

Personal Space Intrusion in Human-Robot Collaboration

Jessi Stark, Roberta R.C. Mota, Ehud Sharlin

University of Calgary
2500 University Drive, N.W.,
Calgary, Canada
{jtstark, roberta.cabralmota, ehud}@ucalgary.ca

ABSTRACT

Our research aims toward a method of evaluating how invasion of personal space by a robot, with appropriate social context, affects human comfort. We contribute an early design of a testbed to evaluate how comfort changes because of invasion of personal space by a robot during a collaborative task within a shared workspace. Our testbed allows the robot to reach into the human's personal space at different distances and urgency levels. We present a collaborative task testbed using a humanoid robot and future directions for this work.

ACM Reference format:

J. Stark, R.R.C. Mota, and E. Sharlin. 2018. Personal Space Intrusion in Human-Robot Collaboration. In *HRI'18 Companion: Conference on ACM/IEEE International Conference on Human-Robot Interaction, March 5-8, 2018, Chicago, IL, USA*. ACM, NY, NY, USA, 2 pages. DOI: <https://doi.org/10.1145/3173386.3176998>

1 INTRODUCTION

Personal space has been defined as “the area individuals maintain around themselves into which others cannot intrude without arousing discomfort” [3]. Consequently, maintaining appropriate interpersonal distance is important in social interactions. However, there are many scenarios in which interaction with a robot within personal space may be appropriate or necessary. For example, research has shown that robot-assisted movement training may be useful after a stroke [8]. We are therefore investigating how invasion of personal space by a robot affects comfort. We present an early testbed to evaluate comfort during a collaborative task with a robot, and future directions for this work.

2 RELATED WORK

In [1], Argyle and Dean present their equilibrium theory for social interactions. This theory recognizes that the appropriate distance for interaction may be inside the typical personal space boundary depending on other factors of interaction such as amount of eye contact, intimacy of topics discussed, and amount of smiling.

In [11], Walters et. al. used the stop-distance technique to define a personal space boundary when interacting with robots;

however, their work did not include interaction within that boundary. There has been similar work about robots approaching groups of people [5]. Some related studies have also been done in human-robot hand-over [7], but these pertain mainly to technical safety and path-planning rather than comfort.

Further to these examples, we build on previous work by using heart rate to non-intrusively measure stress related to personal space invasion [4]. We also explore two different approach angles, a factor shown to affect people's interaction preferences in [10].

3 PERSONAL SPACE INTRUSION TESTBED

The purpose of this testbed is to provide a way of measuring how a person's comfort changes because of personal space invasion by a robot during a collaborative task. We believe our simple Lego-building task described in this section will scale to other types of collaborative tasks such as those that might occur in the workplace.

Our testbed is based on a Rethink Robotics Baxter humanoid and Wizard of Oz [9] implementation. We designed two versions of the testbed to accommodate a scenario in which the builder is seated across the table from Baxter (Figure 1, top) and builds a Lego house, and a scenario in which the builder is seated next to Baxter on the same side of the table (Figure 1, bottom) and builds a Lego vehicle. These scenarios allow Baxter's reach to approach the participant from the front and from the side. While the participant is building, Baxter repeatedly reaches into their personal space to deliver additional Lego blocks. There are six reach states in each scenario, defined by three different reach distances and two different levels of urgency.

The two urgency levels are defined by the amount of time it takes Baxter to complete the dump. In the “hurried” states, Baxter dumps the Lego as soon as the arm arrives at the reach distance. This results in Baxter's arm remaining within the builder's personal space for a shorter time. In the “relaxed” states, Baxter waits for 1.5 seconds before dumping the Lego and before returning to the waiting state, maintaining the intrusion for a longer time.

In the Across scenario, Baxter's reach distances are 6, 8 and 12 inches from the participant's edge of the table. In the Beside scenario, the reach distances are measured from the participant's edge of the additional table separating them from Baxter (Figure 1, bottom). The medium distance is at that edge, while the near distance is 2 inches closer to the participant and the far distance is 2 inches closer to Baxter. This setup allowed closer reaches.

