Where Should I Sit? Exploring the Impact of Seating Arrangement in a Human-Robot Collaborative Task

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ABSTRACT

Robots are increasingly becoming present in workplaces and social scenarios, where people are interacting and completing tasks with them. In this paper, we explore the importance of the physical seating arrangement or placement of the robot in relation to the human. We designed a novel collaborative human-robot task for exploring how human-robot seating arrangement may influence interaction and the person's perceptions of a robot, and present the results from a pilot and two formal experiments (total 72 participants). Drawing from proxemics literature, we compared a person sitting next to a robot to being across a table from it or beside it, with a corner between them. Our results highlight a range of impacts on participant attitudes toward the robot, as well as their behavior and interaction with it. In particular, seating arrangement impacted participant preferences for the robot, and their use of aggression or condescension during disagreements with it. Our results highlight the importance of seating arrangements for collaborative human-robot teams.

CCS CONCEPTS

•Human-centered computing ~ Human computer interaction (HCI) ~ HCI design and evaluation methods ~ User studies

KEYWORDS

Human-robot collaboration, proxemics, seating arrangement.

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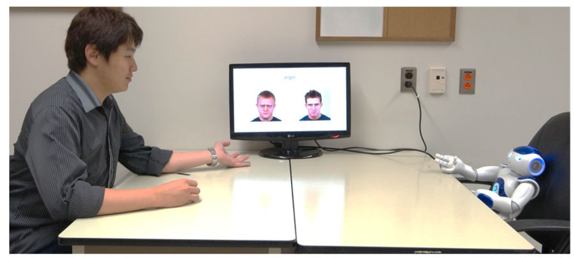
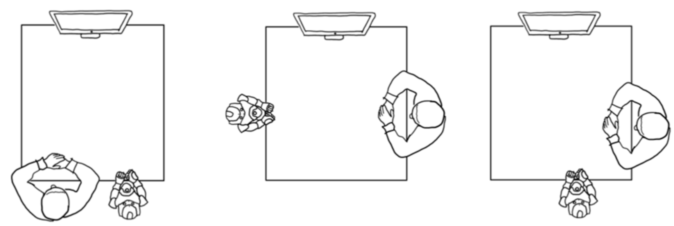


a) A person collaborating with a robot, seated across from it, to classify facial emotions.



b) Sitting arrangements used in our studies: side-by-side, face-to-face, and corner-to-corner (from left to right.

Figure 1. We explore impact of seating arrangement on collaboration with a robot.

1 Introduction

Robots are increasingly emerging in work contexts including search and rescue, factories, and offices, where they work alongside people as team members. The social Human-Robot Interaction (HRI) community continues to investigate how elements of robot design can shape collaboration with robots in such scenarios, for example, to build rapport and reduce social friction [13, 26]. In this paper we focus on proxemics, the physical and psychological spacing between individuals [8]. We specifically study the human-robot seating configuration in a collaborative task, as a key social component for designing human-robot team interaction.

Proxemics research broadly demonstrates that inter-personal physical distance and seating arrangement is related to perceptions of power, social hierarchies, and a person's feeling of collaboration versus competition [8, 28], social impacts highly relevant to human-robot teams. In HRI, proxemics has been explored in relation to how close people stand to a robot (e.g., to reflect comfort [23]) or how they walk alongside a robot [7, 32]. In this paper, we continue this thread by investigating how proxemics, specifically human-robot seating arrangement, can impact human-robot collaborative tasks.

We iteratively designed and refined a task and study specifically for exploring impacts of proxemics on human-robot collaborative work. We created a novel knowledge-work based task that required a participant and a robot to engage in simple dialog to assess problems and come to a consensus. Participants and a robot labeled faces with given emotion tags, and used simple dialog to resolve conflicts. The result is a discussion-based task (in contrast to the physical tasks more commonly used in collaborative experiments, e.g., sorting tasks) that researchers can use as a test bed for exploring impacts of seating arrangement on how participants perceive a robot and interact with it. We conducted a pre-study design pilot, and two formal experiments (72 participants total) to develop and iterate on our experimental design.

Our evaluation focused on the impact of seating arrangement on perceptions of the robot and how participants engaged in collaboration. We compared between three arrangements, drawing from proxemics literature: a person sitting next to a robot, across a table from a robot, or beside the robot with a corner between them (Figure 1, top). Due to the exploratory nature of the research we did not establish hypotheses beforehand, but instead sought to understand the general impacts of seating arrangement on perceptions of the robot. Overall, our results indicate that seating arrangement indeed can impact how conversational or confrontational participants found the robot, and how much they would prefer it to be a colleague. While some results are mixed, depending on the seating arrangement participants exhibited more aggressive and negative behaviors, or more collaborative ones. We did not find any effect of seating arrangement on task outcomes, that is, robot's ability to convince participants to agree with it.

