Methods for Studying Group Interactions in HRI

Marynel Vázquez [1], Elizabeth J. Carter [3], Jodi Forlizzi [2,3], Scott E. Hudson [2,3], and Aaron Steinfeld [1]

[1] Robotics Institute
Carnegie Mellon University
Pittsburgh, PA
{marynel, steinfeld}@cmu.edu

[2] HCI Institute
Carnegie Mellon University
Pittsburgh, PA
{forlizzi, scott.hudson}@cs.cmu.edu

[3] Disney Research
Pittsburgh, PA
liz.carter@disneyresearch.com

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Abstract
In recent years, we have conducted several Human-Robot Interaction (HRI) experiments with small groups of people. To do so, we developed four different protocols to investigate human spatial behavior or trust in robots. We now look back at these efforts and highlight the opportunities and challenges of each experimental method. We also describe various group phenomena that we observed during the interactions. By sharing our experience, we hope to inform the community of the lessons that we learned in HRI and emphasize the importance of studying group interactions to enable robots to operate in public human environments.

ACM Classification Keywords
H.1.2 [MODELS AND PRINCIPLES]: User/Machine Systems—*Human factors*

Introduction
Studying group encounters in Human-Robot Interaction (HRI) is important because these encounters are common in human environments and induce interesting social phenomena. For example, group spatial behavior can provide information about user engagement in HRI. Likewise, social influence can potentially alter the dynamics of multiparty encounters.

Figure 1: Chester is a mobile furniture robot. Blink, the lamp on top of Chester, is his sidekick. Blink can be turned on selectively for certain interactions.

Figure 2: Four participants got their souvenir (top), and only one of them kept conversing with the robot (bottom).

In this paper, we look back at four different HRI experiments that we conducted with small groups of participants [9, 11, 8, 7]. Even though these experiments were designed specifically to study human spatial behavior and trust in robots, their protocols could be further used to investigate other aspects of multi-party interactions. We highlight these opportunities as well as the challenges of each protocol in the next sections, starting with the most uncontrolled and challenging experiment. In discussing these experiences, we hope to convey the potential of studying group interactions in HRI and encourage other researchers to work on this topic.

Experiment 1. Unanticipated Encounter

Even in laboratory settings, unanticipated encounters with robots can provide interesting insights into how people may naturally interact with these machines. For example, we used an unanticipated encounter to study the effects of a sidekick character in HRI [11]. In this exploratory study, we surprised groups of children between the ages of four and ten years with a mobile furniture robot. The robot interacted as one or two characters simultaneously (Fig. 1), engaged in a brief social conversation with the children and gave them a small souvenir as a reward for coming to the lab to test various technologies. Kids were free to approach and touch the the platform as desired throughout the study.

Our findings suggested that the presence of a co-located sidekick character in HRI may increase attention to spoken elements of the interaction without altering users' proxemics behavior. In addition, the results of the study reinforced earlier work that suggested that pieces of furniture can be a good robot design for children [12] and that the anthropomorphization of household objects can produce positive engagement effects [4].

Opportunities

The unexpected nature of the encounter and the lack of parental control made the interaction naturalistic, allowing for human behavior typical of HRI encounters in the wild, e.g., as in [2]. Some kids stood in front of the robot during the experiment; others ran around it to see its back side. Very adventurous children tried leaning on top of the platform or sticking their fingers in its drawers. When young kids felt insecure about the furniture robot, they tended to approach older children to interact together.

Overall, the kids' reactions led to varied spatial behavior during the experiment. Children occupied different spatial zones with respect to the front of the robot, depending on their activity and the robot's motion. Older kids tended to establish spatial formations with the platform that were typical of human-human conversations.

The children's behavior also motivated us to use this experiment to explore social influence in the context of HRI. For example, the robot said "Ouch!" with a sad face and "Don't poke me!" with an angry face to try to prevent very outgoing children from touching it in dangerous ways. While these responses made some kids laugh, they often influenced children who empathized with the robot. Some participants even responded to the robot by trying to control their younger peers during the interaction.

Challenges

We recruited three to four children per session of the experiment to interact simultaneously with our robot. At times, though, the interactions had fewer participants than we expected. For example, some children noticed the robot and approached it sooner than others at the beginning of the experiment. After they got their souvenirs, kids often got distracted trying to check each others' presents and ignored the robot (Fig 2). These circumstances were often difficult to analyze and motivated us to work on detecting social group conversations based on spatial behavior [10]. The group detection method that we developed is complementary to other approaches used to recognize social engagement and enabled our robot to adapt to dynamic conversations [7].

