Factors Influencing The Human Preferred Interaction Distance

Vineeth Rajamohan[1], Connor Scully-Allison[2], Sergiu Dascalu[3], and David Feil-Seifer[4]
Department of Computer Science & Engineering
University of Nevada, Reno, Reno, NV 89557
vrajamohan@nevada.unr.edu, cscully-allison@nevada.unr.edu, dascalus@cse.unr.edu, and dave@cse.unr.edu

***Abstract*— Nonverbal interactions are a key component of human communication. Since robots have become significant by trying to get close to human beings, it is important that they follow social rules governing the use of space. Prior research has conceptualized personal space as physical zones which are based on static distances. This work examined how preferred interaction distance can change given different interaction scenarios. We conducted a user study using three different robot heights. We also examined the difference in preferred interaction distance when a robot approaches a human and, conversely, when a human approaches a robot. Factors included in quantitative analysis are the participants' gender, robot's height, and method of approach. Subjective measures included human comfort and perceived safety. The results obtained through this study shows that robot height, participant gender and method of approach were significant factors influencing measured proxemic zones and accordingly participant comfort. Subjective data showed that experiment respondents regarded robots in a more favorable light following their participation in this study. Furthermore, the NAO was perceived most positively by respondents according to various metrics and the PR2 Tall, most negatively.**

KEYWORDS

Human-Robot Interaction, proxemics, socially-aware navigation

I. INTRODUCTION

Human-human interpersonal navigation behavior is governed by social rules, both written and unwritten. Field research with robots has demonstrated the importance placed on robots obeying these rules as well [14]. While automated systems can be created to obey social norms [6], such systems may utilize features of the robot itself in its model of appropriate navigation behavior [2]. An important question is, *at what distance does a person feel comfortable and safe when interacting with a robot?* In order to enhance the quality of communication between humans and robots, a robot should be able to autonomously position itself in a social setting in order to make interaction as comfortable as possible.

Proxemics, defined as the study of human use of space [1], establishes rules for both stationary and moving agents. Personal space is the distance between two people such that they both feel comfortable when interacting [11]. This concept of personal space has been defined as "proxemic zones," which define how people interact with each other namely, public (>3.6m), social (1.2m - 3.6m), personal (0.45m - 1.2m), and intimate zone (<0.45m) [9]. These zones are only defined in static distances that don't take into account an agent's motion at all.

By contrast, this work examines factors that influence a person's preferred interaction distance beyond just interpersonal distance. This can be different, for example, when a robot approaches a person and when a person approaches a robot. While it is likely that these proxemic zones also exist in human robot interaction scenarios [14], it is also likely that these zones can be different based on features of the robot, user preferences, and relative motion of the two agents. The main goal of this study is to detail more accurately at what physical distance each zone exists when a person is approaching and being approached by a robot. For example, a robot that serves as a caregiver might need to interaction with a human in his/her intimate or personal zone whereas an interaction with a robot that provides information in shopping mall needs interact within a person's social zone. We also want to determine if the height of a humanoid robot has a direct effect on the preferred interpersonal distance.

In this paper, we present a user study that investigates the factors influencing preferred interaction distance from a robot. We examine a participant's gender, method of approach, and the robot's height. The objective measure evaluated was the physical distance between the robot and human that a person deems proper. Subjective analysis involves human comfort and perceived safety.

II. BACKGROUND

Many human-robot interaction and psychology experiments have been conducted to investigate if height influences the size of human's personal space. In this section, we outline prior work for both human-human and human-robot proxemic interaction.

A. Human-Human Proxemics

The stop-distance technique is a well-used technique to examine the interpersonal distance at which a person is comfortable [12]. In this technique, one agent is approaches another; a person will say "stop" when s/he feels uncomfortable with the interpersonal distance. This work has shown that some participants required a larger personal space when compared to other participants, especially when approached from a rear angle. Our experiment leverages this stop distance technique to examine preferred interpersonal distance.

