Team-Building Activities For Heterogeneous Groups of Humans and Robots

Zachary Carlson, Timothy Sweet, Jared Rhizor, Jamie Poston, Houston Lucas, and David Feil-Seifer

Robotics Research Lab
University of Nevada, Reno 89557, USA
zack@nevada.unr.edu|timothy.l.sweet@gmail.com|me@jaredrhizor.com
jposton@nevada.unr.edu|houstonlucas@nevada.unr.edu|dave@cse.unr.edu

Abstract. As robots become more integrated into society and the workforce, people will be required to work cooperatively with not just other people, but robots as well. People engage in team-building activities to improve cooperation and promote positive group identity. This paper explores the effect that a team-building activity had on humans working cooperatively with human and robot teammates with the goal of better understanding how to improve cooperation between a human and a robotic agent. We conducted a 2x2 study with the presence or absence of a team-building activity and the possibility or impossibility of the cooperative task. 40 participants conducted a group search task with a robot and another human partner. Half of the participants engaged in a short team-building exercise. Surveys were used to capture participants' perceptions before and after the session. Success and failure of the task was also measured to identify any changes related to the outcome of the team-building task. It was found that humans' perceptions of robots improve after performing team-building activities. We also found that this effect was comparable to the change of perception when the group succeeded on the task.

Keywords: Team building, collaboration, human-robot cooperation

1 Introduction

Human-robot cooperation in groups is an important facet of Human-Robot Interaction (HRI). When groups work together it may be important to promote a collaborative atmosphere between all group members, including mixed groups of humans and robots. Team-building is regularly used to promote a collaborative atmosphere for human-human interaction. Including robots in team-building exercises may have a similar effect on human and robot group interactions. This study investigates team-building exercises on a group consisting of two humans and a robot, and how this introduction changes the perceptions of each member of the group (human and robot).

Humans often engage in team-building activities to improve cooperation between team members and promote positive group identity. Many team-building activities provide "a sense of unity and cohesiveness," which can improve the function of teams [16]. While these activities are well-known in the human-human setting, it leads researchers to the question, *can the human-robot relation also improve with a sense of unity through similar team-building activities?*

This is crucial for long-term HRI in the workplace since, depending on the environment, success of teams can be limited by the trust and willingness to collaborate within the team [12]. A coworker who is unwilling to collaborate and trust the abilities of their fellow teammate may refuse to include that teammate in many job related tasks due to territorial behaviors [2]. As one would think, this exclusion of the team member might eventually lead to a lack of productivity.

What might happen if a robot were introduced into a workplace to assist with tasks within a heterogeneous team of both robots and humans? If the team members believe that the robot is not capable, they are most likely not going to rely on that robot. It is easy to see that the success of a heterogeneous team of robots and humans can be limited by the unwillingness of humans to collaborate with a robot teammate. In the human-human collaborative setting as these problems were addressed by using team-building activities [16]. This research study looks to understand how the use of team-building activities can facilitate human-robot group interaction.

In this paper, the results of a study involving heterogeneous groups of humans and robots are analyzed to identify how humans perceive robots before and after performing a team-building activity. First, some of the most recent research related to robot teams will be explored. Next, a controlled experiment design is presented. The results of the study will be presented, then discussed and finally compared with the original hypothesis in conclusion. These results will contribute to our overall understanding of how team build activities can affect heterogeneous teams of robots and humans.

2 Related Work

In order to understand how to promote human-robot cooperation, there first needs to be an exploration of how team-building works for human-human interaction. As Reeves and Nass found in their research, computers (and by extension robots) are often treated by people as social actors [15]. As such, studies of human-human teaming may provide valuable insight into human-robot teaming. There is also a wealth of research into human-robot teaming, showing how such teams can be disrupted or promoted. This section will provide a survey of related work in human-robot interaction, as well as how to measure social cohesion with another agent (human, computer, or robot).

Dyer and Dyer have shown that through team-building exercises, specifically the first team exercises issued at the initial team meeting, can build trust and a mutual understanding that helps teams [3]. It has also been shown that team-building activities serve as a bridge between meeting people and can help build a sense of "trust and connectedness" [16]. Miller focused on minimizing failures within team-building exercises, and found that participants could not fully gain the desired results of team-building, if care was not given to carefully controlling the process [9]. Additionally, Miller outlined activities that are appropriate for team-building. Each team-building activity is presented within guidelines of how to run the team-building activity so the participants benefit the most.