Overall, this work serves as a springboard for establishing the importance of seating arrangement in collaborative human-robot teams, and provides a study design that can be used for further exploration. Our results highlight the importance of selecting positioning of a person and robot for social reasons, above and beyond the practical convenience for a specific task.

2 Background: Proxemics, Collaboration, and Seating Arrangement

The study of proxemics is the interplay between the physical and psychological distance between two people [9], where the two are closely linked; one can observe the inter-personal physical distance to make inferences about the psychological distance. For example, people standing closely together can be assumed to be more familiar than people standing far apart. The foundational proxemics framework [8] outlined distance-based spatial zones, which were later refined, that dictate the types and meanings of interactions between people: these were intimate (0–0.15 m), close intimate (0.15–0.45 m), personal (0.45–1.2 m), social (1.2–3.6 m), and public (3.6+ m) [17]. Thus, we can expect the distance between a person and a robot to similarly impact their relationship and interaction.

Sommer [28] noted the importance of body orientation toward other people as an additional indicator of psychological closeness, for example, directly facing each other versus turned slightly to one side. When engaging in a collaborative task, then, we expect individuals to situate themselves in an arrangement depending on the task at hand and their relationship to each other. For HRI, this suggests that the orientation between the person and the robot – and not just the distance – will be a factor in how people interact.

The relative social status of the interactants impacts how space (distance and orientation) is used, and what it means. Some research indicates that people of equal status keep closer distances than those of unequal status [19] (although others have failed to find such differences [22]). Further, people orient their bodies more directly towards people of higher status than lower status, and equal-status pairs are more likely to face directly than unequal-status pairs [22]. Other relevant factors include gender and likeability, where women tend to place themselves in closer positions and face more directly than males, and individuals who like each other choose to be closer and in more direct orientations. It may be difficult to measure what the relative social statuses would be between a person interacting with a robot, but this factor will need to be carefully considered, for example, how the robot is introduced and what role it is given.

Proxemics is closely related to the nature of a collaborative task, for example, people are more likely to face each other for a competitive task, and face away for a conversational task, perhaps to reduce tension of an encounter [5]. Sommer [28] specifically examined seating arrangements and found that individuals preferred a side-by-side arrangement when cooperating, due to the ease of sharing tasks such as reading from a paper or working on the same object. Individuals indicated that they preferred being face-to-face for competitive tasks as it stimulates competition. Lastly, individuals chose a corner-to-corner seating arrangement for conversation due to the physical proximity and non-confrontational visual contact. In this work, we explore the inverse: how does setting the seating configuration impact how people interact, for example, how competitive they are (or see the robot to be).

This work highlights the importance of the seating arrangement in collaborative teams, including human-robot teams, such as how close a person is to the robot and their physical positionings, and how this arrangement can shape interactions with the robot.

3 Related Work

Research in HRI has explored how a range of robot attributes affect collaboration and interaction, such as the physical robot design (whether it looks human-, animal-, or machine-like [3, 6, 18]), type of speech and gestures used (e.g., human-like [1]), and whether the robot appears to have social skills such as friendliness, a personality, or empathy [14, 27]. All of these can impact how people see the robot, for example, as a social other or collaborator, how positively they see it, or experience sympathy or empathy toward it.

Proxemics frameworks have been used for considering and explaining interaction with technology in general [9, 20], such as in multi-device contexts [11], or with interactive public displays [16]. In HRI specifically, proxemics has been studied in relation to the social interactions between a person and a robot [23], often relating to how comfortable to a person may feel at different distances from a robot. Some have investigated the distances between humans and robots that people are comfortable with [23], and the effects of power structure and physical distancing [15]. For example, people tend to select closer distances with robots they like, and further distances with ones they dislike [23]. Other research has also found that people with more experience with robots (or pets) tend to remain closer to robots than those who do not [29]. We extend this by exploring specifically a forced seating arrangement (distance and relative facing direction) in a collaborative work scenario.

Some robots have been designed to engage in proxemic behaviors, for example, interpreting human states and actions, and altering their behaviors [21, 31]. Similarly, some work has explored how a robot should situate itself in the physical space when following a person (e.g., behind, to the side, or in front), reflecting on the social and interaction implications of these proxemics decisions [7, 30, 32]. Additionally, researchers have found that children respond to robots differently based on seating arrangement [12].

While proxemics is established as an avenue of inquiry in HRI, and the seating arrangements of groups of people has been studied in psychology, this intersection has not yet been explored with adults and robots. In this paper, we investigate how the seating arrangement of a human-robot team impacts the person's perceptions of the robot, and the interaction between them.

4 Study 1: Within-Subjects Proxemics Experiment

We first conducted a within-participants study to investigate the impact of seating arrangement on interaction. We designed an original human-robot collaborative scenario, with the focus relying on a robot and person being seated while completing a cognitive, discussion-oriented task.