Experiments have shown that the size of person's personal space can be influenced by the height of the person who

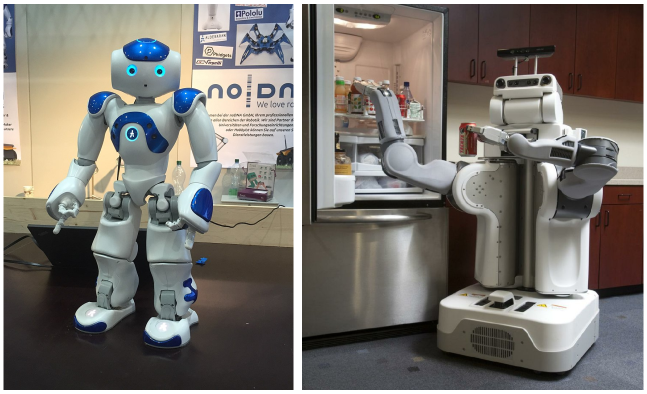

Fig. 1: **left:** the NAO robot; **right:** PR2 robot with height set at 133cm

approaches. Human-human proxemics research suggests that people require more space when interacting with a taller agent when compared to smaller agents [4]. An experiment conducted by Hartnett [10] used two experimenters of different height (1.9m and 1.6m) in order to examine the human's personal space distance. In the study the participant was asked to use the stop distance technique by approaching the experimenter. The results obtained show that the height and pose action of the experimenters played a significant role.

B. Human-Robot Proxemics

Experimental research provided a subjective preferred distance for male and female adults while interacting with a tall and short robot [19]. Human-robot interaction studies have gone one step further to analyze if age, gender [14], and whether robot is being approached by the human or the human being approached [18] affects the human's personal space. Other work examining whether age and gender has any influence on human preferred distance in human robot interaction by directly considering the height of the robot. Results showed that age and gender are a significant factor in determining the preferred interaction distance [19]. This experiment had a variety in age and gender among the participants and used two different robots to study proxemic behavior. However, this experiment only used a visual method for measuring the interaction distance. Participants were not asked to fill out any subjective questionnaires which makes it difficult to get a participant's perspective. Our study makes use of three different robot heights in a laboratory setting.

Another work involved evaluating the social distance for passage in a corridor environment based on the proxemic rules [15]. Results indicated that entering the intimate sphere of people is less comfortable. This is one of the experiments that considered a very common place of interaction i.e, corridors to study proxemic behavior. On the other hand, this study did not include any factors like participant's age, gender, etc. which play an important role in proxemic behavior. In our study we included participant's gender to investigate if gender play a crucial role in preferred human distance from a robot. Duncan and Murphy [5] studied the comfortable approach distance and height for human interaction using a small unmanned aerial vehicle (sUAV). The sUAV approached a human at above head height and below head height, but was unable to find any conclusive comfort difference.

III. Methodology

The main purpose of this user study is to investigate the factors influencing preferred interaction distance from a robot considering the robot's height, participant's gender, and method of approach. The objective measure evaluated was the approved physical distance between the robot and human. Subjective analysis includes human comfort and perceived safety.

We designed our study to examine the effects of approach type (robot approaching human or human approaching robot), participant gender, and robot height in a controlled experimental setting, which could be replicated outside the lab in the future. We employed the stop-distance technique in order to obtain an objective measure of where each participant's comfortable interpersonal distance was, given the experimental conditions. We also used subjective measures of the participants' experience to provide further detail about a participant's comfort with the robot's interpersonal behavior.

A. Experiment Design

We designed a within-participants 2x3x4 experiment with three factors: methods of approach, robot height, proxemic zones. Methods of approach had two levels, human approaching robot and robot approaching human. Robot height had three levels: short, medium, tall. Proxemic zones had four levels: public, social, personal, and intimate. With 40 participants, this results in 960 different data points gathered as data. This will investigate factors affecting the dimensions of personal space for each proxemic zone when a human is interacting with a robot.

Independent variables in our study include the gender of the participant, three different robot heights, two methods of approach. Dependent variables are the size of intimate zone, personal zone, social zone, and public zone. For the three different robot heights we used two different robots as mentioned in Section III-B. Two methods of approach were used in the study. One method of approach is when the participant approaches the robot and the second method is when the robot approaches the participant. Our conditions were tested in a laboratory setting and all participants approach or be approached while standing. The study was conducted inside a laboratory on the University of Nevada, Reno campus.