Recent research has focused on improving trust in human-robot team relationships [8, 18] as well as using robots to learn and observe from their human teammates [13]. Most of these approaches look at improving the team dynamic directly through the robot or human teammates. In this paper we are looking to improve the robot-team relationship through the use of an independent factor; in this particular case a team-building activity.

The area of heterogeneous human-robot teams often involves organization and planning for large teams. Nagavalli looked specifically at how humans interact with large swarms of robots [11] and Ponda orchestrated heterogeneous collaborative tasks [14]. While creating group plans to achieve tasks, we believe that this is a separate problem compared to unifying a heterogeneous team before a task. With the Wizard of Oz approach, we accomplish human-like planning.

Research involving interaction between heterogeneous groups of robots have focused on the usage and design of a specific robot and the activities or circumstances that change the behaviors and perceptions of both humans and robots. Prior work has examined how robots fit in the workplace [10]. Active research has explored a variety of aspects of the human-robot team setting, ranging from how a robot should navigate [4, 7] to dialogue structuring [6]. This paper is distinguished from prior work by exploring easy social interventions which may facilitate human-robot cohesion. We look to study this idea by exploring the beneficial effects of using a team-building activity as an "ice breaker" before a human-robot team performs a task.

This approach was inspired in part by [17], which used an industrial robot as a platform to evaluate how fluidity, comfortableness, and noticablility changed with several parameters in fetch-and-deliver tasks involving a robot and a human. The robot and human work collaboratively to complete a simple task. The robot has very limited in communication with the human counterpart, which may very well be a believable real-world constraint. [5] uses the concept of presenting a robot as a partner instead of a tool. Although we do not extend this concept to collaborative control like Fong, we actively choose to introduce the robot as a third participant in the study.

Bartneck, et al., developed a survey instrument to evaluate robot agents. This instrument uses five sub-scales, anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety to evaluate perceptions of human-robot interaction [1]. These metrics are used in the Godspeed Questionnaire, which evaluated participants' experiences with the robot and with the other participant. The Godspeed Questionnaire uses a differential scale made of several five point Likert questions for each measure.

3 Experiment Design

This section details the overall design of the experiment, the procedure and materials used to recreate the study, as well as a thorough explanation of the tasks (including the team-building activity) and how it was used in the study.

Fig. 1. The Pioneer 3DX Robot that was used in across all conditions of the experiment and the private room where the study sessions took place.

The experiment is designed to represent a simple task in which teamwork between humans and a robot would increase the probability of the tasks success compared to the humans working alone. This is meant to be representative of many real-world activities requiring human and robot teamwork. In this task, the team consisting of two humans and one robot are instructed to locate a particular object in a large room (Figure 1). The participants are shown that the robot is capable of finding the marker before the task starts. The team was give one minute to find a marker hidden within a cluttered room.

We employed a 2x2 between-subjects factorial design. There were two factors: team-building vs. not team-building, and task possible vs. task impossible. For the first factor, participants would either engage in the "Two Truths and One Lie" team-building activity with their team or not prior to the study activity. The second factor, had two levels: possible success or guaranteed failure. The second factor was varied by making the task possible by hiding the object somewhere in the room, or making the task impossible by telling the participants to find the object, but not actually putting the object into the room. All participants that participated in the possible success successfully completed the task.

40 college-aged participants ranging in a variety of majors volunteered to participate in a cooperative task where they were paired with another participant and a robot partner that formed a team of three. The participants were then randomly assigned to one of the four groups.

We hypothesized the following:

H1: Participants will perceive the robot to be more human-like after participating in a team-building exercise.

H2: Participants will perceive the robot to be more intelligent when the group succeeds at the primary task.

These hypotheses submit that similarity of a robot to a person would be judged by its social behavior. The capabilities of that robot would be judged by its success at stated goals.

3.1 Procedure

Participants were recruited from a university library at random and asked if they would participate in a study involving human-robot collaboration. Two participants at a time were brought into the study room and consented, then introduced to each other and the robot. The participants were only asked to state their name, and the facilitator introduces the robot as "a Pioneer 3DX". Participants were asked if they have met each other and were dismissed or re-paired until the partners did not know each other to eliminate the possible confounding variable of the familiarity between participants. Study personnel told the participants that the robot was capable of finding the blue marker by placing it in front of the robot while the robot operator played a sound clip stating "I found it" from the robots on-board speaker. The camera was not actually used for detection, the remote operator used the Wizard of Oz method to create this effect. This was chosen to reduce the probability of technical difficulties in demonstrating the robots competency. However, this is a task that can reasonably be completed autonomously without error.