To develop our scenario we conducted a series of human-human role-playing pilot trials (where one person acted as the robot), to test ideas and explore potential reactions. We focused on believability and task flow, drafting the robot dialog and decision tree alongside the task. Following, we conducted a set of pilots with 12 different participants to fine-tune our task, robot dialog, and study protocol (e.g., how the task was introduced and framed), to ensure active collaboration, a practical and believable robot dialog tree, and opportunity for the robot and person to have conversations.

4.1 Collaborative Emotion Labelling Task

We created an emotion labelling task where a participant and robot were asked to label the emotions of a set of images of people's faces. Participants sat in a prescribed seating arrangement at a table with a robot and a computer monitor, and we tasked them with collaboratively labelling faces displayed on the monitor (Figure 1, first page). Specifically, the monitor showed a pair of faces and an emotion keyword (e.g., "joy", Figure 2). We designed the procedure so that the person and robot had to collaboratively decide as a team which face best suited the keyword. The collaborative nature of the task was intended to mimic many collaborative tasks that people complete with robots (i.e., in lab and real-world).

For each pair of faces, we asked the participant to first think about their answer carefully, and then to verbally express their initial opinion on which face best matched the keyword. The robot would then either agree or disagree with the participant. We instructed participants to only record their selection if they and the robot agreed, and then a new pair of faces would be displayed. If the participant and robot disagreed, we instructed participants to have a conversation with the robot about why they had each picked the face they did, and to only continue when they had reached consensus by either changing their opinion to match the robot's, or the robot changed its opinion. We carefully scripted a rigid robot conversation tree with generic explanations of the robot's choice, representative of a feasible autonomous robot (see Section 4.2).

Figure 2. Example face pairs displayed during the task. The participant first selected which face better represents the given emotion.

4.1.1 Face Set

We designed our set of face pairs such that they were similar enough for the "correct" emotion to be somewhat ambiguous. This was important to ensure discussion (i.e., the person may doubt themselves) and to create opportunities for the participant and robot to have prolonged conversations, to collaboratively come to consensus. If we had used drastically different faces with an obviously correct answer (e.g., angry vs. happy with a "happy" label) the person would have been unlikely to discuss the choice with the robot, or be confused about the robot's disagreement, casting doubt on the quality of the robot.

We selected faces from the Warsaw Set of Emotional Facial Expression Pictures [24], representing five different emotions: joy, fear, anger, disgust, and surprise. Within each category, we selected faces that were ranked highly within the system (>70% agreement), such that all the faces were good representations of the emotion.

4.2 Robot Script and Wizard of Oz Protocol

During the experiment a researcher secretly controlled the robot from a separate room, following a carefully scripted protocol. For basic study progress (e.g., stating opinion) a static protocol was used. When the robot disagreed with the person, it simply provided a generic reason for its selection such as noting that the eyes, or mouth, represented the emotion better, for example, "I disagree, the eyes do not fit the emotion." The feature selection and exact phrasing was chosen randomly to increase the naturalness of the robot speech. As the participant and robot continued to discuss and consensus was not reached, the robot continued to justify its choice in the same fashion. This was done up to three times total with varying justification (e.g., if the robot first commented on the mouth, it would comment on the eyes or nose during the second comment, and so on). If the participant disagreed after the third justification, the robot would then change its answer and agree with the participant. Following, the next pair of faces would appear on the screen for the participant and robot to discuss.

4.3 Instruments and Measures

For our studies we used an Aldebaran Nao H25 v5 humanoid robot remotely controlled using a wireless network connection. The robot was seated on a chair near the participant. Images of faces were shown on a computer monitor placed on the table close to the participant and the robot (Figure 1).

Post-test, to get a sense of the participants' perceptions of the robot we administered sections from the Godspeed questionnaires [2] to measure how much they found the robot to be kind, friendly, polite, or stubborn. We created and included additional questions that asked the participant the extent to which they thought the robot was being conversational, competitive, and cooperative, and if they would want to work with the robot in the future. In addition, we recorded how often participants changed their answer to match the robot's, which could be considered a measure of trust or persuasion. Given our exploratory purpose and small sample size, we use a p value of .1 as our target.

4.4 Seating Arrangements

We designed three seating configurations to investigate the impact of proxemics on participant perceptions of the robot: side-by-side, face-to-face, and corner-to-corner (Figure 1, first page). Drawing from prior psychology literature (see Section 2), we expect that the different seating arrangements between the person and robot will impact perceived intention and the outcomes, including the kinds of interaction people engage in. For example, we expect people to be more competitive and confrontational with face-to-face conversations [5, 28]. While we know that people tend to situate themselves in a face-to-face seating arrangement during competitive tasks, side-by-side for cooperative tasks, and corner-to-corner (sitting with a corner between each other) in conversations [28], in this study we force the seating arrangements and explore the outcomes, as opposed to allowing participants to choose their preferred seating configuration.