B. Hardware Platforms

We used two different robots with three different heights which are described in detail below. These robots were used to change and test the effect if the height of the robot play a role in the size of each proxemic zone. ROS and Choregraphe software allowed us to control the movement of each robot. A robot's movement had to be manually controlled to either stop movement or move it forward. For other materials

Fig. 2: PR2 robot with height set as 164.5cm referred as PR2 Tall

we used a tape to mark the position of the robot and the participant. The distance between the participant's marked position and the robot's marked position was measured using a measuring tape. The different types of robot and the software that were used in the study are discussed below:

1) Nao: Nao [7] as shown in Figure 1 below is an autonomous, programmable humanoid robot developed by Aldebaran Robotics. Nao robots have been used for research, health care, and education purposes in numerous institutions worldwide. The robot is 58cm tall that can move, talk, and is capable of speech and face recognition. NAO contains several sensors, motors, and software driven by NAOqi and also has a dedicated operating system. In addition, the NAO has 25 degrees of freedom for movement, two cameras to visualize its surroundings, an inertial measurement unit that allows the robot to detect if it is upright or sitting down, touch, and four directional microphones.

2) PR2 and PR2 Tall: The PR2 [13] (Personal Robot 2) is an open and robust robot platform designed from the ground up by Willow Garage for software developers and researchers. The PR2 robot is fully integrated with ROS and allows software experts to immediately create new functionality on the robot. The PR2 robot has backdriveable arms, spring counterbalance, wrist, and gripper for manipulation. The telescoping spine and an omnidirectional base allows for better mobility. Since the spine of the PR2 robot can be adjusted, its height ranges between 133cm (referred as PR2) as shown in Figure 1 and 164.5cm (referred as PR2 Tall) as shown in Figure 2.

C. Study Procedure

Once the participant had agreed to take part in the study only then s/he was invited to enter the laboratory room along with the researchers. The participants were asked to place any of their personal belongings such as a backpack, water bottle, notebooks, and etc. in one corner of the room so they can freely perform the task. Next, a consent form was provided to the participant to fill out prior to the start of the experiment. Prior to data collection, participants were asked to fill a pre-experiment questionnaire regarding their attitude towards situations and interactions with robots [17].

A demo of the task was then shown prior to any task performed so that participants could get more familiar with the procedure. No training or practice was given to the participants since it may allow familiarity with a particular robot compared to the others. This in turn could skew resulting data. Participants were asked to stand at a marked position referred to as the starting point facing straight towards the robot. The distance between the robot and the starting point was set to 8m. Next, the experimenter briefly explained about each of the four proxemic zones to the participants [8]. The participants were allowed to ask questions to clarify any details that they needed.

One of the three robots as mentioned before was randomly chosen. The participants were asked to perform a task, described in Section III-D. Once the participant completed both tasks for a particular robot, they were given an in-experiment questionnaire [3] asking their impression about the robot. A small 15 seconds break was given to the participants while the experimenters switched to a different robot. The entire process was performed with the other two robots, one after the other in a randomized order. Once the task was completed, the participants were provided with the post-experiment questionnaire, the same as the pre-experiment questionnaire in order to determine any significant changes regarding their attitude towards situations and interactions with robots [17]. In addition the post questionnaire also included details involving demographic data. The entire process for each participant was complete in 18-25 minutes.

Questionnaires were given to the participants towards the end of the study which served as qualitative data for us to examine. Factors that were considered for quantitative data include the distance between the participant and the robot, method of approach, and participant's gender.

D. Experiment Conditions

There were two movement tasks in this experiment. One task required the participant to move towards a stationary robot and the other task involved the robot to approach a stationary participant. Each of the task are discussed in detail below.

First an experimenter told the participant which proxemic zone was currently being tested. The proxemic zone was chosen at random in order to avoid any pattern displayed by the participant when approaching the robot. The participant then walked slowly from the starting point towards a robot and stopped when he/she felt that they reached the edge of the indicated proxemic zone as shown in Figure 3. After stopping, the researcher recorded the position of both the participant and the robot. Next, the participant was asked to move back to the starting point. The researcher then let the participant know the next proxemic zone being tested. The previous steps were repeated for all four proxemic zones. Once all four proxemic zones were tested, the participants were asked to repeat the entire procedure for the other two remaining robots. Throughout the task the robots remained

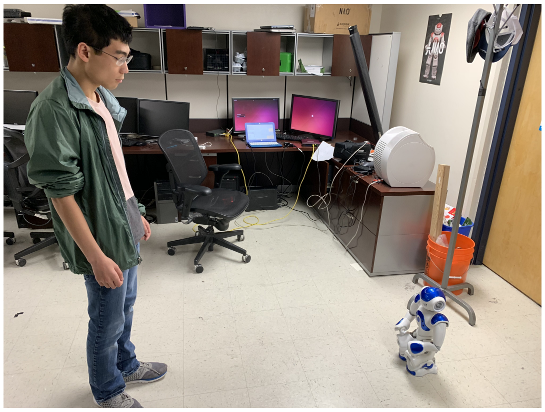

Fig. 3: Task 1 being performed with the NAO robot in which the participant was asked to approach the personal zone.