Participants were then separated and asked to fill out the Godspeed Questionnaire [1] with respect to their human teammate and again for their robotic teammate. After completion, they were brought back together in the main study room. Half of the groups partook in the team-building activity described in 3.3. Then, all groups partook in the primary task described in 3.4, and in half of those cases the task was possible to complete and in the other half it was impossible with the marker removed from the room. The four conditions were:

- NS: No Team-Building Activity and Possible Marker (Team Succeeded)
- NF: No Team-Building Activity and Impossible Marker (Team Failed)
- TBS: Team-Building Activity and Possible Marker (Team Succeeded)
- TBF: Team-Building Activity and Impossible Marker (Team Failed)

After finishing the primary task, participants were separated again and asked to fill out the same Godspeed questionnaire for their human teammate and again for their robotic teammate. After finishing the questionnaire participants were debriefed and dismissed. The facilitator used a script throughout the experiment, but was allowed to respond to participant questions during the initial consent of the study and during the debrief period. This was to ensure that participants fully comprehended all consent and debrief forms provided to them.

3.2 Materials and Setup

The Adept MobileRobotics Pioneer 3DX shown in 1 was used as the robotic base for the experiment. It was equipped with a SICK Laser Rangefinder for navigation, an Xtion Pro for detecting the object, and additional computational components. A laptop running the Robot Operating System was mounted on the Pioneer. The robot's on-board Raspberry Pi is controlled from a separate computer in a different room by a human (participants are unaware of this Wizard of Oz usage: they were told the robot was navigating autonomously).

We used a library study room, set up to be sufficiently cluttered so that finding an object took some time. The object used was a blue whiteboard marker, chosen because it was easily concealable but also easily recognizable to both the humans and the robots camera due to its bright color. The object was hidden such that the robot would be able to see it. A Sony camera, handycam model HDR-CX220 with a resolution of 1080p, on a tripod in the corner of the room was used to record audio and video for the duration of the study.

3.3 Team-Building Activity

Half the groups participated in a "Two Truths and One Lie" icebreaker, prior to completing the primary task. Each participant told the rest of the group two truths and one lie about themselves, then their human teammate and the robot would guess which statement was a lie. Unknown to participants, the remote human operator actually just played canned sound clips from the robots on-board speaker which stated "I believe your second/third statement was a lie" for the first and second human teammate, respectively, regardless of their statements. Finally, the remote operator played canned sound clips from the robot which stated its two truths and a lie: "I was manufactured in 2003" (truth); "I have traveled outdoors" (truth), "I can travel up to two meters per second" (lie). Participants then guess which statement was a lie, and the remote operator played a sound clip stating "I can only travel one meter per second".

The facilitator within the room gestures at each participant when it was their turn to speak (both the humans and the robot). The remote operator could see the facilitator gesture on the video feed, which was used as the cue to advance.[1]

3.4 Primary Task

Participants were told that there was a blue whiteboard marker hidden in the room somewhere. They were given sixty seconds to find it, with the help of their human partner and the robot. Participants were told the robot would announce "I found it" if it found the marker, however the robot was actually driven by the remote operator and would not announce if it "saw" the marker. For half of the groups the marker was actually hidden in the room, but for the rest of the groups the marker was not in the room (thus the participants would run out of time before finding the marker). In the case that it was in the room, the marker was hidden under one of the legs of the table. Our intention was that participants would not be able to see it from their starting positions.

4 Results

The details of the experiment results and analysis are presented in this section. The survey data were analyzed to support or refute the experimental hypotheses presented in Section 3. For each sub-scale of the Godspeed Questionnaire [1], the differences of the before and after Questionnaires were analyzed using a multivariate two-way analysis of variance (ANOVA) between subjects across all conditions. Additionally, the post surveys were analyzed using a multivariate two-way analysis of variance. There were 10 participants per cell, with a total of 40 participants that were analyzed and assigned to each condition.

[1] Note that we avoided anthropomorphizing the robot because this study did not focus on human-like robots. The voice used was a very "machine-like" voice.