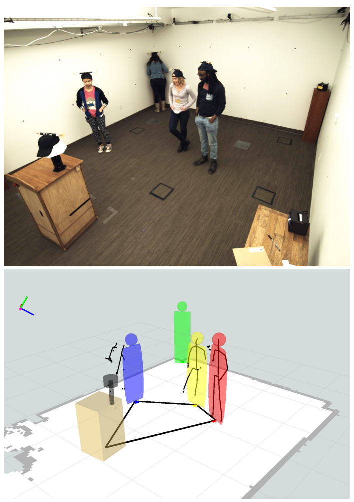

Figure 3: Brainstorming activity (top) and status of our perception system (bottom). The polygon on the ground connects the estimated members of the robot's conversational group.

The diffusion of responsibility phenomenon [3] seemed to affect some children in the study. In one-on-one human-robot interactions, there is a clear role for each participant. When the robot speaks, the user listens. If the robot asks a question, the user is put on the spot to reply or the conversation stops. However, when more people interact, they may feel like any other person can take the lead of the conversation. Thus, it is more socially acceptable for them to avoid participating. In our study, some children became simple spectators.

Responsibility diffusion can be reduced by assigning active roles to the participants in group experiments. For example, we achieved this goal in two other studies when engaging people in a brainstorming activity and in a social role-playing game. The next two sections provide more details about these experiences.

Experiment 2. Brainstorming Activity

We designed another experiment to study group spatial behavior further and try to reduce the diffusion of responsibility phenomenon. In this protocol, the robot led a brainstorming session with three to four participants in a laboratory [7]. To start the activity, the robot explained that the project for which it was built had ended. The only way to prevent the lab from retiring him was to find ways in which it could help or entertain people in the office.

The robot encouraged participants to think of how it could be useful in the lab environment and provided some examples on its own. For example, the robot said that it could entertain people by telling jokes and playing games. It could also provide useful information, like the weather forecast. In some cases, the robot encouraged participants to provide details about their thoughts or discouraged unrealistic and complicated suggestions. When someone had a good idea, the robot asked this person to write it on a piece of paper at a table nearby and to deposit the paper slip in a box in the room.

Even though this experiment was run in a laboratory setting, participants were free to move in the environment as desired and, periodically, were induced to leave the robot's conversational group to document their ideas. This dynamic created a variety of group formations on a frequent basis, and allowed us to test our group detection approach in real-time (Figure 3).

We also used this experiment to evaluate body and orientation behaviors for our robot. The results showed that the gaze behaviors under consideration affected the participants' perception of the robot's motion. Likewise, its motion affected the perception of its gaze. This mutual dependency suggests that robot gaze and body motion must be designed and controlled jointly, rather than independently of each other.

Opportunities

In comparison to the first experiment, the brainstorming activity led to more organized interactions. Nonetheless, it was flexible enough to allow the participants to move around the robot as desired while keeping them engaged. Interestingly, some participants changed their path abruptly as they were moving in the room to prevent crossing in-between conversational groups. This kind of behavior suggested that the use of social norms naturally emerged during the experiment.

Because the brainstorming activity encourages collaboration, it could be an interesting setting to study group dynamics and processes other than spatial behavior. For example, brainstorming sessions could be used to further learn about decision making, problem resolution strategies, social influence, or negotiation.

Challenges
The behavior of the leader of the brainstorming activity can have a strong effect on the interaction. Because the robot undertook this important job in our experiment, we had to heavily test and adjust its dialog as we were piloting the protocol. Even then, there were a few incidents that made the participants feel ignored or excluded by the robot unintentionally. For example, one participant was ignored by the robot or misunderstood several times because she spoke very quietly. Unfortunately, the lack of positive response from the robot made the participants think that it did not like her.

Figure 4: The robot played *Mafia* (top) or moderated the game (bottom).

Experiment 3. A Social Role-Playing Game

We used an established social role-playing game named *Mafia* as another activity for group experiments [8]. We chose this game due to its potential to reduce the diffusion of responsibility phenomenon. The game involves players in group discussions to try to discover each other's secret roles: mafia or villagers. The mafia players hide their identity and try to "kill" the villagers one by one. The villagers "convict" people who they think are part of the mafia to try to save themselves in the game.

As in the other experiments, we recruited groups of three or four participants to play *Mafia* with the robot. We let them stand and move freely in our laboratory space to observe the spatial arrangements that naturally emerged from the interaction. Our only request for the participants was that when they got killed or convicted in *Mafia*, they stepped away from the remaining group. This request facilitated identification of the people that were still playing and induced group interactions of various sizes.

In one condition, the robot played the game with the participants. In the other condition, it was the moderator and led the activity (Fig. 4). Several factors influenced users' preferences for these roles, which were reflected in ratings of desired interaction time, entertainment, role skills, the robot's value to the game, and social inclusion.