Fig. 4: Task 2 being performed with the PR2 robot in which the robot approached the social zone.

stationary. After all four proxemic zones for each of the three robots were tested the participant was then asked to perform the second task.

In the second task the participants were asked to remain standing stationary in the starting point. The robot was placed at a 8m distance from the participant and slowly approached the participant approximately 0.1 m/s. The participants were asked to raise their hand and also say the word "stop" when the robot reached the specified zone. Once a researcher received a stopping signal he stopped the robot as seen in Figure 4. The position of the robot was marked and recorded in order to measure the preferred distance between the robot and the participant. Then the robot was moved back to the initial position and the same method were repeated until each of the four proxemic zones were covered. Afterwards, the entire procedure was repeated for the other two remaining robots.

E. *Experiment Hypotheses*

Based on our literature review, we constructed hypotheses:

- **H1**: The size of each proxemic zone will differ based on the situation of whether a human is approaching a robot or when a robot is approaching a human.
- **H2**: The size of each proxemic zone will be smaller when men approach the robot or is approached by a robot compared to women.
- **H3**: The size of each proxemic zone is directly proportional to the height of the robot.

F. *Participant Recruitment*

We recruited a total number of 40 participants for our study (50% male/50% female) from college students at the University of Nevada, Reno. None of the participants chosen knew about the robots nor they had any prior interaction with a robot. Recruitment occurred through word of mouth. Participants were given snacks for participating in the study.

IV. Results

We analyzed all collected data to evaluate how well it proved the hypotheses enumerated in Section III-E. We ran

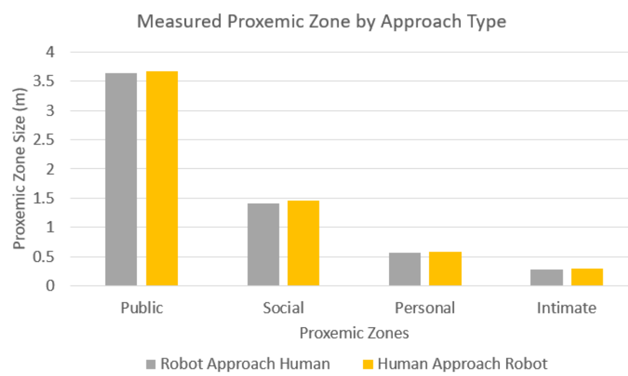

Fig. 5: Averages of absolute distances of measured proxemic zones organized by approach type. Supporting **H1**, proxemic zones were smaller, in general, when robots approached humans compared to humans approaching robots. Upon further analysis we found no statistically significance ($F_{1,38} = 9.437$, $p < .01$) in proxemic size when averaged across all robots and both genders.

an ANOVA analysis on the sole dependant variable collected across all levels of this experiment: Measured Proxemic Zone Size.

A. *Hypothesis 1*

H1 asserted that the size of each proxemic zone will differ based on the situation whether a human is approaching a robot or when a robot is approaching a human. The chart visible in Figure 5 shows that there is a subtle difference in the recorded values of measured proxemic distance when averaged across all robots and both genders.

The difference in these measurements appear minimal (.032 meters for the public zone, 0.034 for the social zone, .004 meters for the personal zone and 0.017 meters for the intimate zone). Using an ANOVA ($F_{1,38} = 9.437$, $p < .01$), we found a significant difference in how close respondents judge a proxemic zone when approaching a robot compared to being approached by robot; respondents consistently stopped the robots closer upon approach to themselves compared