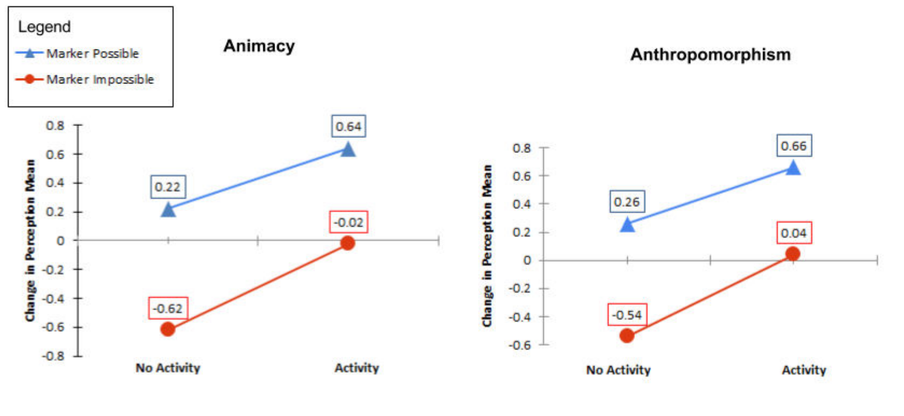

Fig. 2. Significance was found between groups when analyzing the average mean representing the difference in the participants' perception of how animate [left] ($F[3, 36] = 2.973, p < .05$) and anthropomorphic [right] ($F[3, 36] = 3.197, p < .05$) the robot was between the pre and post surveys for all conditions.

Ten categories were measured in both multivariate analyses, one for each sub-scale of the Godspeed questionnaire for the human and the robot partner. When analyzing the differences between the pre and post surveys, there was a significant difference in how anthropomorphic participants perceived the robot ($F[3, 36] = 3.197, p < .05$) and how animate they perceived it to be ($F[3, 36] = 2.973, p < .05$). There was a significant interaction for marker possible and team activity of the participants' perception of the perceived intelligence of the robot was also significant ($F[3, 36] = 2.970, p < .05$).

Figure 2 shows the means of the difference between pre- and post- surveys within each condition, representing the change in how anthropomorphic and animate the robot was perceived to be. When the team successfully found the marker there was a positive increase in their perceptions. When participants could not find a marker and they participated in the team-building activity, there was close to no change in their perceptions from before the activity to after. When they did not participate in the team-building activity, failing the task had a negative impact on their perceptions.

Figure 3 shows that when participants participated in the team-building activity with the robot, no matter if they failed or succeeded at the task, they perceived the intelligence of the robot to be the same. When there was no team-building activity, there was a clear difference in the intelligence they believed the robot to have depending on whether or not they succeeded at the task. They perceived the robot to have as much intelligence when they participated in the team-building activity as when they succeeded in the task.

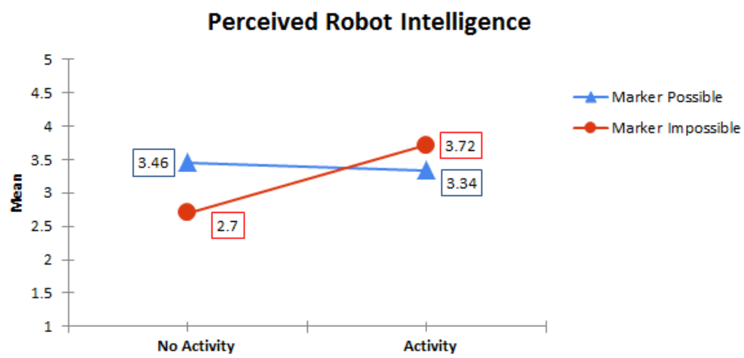

Fig. 3. Significance was found between groups when analyzing the average mean representing participants' final perception of how intelligent the robot was at the end of the study session ($F[3, 36] = 2.970, p < .05$).

5 Discussion

The animacy and anthropomorphism results support hypothesis #1, *"Participants will perceive the robot to be more human-like after participating in a team-building activity."* The intelligence sub-scale results partially support hypothesis #2, *"Participants will perceive the robot to be more intelligent when the group succeeds at the primary task."* We instead found that participants would find the robot more intelligent when the group succeeded *or* when the team-building activity occurred. The power of the team-building task, then is that it can cause participants to forgive the robot's failure to meet its goals.

Further exploration of the team-building activity was analyzed, using a one-way ANOVA to compare the means of all the participants that participated in the team-building activity and those that did not, no matter if they succeeded or failed. This test showed no significance.

This shows that the team-building activity alone did not significantly alter the participant's perceptions. The team-building activity needed to be coupled with success, which is supported in Figure 2 where all cases show that when the team could not complete the task (Marker Impossible), the participants' perceptions of their team were negatively impacted. As for the groups that successfully completed the primary task (Marker Possible), they always had a positive increase in their perceptions of the team members.