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the Owner/Author.
HRI '18 Companion, March 5-8, 2018, Chicago, IL, USA
© 2018 Copyright is held by the owner/author(s).
ACM ISBN 978-1-4503-5615-2/18/03
<https://doi.org/10.1145/3173386.3176998>

Baxter's head LCD screen displays a neutral face and gazes down toward the table where the participant is building and blinks or glances up toward the participant randomly throughout the interaction. The neutral face was chosen since

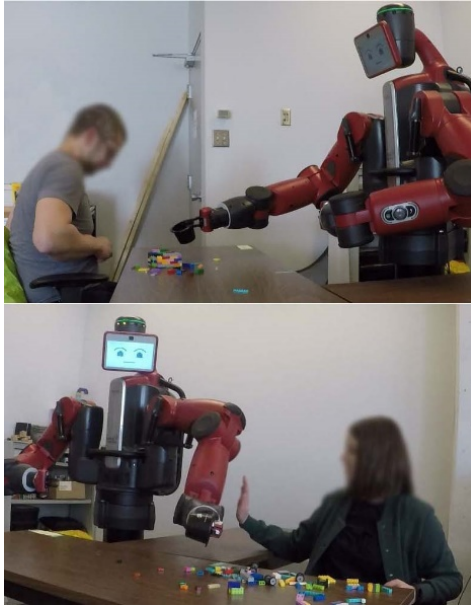


Figure 1. Personal space intrusion in the Across (top) and Beside (bottom) scenarios during a collaborative Lego-building task.

facial expression may affect the results [1], but we chose to focus only on depth and duration of personal space intrusion at this stage in our work.

In a pilot study we conducted, the reaches were counterbalanced using Latin Square. Each of the six reach states are repeated six times to obtain sufficient data, resulting in 36 reaches for each participant. The order of the scenarios is also counterbalanced between participants. After both scenarios are done, the participant fills out the Robotic Social Attributes Scale (RoSAS), found in [2]. We chose RoSAS because it contains items to measure discomfort.

Our testbed is based on evaluating the participants' comfort levels using qualitative and quantitative measurements. Our qualitative measurements include reflection on the participants' body posture and movements during the interaction which we captured on video, and on the RoSAS questionnaire. Our quantitative measures include heart rate data obtained during the task from the participant using a Xiaomi Mi Band 2 [12].

4 DISCUSSION AND FUTURE WORK

We conducted a pilot study using our testbed with 3 participants. Our observations showcased the potential of our testbed to uncover insight about comfort and invasion of personal space by robots, but we do not currently have enough data to draw conclusions.

In a full study still to come, the question we will aim to answer is: When a human's personal space is violated by a robot during collaboration on some task, how is the human's comfort affected by different levels of portrayed urgency and depths of intrusion? We hypothesize that decreased urgency, or greater duration of intrusion, as well as greater depth of intrusion, will elicit stronger reactions from participants.

Future planned work in this direction includes testing additional variables such as speed and facial expression. Collaboration with different robots will also be considered; Baxter's large arms and body size may be intimidating, which will likely affect the findings.

We believe that further investigation of the ways in which robots should intrude on people's personal space would provide insight into how robots should behave in social situations, particularly during collaborative tasks that require intrusion into people's personal space, for example, in the workplace or the intimate touch required during many healthcare tasks.

5 REFERENCES

- [1] Argyle, M., and Dean, J. Eye-contact, distance and affiliation. *Sociometry*, vol. 28(3), 289-304. 1965.
- [2] Carpinella, C. Wyman, A. Perez, M. and Stroessner, S. The robotic social attributes scale (RoSAS): development and validation. *HRI 2017*.
- [3] Hayduk, L.A. Personal space: An evaluative and orienting overview. *Psychological Bulletin*, vol. 85(1), 117-134. 1978.
- [4] Hayduk, L.A. Personal space: Where we now stand. *Psychological Bulletin*, vol. 94(2), 293-335. 1983.
- [5] Joosse, M.P., Poppe, R.W., Lohse, M., Evers, V. Cultural differences in how an engagement-seeking robot should approach a group of people. *5th ACM International Conference on Collaboration Across Boundaries*, 121-130. 2014.
- [6] Kanaga, K.R. The relationship between invasion of personal space and stress. *Human Relations*, vol. 34(3), 239-248. 1981.
- [7] Kulic, D. and Croft, E.A. Safe planning for human-robot interaction. *Journal of Robotic Systems*, vol. 22(7). 383-396. 2005.
- [8] Lum, P.S., Burgar, C.G., Shor, P.C., Majmundar, M.J., and Van der Loos, M. Robot-assisted movement training compared with conventional therapy techniques for the rehabilitation of upper-limb motor function after stroke. *Archives of Physical Medicine and Rehabilitation*, vol. 83, 952-959. 2002.
- [9] Maulsby, D., Greenberg, S., and Mander, R. Prototyping an intelligent agent through Wizard of Oz. *INTERCHI '93*. 1993.
- [10] Walters, M.L., Dautenhahn, K., Woods, S.N., Koay, K.L. Robotic etiquette: results from user studies involving a fetch and carry task. *HRI 2007*.
- [11] Walters, M.L., Oskoei, M.A., Syrdal, D.S., and Dautenhahn, K. A long-term human-robot proxemic study. *2011 RO-MAN*.
- [12] Xiaomi. <http://www.mi.com/en/miband2/>