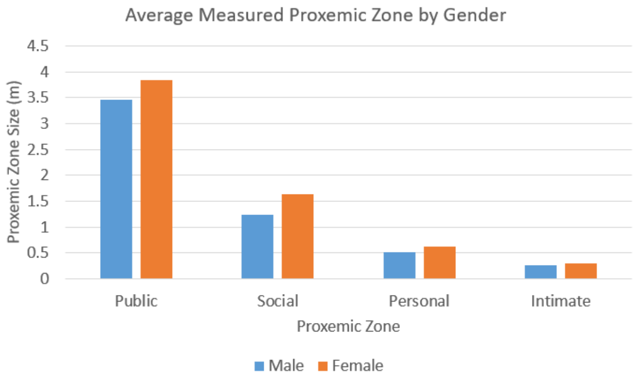

Fig. 6: Averages of absolute distances of measured proxemic zones organized by gender. Proxemic zones are noticeably and consistently smaller for men compared to women across all proxemic zones. Further analysis of variable interactions with the type of robot shows statistically significance ($F_{1,38}$ = 9.201, $p < .01$) that these differences are more pronounced as the height of interacted robots increases, supporting **H2**

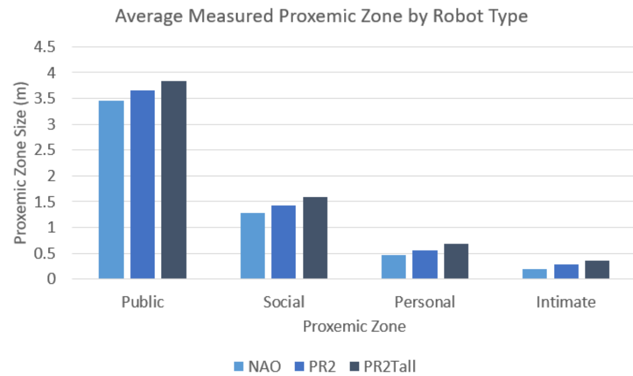

Fig. 7: Averages of all measured proxemic zones organized by robot type. Supporting **H3**, a direct correlation between the height of a given robot and the measured proxemic zone shows statistically significance ($F_{2,76}$ = 188.019, $p < .001$) across all zones in this graph.

with their approach to the robot. Analysis of interaction effects with approach type showed no statistically significant interactions between the method of approach with gender, robot height and the chosen interaction zone.

If we take the measured proxemic zone to be an indicator of social comfort and appropriate use of social space, these data indicate that participants were more comfortable being approached by a robot compared to approaching a robot. It is important to know that the operator's reaction time could have been been involved in the subtle difference obtained between the approach types. No other independent variables played a significant role when the approach type was varied. This supports our conclusions about the effect of approach type on measured proxemic distance. However, the effect size is very minimal.

B. Hypothesis 2

For **H2** we predicted that the size of each proxemic zone will be smaller for men compared to women. Figure 6 shows the differences in measured proxemic zone as divided by respondent gender averaged across all robot heights and approach types. When juxtaposed against Figure 5, it appears that gender plays a significant role on the measured proxemic zone with male participants consistently allowing robots closer to them regardless of the approach method. Accordingly, this strongly supports our hypothesis that the proxemic zone will be smaller for males compared to females.

Numerically, this measured difference is higher in the social and personal proxemic zones, with relative differences of 31% and 19% respectively. It was lower for the public and intimate zones at 10.8% and 10.4% respectively. These measured values based only on the factor of gender were found to be statistically significant ($F_{1,38}$ = 9.201, $p < .01$).

When looking at the independent variable of gender alone it can be hard to deduce exactly what might cause this large discrepancy without devolving into speculation. However, when we look at the interaction effect between gender and the robot height ($F_{2,76}$ = 4.039, $p < .05$) this may give us some better clues as to what causes this gender based discrepancy in measured distance. In Table I we can see that gender-based differences between measured distance widen with the PR2 Tall when compared the PR2 and the NAO.

This intuitive examination is supported with an post-hoc analysis of the collected data averaged across approach type and proxemic zone. Of the 15 unique combinations analyzed by the post-hoc test the most meaningful, statistically significant, interaction was between gender and the PR2 Tall robot. Direct comparisons between genders and robot height with the NAO and PR2 were not statistically significant. When we compare this against the average heights of men and women surveyed we find an interesting relationship.

The average height of men studied in this experiment was 179.07 centimeters and the average height of women studied was 157.60 centimeters. Men averaged 15cm taller than the PR2 Tall robot, whereas women were 7cm shorter than the PR2 Tall robot, on average. As height is a cue for dominance, the difference in relative heights might explain the gender effects that were observed in this study. It should be noted that there are possibly other factors which influence this difference as there was a consistent difference across robots, however a more focused study may be needed to make more concrete conclusions.