4.6 Procedure

We recruited participants from our general university population using advertisements posted on bulletin boards around our campus. This study was approved by our institutional research ethics board, and participants received $15 for their participation.

When participants arrived, the experimenter gave them a brief overview of the experiment, and provided them with a consent form to sign. Participants then completed a demographics questionnaire, and the experimenter introduced them to the robot, mentioning that it was autonomous (acted on its own) with artificial intelligence. The experimenter then explained the emotion-labeling task, and placed the participant in one of the three configurations with the robot (Figure 1). To establish context, we told participants that they would be helping to evaluate our robot's algorithm for reading human facial expressions, and through discussion, could help improve the robot's algorithm. Participants were told that the robot had highly advanced artificial intelligence, and could have normal conversations with them, but that it also might not be able to express itself as well as humans can. In reality, the robot was remotely controlled and answered in a consistent pre-determined fashion as explained earlier. After the experimenter left the room, the robot told the participant that it was time to begin the task, and the participant clicked the 'start' button on the screen.

A set of 60 pairs of faces was divided into 3 sets of 20 faces (one set per seating arrangement). The pairs of faces were shown on a computer monitor situated at one end of the table that the participant and robot sat at (Figure 1). When a pair of faces was shown, the participant had to state first (before the robot said anything) which face they thought better suited the emotion. The robot then agreed or disagreed with the participant. The robot would usually agree with the participant (45/60 pairs), but would disagree in 15 predetermined instances, which were distributed throughout the experiment; we used the same distribution and order for all participants. Once consensus had been reached between the participant and robot, the participant selected the chosen face using a computer mouse, and the system automatically continued to the next face.

After each set of 20 faces was completed by the participant and robot, the researcher returned to the experiment room, and handed the participant questionnaires to complete before moving on to the next condition. At this time the researcher also rearranged the placement of the robot to form a new seating arrangement. We explained the changes in seating as a secondary aspect of the study, in which we wanted to test the robot's hearing abilities. Once the participant finished completing the questionnaire, the researcher told the participant that now they would be trying a different algorithm for the robot in a new seating arrangement. The order of the seating arrangements was counterbalanced between participants.

4.7 Results

Twenty-four participants aged 18-41 (M=24.79, SD=6.11, 17 females, 7 males) took part in this experiment. We conducted a repeated-measures ANOVA, with participant sex as a between-subjects factor due to previous literature suggesting that gender has an effect on how people resolve conflict [4]. The ANOVA indicated that participants rated how conversational the robot was differently in the corner-to-corner (M=3.9, SD=1.00, 1-5 scale, higher numbers indicate higher agreement), face-to-face (M=3.4, SD=1.06), and side-by-side (M=3.5, SD=1.27) conditions ($F_{2,44}$=3.47, p=.04, η_p^2=.14; Figure 3). Post-hoc pairwise comparisons with Bonferroni correction found face-to-face to be lower than corner-to-corner, (t_{23}=-2.15, p=.08); other post-hoc tests were not significant.

Participants also reported that they would want the robot as a colleague to a different extent in the corner-to-corner (M=4.2, SD=1.01, 1-5 scale), face-to-face (M=4.0, SD=1.08) and side-by-side (M=4.0, SD=.98) conditions ($F_{2,44}$=2.30, p=.09, η_p^2=.12; Figure 3). Post-hoc pairwise comparisons were not statistically significant. On average, participants changed their answer to match the robot's 3.2 times out of 5 (64%) in the side-by-side condition, 3

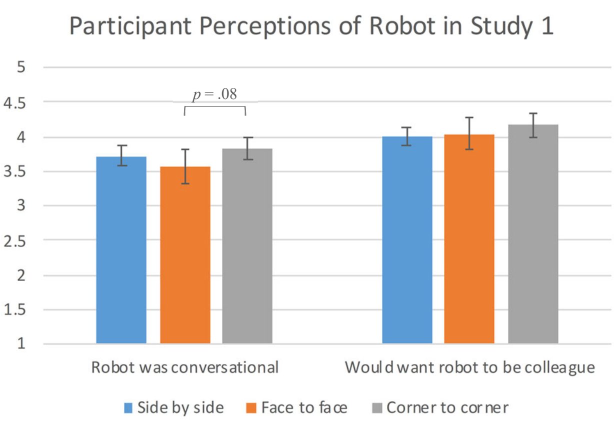


Figure 3. Study 1, participant responses on questions with statistically significant differences. Higher number is more agreement (1-5 scale). Error bars represent standard error.

times out of 5 (60%) in the face-to-face condition, and 3.1 times out of 5 (62%) in the corner-to-corner condition. All other measures, including gender effects and interactions were not statistically significant.