Opportunities
Mafia is an interesting scenario to study the effects of the role of a robot in group interactions. For example, the data from our experiment suggested that this factor could potentially influence human spatial behavior. Moreover, it may be possible to accentuate a particular role by manipulating the distance of the robot to the participants.

The underlying structure and flexibility of the game makes it a practical choice for human experiments. Rules are often added to *Mafia* and modified to tailor the activity to specific interests. For example, other efforts outside of HRI have used the game to study human deception [5] and the effects of physical presence [1].

Challenges
People need to understand the rules of *Mafia* well to fully engage in the game. We explained these rules in our experiment with a professional video that demonstrated step by step how to play. While we expected participants to grasp the dynamics of *Mafia* with this demonstration, it was hard for some of them to envision the consequences of their actions. For example, groups often convicted the robot erroneously and made it lose the game. Yet, they were surprised and regretted having to stop interacting

Figure 5: Groups of participants playing ShakeTime! in our experiment.

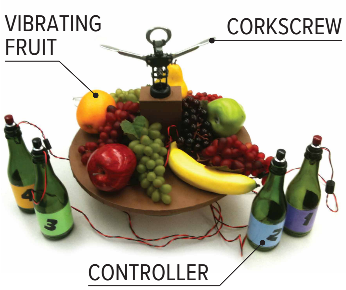

Figure 6: Main components of the robot that we built for ShakeTime!

with it. Practicing the game at least once at the beginning of the experiment could help clarify game dynamics.

Experiment 4. A Reaction Game

We conducted a more controlled experiment to study engagement and robot deception in HRI [9]. For this protocol, we designed a multi-player reaction game named ShakeTime! (Fig. 5). The main body of the robot used in the game consisted of a turntable, concealing electronic components from players (Fig. 6). The turntable held vibrating plastic fruits and a quasianthropomorphic corkscrew that acted as a referee figure in the game. The turntable was placed in front of a monitor during the experiment to provide visual support to human-robot communication and to accelerate the rate at which players learned the mechanics of the game.

The main objective during a round of ShakeTime! was detecting the vibration of a specific "target" fruit. The first of four players to react by pressing a button was the supposed winner. Winners ate grapes as a reward, while those who lost consumed small pieces of carrot.

Whenever possible, the robot tried to balance winning between participants by subverting human expectations for robot characteristics. If a group of players reacted to the target within a short window of time, the robot declared as the winner whoever had lost the most within the group.

Opportunities
Similar to *Mafia*, ShakeTime! is a competitive game with flexible rules. In our experiment, we used the game to demonstrate that it is possible to co-opt stereotypes about robot behavior in multi-party interactions. Interestingly, participants' ratings of suspicion were correlated with feelings that the robot was malfunctioning even when the robot altered the outcome of the game noticeably.

Our study reinforced the idea that deception may not negatively impact users' willingness to interact with robots [6]. Nonetheless, we doubt deception will be equally accepted in different circumstances. Participants' responses showed more acceptance of lying behavior from our robot compared to robots in general, suggesting that robots for entertainment will be given more room to lie.

Challenges
Participants generally behaved as expected, but their reactions to the game sometimes reduced engagement levels with the activity or influenced their interaction. For example, some participants got distracted when they started to discuss ways to figure out the robot's behavior. A player that did not want to eat more carrots also tried to influence the other participants in the group to let him win and eat grapes. This player asked people to let him react first to the target fruit "in the spirit of the team", even though they were not playing together but competing against each other. While we do not think that these kind of situations negatively impacted our experiment, they can potentially alter the outcome of the game and group interactions.

Discussion

This paper described four experimental protocols that we used to study groups in the context of HRI. Even though some protocols are more controlled than others, they all involve participants in social interactions and can lead to the emergence of interesting group phenomena. The protocols provide good opportunities to investigate engagement, turn-taking patterns, and social influence. Furthermore, the first three experiments can be used to study human spatial behavior with and around robots.

Participant recruitment can be a common challenge in conducting group experiments like those we described. In our experience, recruitment can be facilitated by allowing people to participate in experiments with friends or acquaintances. In these cases, it is important to consider the familiarity between the participants as a possible confounding factor in data analysis.

Even though our experiments were conducted in the laboratory and were limited in several ways, we hope that they can be used by the community to further study HRI and, ultimately, help robots better interact in the wild. We plan to continue working on advancing our understanding of group interactions and developing technology to allow these machines to deal with complicated multi-party social dynamics. We expect these efforts will not only help robots better interact with many people, but also make them more socially capable in one-on-one encounters.

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