C. Hypothesis 3

For **H3**, we predicted that the size of each measured proxemic zone would be directly proportional to the height of the robot. As can be seen in Figure 7, which shows an average of measured proxemic zones divided by each particular robot, we can see that this hypothesis holds true. Regardless of gender, or interaction method, individuals studied in this experiment gave the NAO a smaller distance for the public, social, personal, and intimate zones when compared with the PR2 and PR2 Tall. This distance difference held between the

TABLE I: A table showing averages of all measured proxemic zones organized by approach type, robot type and social zone. The top row in both tables is measurements averaged across all 20 male respondents and the bottom row is measurements averaged across all female participants. All measurements are in meters.

Robot Approach Human											
NAO				PR2				PR2 Tall			
Public	Social	Personal	Intimate	Public	Social	Personal	Intimate	Public	Social	Personal	Intimate
3.262	1.1	0.43	0.18	3.47	1.22	0.52	0.26	3.62	1.32	0.60	0.33
3.60	1.43	0.51	0.21	3.82	1.601	0.60	0.29	4.045	1.826	0.742	0.36

Human Approach Robot											
NAO				PR2				PR2 Tall			
Public	Social	Personal	Intimate	Public	Social	Personal	Intimate	Public	Social	Personal	Intimate
3.34	1.14	0.41	0.19	3.49	1.27	0.52	0.29	3.62	1.38	0.63	0.35
3.63	1.45	0.52	0.22	3.87	1.64	0.61	0.30	4.07	1.82	0.75	0.38

PR2 and PR2 Tall as well with the PR2 Tall being given a wider berth across all social zones.

This effect of the robot height on measured proxemic zone was found to be statistically significant via an ANOVA analysis ($F_{2,76}$ = 188.019, $p < .001$). In addition to the aforementioned interaction effect between robot and gender there was also a statistically significant interaction effect between robot and a particular zone of interaction. This interaction effect indicates that the measured proxemic distance scales with both the robot being interacted with in addition to the proxemic zone we are evaluating. This effect can be seen very clearly by the proportionate downscaling of measured distances across zones and robots in Figure 7.

D. Additional Results

As was detailed in Section III users were given pre- and post-test surveys to see if this experiment made any measurable differences on their attitudes and perceptions toward robots. We asked seven Likert-scale questions, ranged 1-5 with 5 being strongly disagree and 5 being strongly agree, about the participants' feelings towards robots, such as: participants safety, nervousness, uneasiness, distrust, and robot's decision making skills when interacting with robots. A paired t-test was used to evaluate if the user study can change a participant's opinion about robots. The results obtained through the test showed no statistical significance ($t = 0.399$, $p > 0.5$) which shows that the robot experience did not have any short-term effect on the participants' opinion about robots.

V. Discussion

The aim of this work was to examine the factors that influence human preferred interaction distance in canonical proxemic zones for two movement types. Factors included the participant's gender, robot's height, and method of approach. The results indicated that all three of these factors did have a measurable impact on the proxemic zone across all 40 participants.

By using an systematic method of hypothesis testing with the aid of ANOVA analyses on our collected data, we determined that all of our hypotheses held true. The method of approach *did* impact the size of our measured proxemic zone. The gender of study participants *did* have an impact on proxemic zone size and, more specifically it was smaller for men compared to women. Finally, the size of each proxemic zone *was* directly proportionate to the height of the robot being approached by or approaching the participant. Across all zones it held true that the PR2 Tall provoked a larger zone compared to the PR2 and the NAO.

From these results we can make a few conclusions about nonverbal conclusions about humans and robots. First, a smaller robot will likely be favorable for social interactions over a tall one. A similarity between a human-robot interaction and a human-human interaction based on height can be seen through the results obtained in this experiment and a study conducted by Buunk *et al.* helps shows that height has influence on behavioural outcomes [16]. Next, women and men seem to perceive robots and interact with them differently, possibly a height effect. Finally, humans seem slightly more comfortable with robots approaching them compared to when they approach robots themselves based on our observation. This could mean that humans are generally comfortable with robots as active social participants, entering into social spaces like humans.