4.7.1 Researcher Observations

Several unexpected participant behavioral patterns emerged during the study. For example, participants would often get frustrated or defensive when the robot disagreed with their choice. When this occurred, some participants tended to react in one of two ways: by either going along with what the robot said, as to apparently reduce the conflict (i.e., amount of arguing), or becoming defensive and uncollaborative, sticking aggressively to their first answer. Anecdotally, these types of actions became more common towards the end of the study session.

We did not expect the task and robot's dialogue to elicit as much conflict as it did, or as prominently. For this reason, we made changes to a follow-up experiment to decrease the amount of conflict in the study.

4.8 Discussion

Overall, we found that seating configuration had a small to medium effect on how participants perceived the robot, in terms of how conversational they felt it was, and whether they would like to be its colleague in the future. We did not find an effect on the task performance measure (e.g., how often the robot convinced the participant to change their mind).

While conducting this study the researchers informally noted a potential learning effect: participants appeared to interact with the robot quite differently in the first condition (i.e., seating arrangement) than in the third. We conducted post-hoc ANOVA repeated measures tests, using counterbalance order as a between-subjects factor, and found a statistically significant interaction effect of counterbalance order on perceived competitiveness (F=2.42, p=.027), as well as a potential trend (given the small sample size) for the trustworthiness of the robot (F=1.89, p=.12). Thus, changes to the experiment to conduct a between-subjects variant and further inquiry are needed to circumvent potential order effects.

In addition, some participants also thought that they were supposed to teach the robot how to read facial expressions, as opposed to completing the task together, so they continually disagreed with the robot's comments, providing a potential confound to our study.

Finally, we mention that following previous research regarding how Wizard-of-Oz experiments can be mentally and emotionally challenging for the wizard [25], we found that our wizard experienced a great deal of distress during the experiment due to participants' frustration and impolite responses directed towards the robot (i.e., the wizard).

5 Study 2: Between-Subjects Proxemics Experiment

Based on the findings from the first experiment, we conducted a follow-up study with an updated protocol to address the many potential issues noted above, including eliminating the learning effects, reducing the negative reactions to the robot arguing with participants, and encouraging participants to take the robot's comments into account. The follow-up study had a between-subjects methodology to avoid any potential learning effects. In this study, each participant interacted with the robot in one seating configuration only. Additionally, we modified the robot's dialogue to make it more positive and less argumentative, in the hopes of lowering negative reactions and interactions with the robot. Like the first study, participants were recruited from our general university population using advertisements posted on bulletin boards around our university. This study was approved by our institutional research ethics board, and participants received $15 for their participation.

5.1 Updated Procedure

The procedure was primarily the same as in the first study, and small changes were made to further reduce the potential for conflict. All other instruments and measures not mentioned in this section remained the same as in study 1.

The robot's dialogue was modified to minimize conflict with the participant, such that it constructively focused on the facial features of the robot's preferred face, and did not say anything negative about the participant or their selected face. As an example, the robot in the first study may have said "I disagree with you. The mouth look(s) wrong." In this study iteration however, the robot might say "Hmmmm… I like mouth on the other face better." Notice that this version does not explicitly challenge the participant by pointing out the disagreement. It also shifts the negative comments about the participant's choice to a positive comment about the robot's own choice.

In addition to the robot's dialogue, we also modified the researcher's script to clarify that participants were not meant to teach the robot, but help us test it. We emphasized that, while the robot may not always be correct, it could also use "advanced algorithms" to notice things that participants may not. In making these changes we intended for participants to not automatically assume that they were correct, but to take the robot's comments into account. We also modified the distance between the participant and the robot, to make it more similar across conditions (Figure 4).

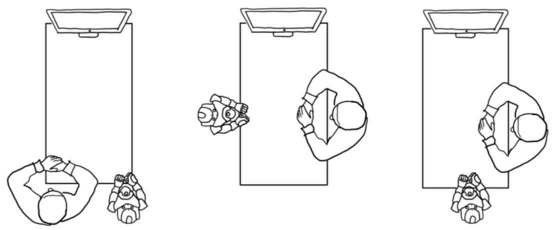


Figure 4. Updated seating configurations. Note how the distance between the participant and robot is much more similar than in Figure 1, where the face-to-face condition had them far apart.

Finally, in moving this variant to a between-participants format, we removed the learning effect between conditions and made the single session longer, increasing the number of opportunities for conversation between the participant and the robot. In this study, each participant kept the same seating configuration while they assessed all 60 pairs of faces with the robot. The robot still disagreed (and argued) in 15 of the cases, and still only protested an additional two times after its initial disagreement.

5.1.1 Qualitative Analysis

Drawing from the results of Study 1, we added a qualitative analysis step to gain further insight into how the seating arrangements impacted participant behavior and interaction overall. Coding was completed by a research assistant *who had no prior knowledge of the project or informal expected results*, which were drawn from background literature. This was to ensure that the open coding was not biased. Further, due to the nature of open coding, one coder was sufficient to extract themes from the videos, as we did not intend to conduct any statistical analyses.

