of hidden objects marked by small red squares. Inset figure shows a sample hidden object.

1 INTRODUCTION

Social robots have far reaching applications, with robotic frameworks designed for use-cases ranging from elderly care [7] to autonomous guide robots [6]. In general, social robots can incorporate a number of methods for communicating information to human subjects. These modes of communication can broadly be divided into three overarching categories: verbal communication, nonverbal communication and a combination of both. For robot designers as well as academic researchers, the question of which kind of communication scheme to employ in a social robot designed for a particular use-case merits deep consideration and can have far reaching implications on the success of the robot in doing its job effectively.

The purpose of this study is to measure if there is a noticeable difference in how effectively human-beings can interpret verbal and nonverbal guidance provided by a humanoid robot in a joint-exploration activity. The results from prior research in the field of HRI indicate that nonverbal communication can be more effective in specific joint-activity tasks because the perceived mental workload of interpreting nonverbal directions is less than the same for verbal directions [5]. Moreover nonverbal cues such as gaze direction [4] can be particularly effective in directing the attention of human subjects and improving information recall [3] and hence can play a role in improving the human-robot interaction in a joint-exploration activity.

2 STUDY DESIGN

We conduct a between-groups study in which a humanoid robots provides directions to human-subjects in exploring an unknown environment and finding three small objects hidden in different places inside the environment by giving either verbal or nonverbal

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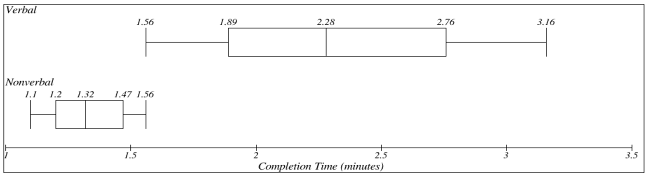

Figure 2: Completion time data from the study groups. The annotated values show the min, lower-quartile, median, upper-quartile and max values respectively from all the experiments.

directions based on the subject's assigned group. The environment consists of an enclosed space which provides a number of places for hiding the test objects out-of-sight. A predefined set of locations is created beforehand based on how clearly the robot can indicate these location either verbally or through pointing gestures from its own preset location inside the environment. Three locations from this set are selected randomly before each experiment which are then used to hide the objects. We conducted the experiment with 8 human-subjects; with 4 subjects assigned randomly to each group.

We use the Nao [2] robot from SoftBank Robotics in our study. The robot is chosen because of its humanoid design and the ease of programming simple motions into the robot using the accompanying software suite [1]. The robot is remotely controlled through Wizard-of-Oz technique. In the verbal mode, it provides directions to the human subjects about the hidden objects from its own perspective e.g., "Please look under the second desk on my left". In the nonverbal case, the robot points in the direction of one of the hidden objects with its hand and directs its gaze in that direction as well by rotating and pivoting its head as shown in Figure 1.

The activity is designed and explained to the human subjects in the form of a game. Before each experiment, the subject is shown a sample object similar to the ones which are hidden and told to find the hidden objects by interpreting the robot's directions as faithfully as possible. The total time limit allotted to the activity is 5-minutes. Once the activity starts, the time taken by the subject to find all the hidden objects is measured[1] and the subject is asked to rate various aspects of the human-robot interaction involved in the study on a Likert scale via an online survey. Figure 1 shows the test environment during one of the experiments; showcasing the robot used, a sample object and the marking the locations in which the objects were hidden for this particular case.

3 RESULTS

Figure 2 plots the results of the time taken by subjects in each study group to complete the game task with the help of the robot. These results show that the subjects which received nonverbal instructions from the robot were noticeably quicker in finding all the hidden objects and completing the game than the subjects who received verbal directions. On average, subjects in the verbal group finished the game ~40% slower than those in the nonverbal group.

In the post-experiment survey, the participants were asked to rate different aspects of the human-robot interaction during the game using the following questions on the Likert scale:

[1]All the subjects were able to find the hidden objects within the time limit.

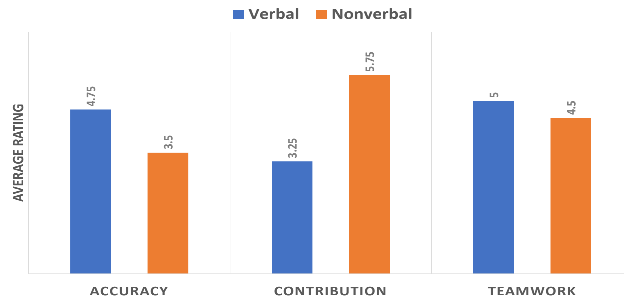

Figure 3: Post experiment survey ratings

- **Accuracy**: How accurate were Nao's directions in finding the hidden objects? (1-Not accurate at all, 7-Very accurate)
- **Contribution**: Were you able to easily understand Nao's directions? (1-Not easily at all, 7-Very easily)
- **Teamwork**: Would you consider Nao an effective team player? (1-Ineffective, 7-Very effective)

The average ratings from the survey for the two study groups is plotted in Figure 3. In terms of accuracy, the participants in the verbal group found the robot's directions to be more accurate. The most likely reason for this is that although the subjects in the verbal group took longer to interpret the robot's direction and often misinterpreted them in the first attempt e.g., if the robot said "Look under the second desk on my left", instead of looking to the robot's left, they start looking under the desk on their left—they attributed the misinterpretation to their own failure of understanding instead of that of the robot. In terms of contribution, the participants rated the robot's contribution more positively in the nonverbal group; indicating that they did not have to exert too much effort themselves to explore the environment. Finally, participants in the verbal group gave a better teamwork rating to the robot. The additional comments provided by the participants in this group indicate that the participants were positively impressed by the verbal articulation of the robot which could have led to their improved perception of it as a better team player.

REFERENCES

[1] [n. d.]. Choregraphe Suite. http://doc.aldebaran.com/2-4/software/choregraphe/index.html.
[2] [n. d.]. Nao: The Humanoid and Programmable Robot. https://www.softbankrobotics.com/emea/en/nao.
[3] Chien-Ming Huang and Bilge Mutlu. 2013. Modeling and Evaluating Narrative Gestures for Humanlike Robots. In *Robotics: Science and Systems*.
[4] Takamasa Iio, Masahiro Shiomi, Kazuhiko Shinozawa, Takaaki Akimoto, Katsunori Shimohara, and Norihiro Hagita. 2010. Entrainment of Pointing Gestures by Robot Motion. In *Proceedings of the Second International Conference on Social Robotics (ICSR'10)*. Springer-Verlag, 372–381. http://dl.acm.org/citation.cfm?id=1948708.1948755
[5] Manja Lohse, Reinier Rothuis, Jorge Gallego-Pérez, Daphne E. Karreman, and Vanessa Evers. 2014. Robot Gestures Make Difficult Tasks Easier: The Impact of Gestures on Perceived Workload and Task Performance. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, 1459–1466. https://doi.org/10.1145/2556288.2557274
[6] Jorge Sales, Jose V Martí, Raúl Marín, Enric Cervera, and Pedro J Sanz. 2016. CompaRob: the shopping cart assistance robot. *International Journal of Distributed Sensor Networks* 12, 2 (2016), 4781280.
[7] C Urdiales, JM Peula, C Barrué, EJ Pérez, I Sánchez-Tato, JC del Toro, U Cortés, F Sandoval, R Annicchiarico, and C Caltagirone. 2008. A new collaborative-shared control strategy for continuous elder/robot assisted navigation. *Gerontechnology* 7, 2 (2008), 229.