Future works include adding additional participant characteristics, such as angle of approach, participant's age, and handedness. A follow-up study is required to ascertain if the height of the participant is an impactful independent variable as well. Also, we would like to conduct our study in public places in order to obtain a real world data. Additionally we would add open ended questions for participants to provide feedback on our user study.

Acknowledgements

This work was supported by the National Science Foundation (IIS-1719027)

References

[1] Personal-Distance Zones. =http://www.study-body-language.com/Personal-distance.html, 2010. [Online; accessed 22-November-2018].

[2] Santosh Balajee Banisetty and David Feil-Seifer. Towards a unified planner for socially-aware navigation. In *AAAI Fall Symposium Series: AI-HRI Artificial Intelligence for Human-Robot Interaction*, November 2018.

[3] Christoph Bartneck, Dana Kulić, Elizabeth Croft, and Susana Zoghbi. Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots. *International journal of social robotics*, 1(1):71–81, 2009.

[4] Marc E Caplan and Morton Goldman. Personal space violations as a function of height. *The Journal of Social Psychology*, 114(2):167–171, 1981.

[5] Brittany A Duncan and Robin R Murphy. Comfortable approach distance with small unmanned aerial vehicles. In *2013 IEEE RO-MAN*, pages 786–792. IEEE, 2013.

[6] Scott Forer, Santosh Balajee Banisetty, Logan Yliniemi, Monica Nicolescu, and David Feil-Seifer. Socially-aware navigation using non-linear multi-objective optimization. In *IEEE/RSJ International Conference on Intelligent Robots and Systems*, Madrid, Spain, October 2018.

[7] David Gouaillier, Vincent Hugel, Pierre Blazevic, Chris Kilner, Jerome Monceaux, Pascal Lafourcade, Brice Marnier, Julien Serre, and Bruno Maisonnier. The NAO humanoid: a combination of performance and affordability. *CoRR abs/0807.3223*, 2008.

[8] Edward Twitchell Hall. *Proxemics: The study of man's spatial relations*. 1962.

[9] Edward Twitchell Hall. *The hidden dimension*, volume 609. Garden City, NY: Doubleday, 1966.

[10] John J Hartnett, Kent G Bailey, and Craig S Hartley. Body height, position, and sex as determinants of personal space. *The Journal of Psychology*, 87(1):129–136, 1974.

[11] Leslie A Hayduk. Personal space: An evaluative and orienting overview. *Psychological Bulletin*, 85(1):117, 1978.

[12] Augustus F Kinzel. Body-buffer zone in violent prisoners. *American Journal of Psychiatry*, 127(1):59–64, 1970.

[13] Wim Meeussen, Melonee Wise, Stuart Glaser, Sachin Chitta, Conor McGann, Patrick Mihelich, Eitan Marder-Eppstein, Marius Muja, Victor Eruhimov, Tully Foote, et al. Autonomous door opening and plugging in with a personal robot. In *2010 IEEE International Conference on Robotics and Automation*, pages 729–736. IEEE, 2010.

[14] Jonathan Mumm and Bilge Mutlu. Human-robot proxemics: physical and psychological distancing in human-robot interaction. In *Proceedings of the 6th international conference on Human-robot interaction*, pages 331–338. ACM, 2011.

[15] Elena Pacchierotti, Henrik I Christensen, and Patric Jensfelt. Evaluation of passing distance for social robots. 2006.

[16] Gert Stulp, Abraham P Buunk, Simon Verhulst, and Thomas V Pollet. Human height is positively related to interpersonal dominance in dyadic interactions. *PloS one*, 10(2):e0117860, 2015.

[17] Dag Sverre Syrdal, Kerstin Dautenhahn, Kheng Lee Koay, and Michael L Walters. The negative attitudes towards robots scale and reactions to robot behaviour in a live human-robot interaction study. *Adaptive and Emergent Behaviour and Complex Systems*, 2009.

[18] Leila Takayama and Caroline Pantofaru. Influences on proxemic behaviors in human-robot interaction. In *2009 IEEE/RSJ International Conference on Intelligent Robots and Systems*, pages 5495–5502. IEEE, 2009.

[19] Tim van Oosterhout and Arnoud Visser. A visual method for robot proxemics measurements. In *Proceedings of metrics for human-robot interaction: a workshop at the third ACM/IEEE international conference on human-robot interaction (HRI08)*, pages 61–68. Citeseer, 2008.