The research assistant conducted an open coding analysis on video data of all participants interacting with the robot. We trained the associate to code for general participant attitude and demeanor toward the robot, participant actions and reactions when the robot disagreed, and general actions and attitudes relating to collaboration. Specifically, the research assistant used existing coding guidelines for rapport building in HRI as a general guide [26]. During training we were careful not to express expectations or the research purpose behind the conditions. Following open coding, the authors cross-analyzed the coded data for similarities and differences between the seating conditions.

5.2 Quantitative Results

Thirty-six participants aged 18-56 (*M*=23.49, *SD*=8.68, 21 females, 15 males) took part in this experiment (12 per condition). Two additional participants were excluded from analysis: one misunderstood the task and was trying to teach the robot, and another did not fill questionnaires correctly. We conducted one-way ANOVAs with seating configuration as the between-participant factor. We found that, based on seating configuration, participants rated how competitive the robot was differently in the corner-to-corner (*M*=3.3, *SD*=1.13, 1-5 scale), face-to-face (*M*=4.2, *SD*=.72), and side-by-side (*M*=3.0, *SD*=1.28) conditions ($F_{2,33}$=4.16, *p*=.02, η_p^2=.20; Figure 5). Post hoc Tukey's HSD tests suggests a statistically significant difference between the face-to-face and side-by-side conditions (*p*=.03). In addition, on average, participants changed their answer to match the robot's 9.7 times out of 15 (65%) in the side-by-side condition, 8.7 times out of 15 (58%) in the face-to-face condition, and 9.4 times out of 15 (63%) in the corner-to-corner condition. No other tests, including participant gender, were statistically significant.

Further, researchers informally noted that participants reacted much more positively when the robot disagreed with them in this study than in the previous one. The robot only focused on why its answer was the correct one, and it therefore did not provide negative feedback in relation to the participant's answer or opinion. This appeared to impact how participants interacted with the robot during the disagreements, and seemed to create a more pleasant, and less hostile interaction than in the previous study.

5.3 Qualitative Results

Open coding was completed on 37 participants. This includes the two excluded from the quantitative analysis, given our goal of exploring participant behavior patterns, but excludes one additional participant due to video recording error; we had 11 corner-to-corner, 14 face-to-face, and 12 side-by-side.

This process resulted in a series of short descriptions for patterns of politeness, friendliness, disagreement, movement, and overall behavior. This was further coded into dominant emergent themes, summarized below. We present participant counts with percentages to facilitate comparison across uneven groups

Participants established a general attitude and tone during initial introduction and robot interaction, with over half of participants (62%, 23/37) exhibiting a friendly and polite demeanor. However, there was a difference between the conditions, with only 45% (5/11) establishing an initial positive mood for corner-to-corner, in comparison to 71% (10/14) for face-to-face and 73% (8/11) for side-by-side. In contrast, more participants were formal and serious, neutral, or obviously negative for corner-to-corner (36%, 4/11), in comparison to the side-by-side (0%, 0/11) or face-to-face (14%, 2/14) conditions. We did notice that some participants were visibly nervous during interaction (14%, 5/37), although these were about evenly distributed between the conditions.

We found across participants that the interaction changed with time, as they gained experience and had opportunities to engage

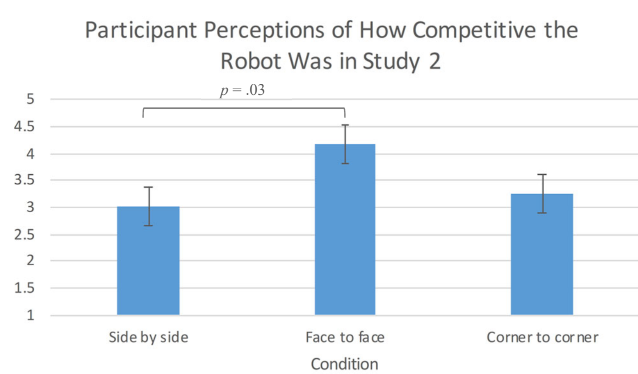


Figure 5. Study 2, participant perceptions of how competitive the robot was (1-5 scale, higher is more agreement). Error bars represent standard error.

with the robot. Over half of participants overall (57%, 21/37) became more assertive with their opinions over time, although only a third (36%, 4/11) exhibited increased assertiveness for side-by-side. In contrast, 79% (11/14) of participants in the face-to-face condition became markedly more assertive and aggressive as the study progressed. While 63% (7/11) of corner-to-corner participants likewise became more assertive; what is noteworthy here is that these participants appeared to be *much* more aggressive and confrontational than the other two conditions.

In fact, half of corner-to-corner participants (55%, 6/11) exhibited explicit antisocial behavior, such as being directly condescending in their voice tone and word choice, using hostile words, being clearly rude (e.g., sarcastic remarks), or smirking to themselves when the robot finally agreed with them. Two corner-to-corner participants would often make faces at the robot or roll their eyes at the robot during disagreement. In contrast, similar behaviors were much less common in the other conditions (21%, 3/14 for face-to-face;18%, 2/11 for side-by-side), with no other participants showing the high level of direct condescension observed commonly in corner-to-corner.

In contrast, some participants (25%, 9/37) became less assertive with time, eventually simply capitulating to the robot's opinions; 36% (4/11) in corner-to-corner, 14% (2/14) in face-to-face, 18% (2/11) in side-by-side. Some of these participants (4 overall) would also visually signal this by leaning back in a relaxed and disengaged pose.

Overall participants generally showed signs of collaborating with the robot during disagreements. Nearly two thirds (62%, 23/37) would explicitly ask the robot for its opinion, in contrast to simply waiting for it to contribute: 72% (8/11) in corner-to-corner, 82% (9/11) in side-by-side, but only 43% (6/14) in face-to-face. Of note is how many participants (43%, 16/37) would aggressively lean toward the robot while trying to convince it, sometimes towering over or widening their eyes to stare; one person would place their hands flat on the table while leaning in, suggesting a desire to demonstrate power over the robot. This happened often in the corner-to-corner (64%, 7/11) and face-to-face (57%, 8/14) conditions. We only observed one participant (9%, 1/11) conducting similar behavior in the side-by-side case.

5.3 Post-Hoc Gender Analysis

As in study 1, we investigated gender as a between-subjects random effect on our measures. While we did not find main effects of gender on results, we did note interaction effects, suggesting further inquiry may be needed. That is, our analysis suggests that the impact of seating arrangement on our measures may have depended on the gender. As such, for exploratory purposes to inform future inquiry, we conducted post-hoc ANOVA tests with the data being split between male and female participants, and Tukey's HSD to obtain condition differences (measures based on 1-5 scales).

In the male participant group, we found no effects of seating arrangement on any measures. In the female group however, participants reported wanting to work with the robot on a project ($F_{2,18}$=4.58, p=.03, η_p^2=.34), more so in the face-to-face condition (M=4.86, SD=.38) than in the side-by-side condition (M=3.25, SD=1.28, p=.02). Participants also reported wanting to work with the robot in general in the future ($F_{2,18}$=4.08, p=.04, η_p^2=.31), with a statistically significant difference between those in the side-by-side condition (M=3.13, SD=1.13) and the face-to-face condition (M=4.57, SD=.54, p=.03). There was a statistically significant difference in the female group on whether participants wanted the robot to be their colleague ($F_{2,18}$=7.06, p=.004, η_p^2=.46) with the difference stemming from the side-by-side (M=3.25, SD=.89) and face-to-face (M=4.71, SD=.49, p= .003) conditions. Lastly, there was a statistically significant difference in how competitive participants perceived the robot to be ($F_{2,18}$=6.11, p=.01, η_p^2=.40), with female participants perceiving the robot in the face-to-face condition (M=4.43, SD=.54) to be more competitive than in the side-by-side (M=2.63, SD=1.41, p=.01) and corner-to-corner (M=2.83, SD=.98, p=.04) conditions. These findings are illustrated in Figure 5.

We highlight that these are post-hoc analyses, and a further study must be conducted to draw concrete conclusions from this. However, these results are sufficient to recommend future proxemics work to explicitly include gender as a study design factor.

5.5 Discussion

Overall, we found that seating arrangement had a range of impacts on both how participants perceived and reported feeling about the robot, and, how they acted toward it. Much of this involved how competitive the robot was perceived to be. The qualitative results paint a picture that highlights how people are more polite, friendly, and less aggressive in the side-by-side condition, may be less collaborative in general in the face-to-face condition, and yet demonstrate a great deal more aggression in the corner-to-corner condition.

Initial post-hoc results also indicate potential gender effects, where female participants reported wanting to work with the robot to different extents, and perceived the robot differently depending on their seating arrangement, yet the same impacts of seating arrangement were not found with male participants. It is possible that this gender difference is due to women generally being more cognizant of social cues (such as body posture and orientation), as previous literature has found that women are better at reading non-verbal cues than men [10]. It is therefore possible that the seating

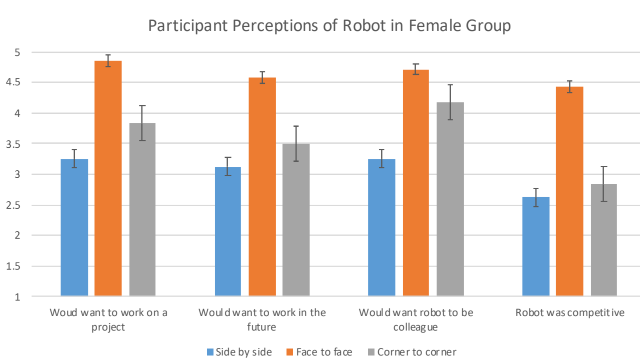


Figure 5. Study 2, post-hoc investigation, female participant perceptions of robot in different seating configurations (p<.05, 1-5 scale, higher numbers indicate higher agreement). Error bars represent standard error.

orientation between the participant and robot had a larger effect on the rapport between them for the female group than the male one.

Anecdotally, the changes that were made from the first study to the second did seem to improve the interaction between the participant and robot, with fewer expressions of frustration or hostility. In addition, no participants (save the one removed from quantitative analysis) indicated they had tried to teach the robot during the experiment, but instead considered the arguments that the robot made for the face that it had chosen.

6 General Discussion

Through the two experiments that we conducted, we found that the seating arrangement between a robot and a person can have an effect on how the robot is perceived, and how people interact with it. There is some inconsistency between the two experiments, where study 1 found results on how conversational or colleague-like a robot appeared, but study 2 results focused more on how competitive the robot was. However, some of this may be due to changes in the study design to make the robot appear less confrontational overall.

We note that the face-to-face condition appeared to be more negative overall, being seen as less conversational (study 1) and more competitive (study 2). This perhaps explains why most participants in this condition became more assertive with their opinions as the study progressed. However, participants were less likely to engage the robot by asking for its opinion on the tasks in comparison to the other configurations.

However, this does not explain why participants were more likely to be outwardly aggressive and condescending to the robot in the corner-to-corner case. This is particularly puzzling given that, in study 1, participants noted that the corner-to-corner condition was more conversational and they would prefer it as a colleague. Perhaps this conversational feel enabled participants to engage the robot to try and convince it, leading ultimately to the aggression. However, we note that participants were more likely to start interaction in a negative demeanor with corner-to-corner (study 2), suggesting that there was something about the setup that set this initial tone; as they became more assertive with time, participants in this condition were particularly aggressive and rude. In this case participants were also somewhat more likely to end up just conceding to the robot, essentially giving up.

Side-by-side appeared to elicit the most generally positive response across our inquiries. In study 1 it was fairly neutral, but in study 2 participants found it the least competitive. Participants were more likely to start the study in a positive manner with this condition, with no participants being rude or negative from the outset, and most participants politely asked the robot's opinion on the task. Further, participants in the side-by-side condition were much less likely to become increasingly assertive with time. We note that participants here were much less likely to use imposing body language to pressure the robot than in the other conditions; perhaps the side-by-side configuration made this a little more difficult to enact.

Overall, the findings from the two experiments suggest that seating arraignment in HRI studies needs to be carefully considered, even when it is not related to the goals of the research. Side-by-side arrangements appear to be the safest for collaborative tasks between robots and people, as they generate the most positive and least negative interactions. Contrary, face-to-face interactions may want to be avoided, as this configuration may elicit more negative perceptions. While both of these findings are aligned with previous research with humans (e.g., [5, 28]), it is unclear why the corner-to-corner arrangement produced such negative encounters. Further research is needed to explore this configuration.

6.1 Limitations

Our experiments had a number of limitations. First, our experimental set up required participants to interact with the robot in a structured, non-organic manner. Further, we prescribed predefined seating arrangements. We employed this methodology to obtain greater experimental control, but it does limit the external validity of our findings. Future work could explore human-robot seating arrangement in a more organic or less structured way.

Post-hoc, we found that the observed power for most of our tests was below 30%, suggesting the need for larger sample sizes to truly conclude whether seating arrangement has an effect on perceptions of the robot. Further research with larger sample sizes could help remedy this.

We found that by describing the experimental scenario for the first study as an attempt to test the robot's learning, participants attempted to sometimes teach the robot, and were not afraid to correct it if necessary. This was largely remedied for the second study, but still appeared for one participant. This points to the incredible importance of carefully considering how the robot and the experiment will be worded to participants, in respect to what is being investigated. A simple change from testing the robot to working collaboratively with it meant that participants interacted with the robot more so as equals in the second experiment.

The unexpected level of aggression and conflict points to the importance of very carefully crafting robotic script when providing feedback to people. We remedied this somewhat for the second study, mainly by removing explicit disagreement, and aiming to avoid directly-conflicting opinions. While conflict was only intended to be a catalyst for discussion in our research, we found that finding the right balance between the two is essential for this type of HRI research.

8 Conclusion

This paper demonstrates the importance of considering the positioning between the human and a robot, for collaborative human-robot tasks. We presented results from two studies that highlight a range of impacts of seating arrangement on a person's perception of the robot and their actions toward it. While we failed to find a simple overarching message (e.g., that one seating configuration is *better* than another), our work highlights the complexity and potential results from selecting a seating arrangement.

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