In the case of the successful teams and hypotheses #2, participants may blame the robot when they are unable to complete the task. This was shown in our results were there was no significant differences in any of the human partner surveys and a negative reflection on the perception of the robot's intelligence. Interestingly, we have found that the team-building activity in the impossible task seemed to offset the perceived lack in intelligence for failing the task. For this particular study, there appeared to be a ceiling of how intelligent the robot was perceived roughly around a value of 3.5 on a scale of 1-5. When the team-building activity was combined with success, the perceived intelligence of the robot was roughly the same as the other two conditions shown in Figure 3, where they failed the task and participated in the team-building activity, and when they succeeded but did not participate in team-building.

6 Conclusion and Future Work

This paper makes a definitive case for the utilization of simple social interaction exercises to facilitate human-robot team cohesion. The results of this paper support the notion that facilitating a team atmosphere can negate the deleterious effects of group failure at a task. A useful extension of this research would be to study the duration of team-building effects on heterogeneous groups of robots and humans. This study incorporated very short interactions with a robot. However, it is unclear whether or not these increased perceptions would be maintained throughout longer use of the robot or more involved team-building.

In this study, the participants' beliefs about themselves are unknown. Participants could be asked to self-rate. The difference between self-ratings and their rating of partners (especially their robotic partner's ratings) could provide some insight into how the human participant relates to the robot, instead of how the human participant perceives the other participant relating to the robot.

"Two Truths and One Lie" was an effective team-building activity. However, comparing multiple team-building activities could reveal differences in effectiveness in different activities with respect to heterogeneous groups. Furthermore, Rivas framed team-building exercises as a task that a "leader" uses to engage followers in upcoming activities [16]. Robots leading team-building activities to direct or manage humans in other tasks is an unexplored area of HRI.

Human robot interactions will undoubtedly increase as the field of robotics advances. The use of heterogeneous groups of humans and robots will most likely increase over time as well. Since team-building is viewed as an acceptable social activity to create cohesive groups of humans, team-building with heterogeneous groups of robots and humans is a natural step forward. The results and further discussion of the study shows that team-building activities, as much as joint success, results in a significant positive increase in perceptions of the animacy and anthropomorphism of robotic team members. This supports hypothesis #1, "Participants will perceive the robot to be more human-like when they participate in a team-building task." Finally, hypothesis #2 was supported, "Participants will perceive the robot to be more intelligent when the group succeeds at the primary task" and it was also found that participating in a team building activity can increase the perception of the intelligence of the robot.

7 Acknowledgments

The material is based upon work supported by the National Aeronautics and Space Administration under Grant No. NNX10AN23H issued through the Nevada Space Grant. This material is also supported by the University of Nevada, Reno, Provost's Office Instructional Enhancement Grant and the Office of Naval Research (ONR) #N00014-14-1-0776. We appreciate the space lent to us by the DeLaMare library and Knowledge Center at the University of Nevada, Reno.

References

1. Bartneck, C., Kulić, D., Croft, E., Zoghbi, S.: Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots. International journal of social robotics 1(1), 71–81 (2009)
2. Brown, G., Crossley, C., Robinson, S.L.: Psychological ownership, territorial behavior, and being perceived as a team contributor: The critical role of trust in the work environment. Personnel Psychology 67(2), 463–485 (2014)
3. Dyer, W.G., Dyer, J., Dyer, J.H.: Team building: Proven strategies for improving team performance. John Wiley & Sons (2010)
4. Feil-Seifer, D.J., Matarić, M.J.: Distance-based computational models for facilitating robot interaction with children. Journal of Human-Robot Interaction 1(1), 55–77 (Jul 2012), DOI: 10.5898/JHRI.1.1.Feil-Seifer
5. Fong, T., Thorpe, C., Baur, C.: Collaboration, dialogue, and human-robot interaction. In: 10th International Symposium on Robotics Research (ISRR). Lorne, Victoria, Australia (November 2002)
6. Jung, M.F., Martelaro, N., Hinds, P.J.: Using robots to moderate team conflict: The case of repairing violations. In: Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction. pp. 229–236. ACM (2015)
7. Kanda, T., Shiomi, M., Miyashita, Z., Ishiguro, H., Hagita, N.: An affective guide robot in a shopping mall. In: Proceedings of the 4th ACM/IEEE international conference on Human robot interaction. pp. 173–180. ACM (2009)
8. McCallum, L., McOwan, P.W.: Face the music and glance: How nonverbal behaviour aids human robot relationships based in music. In: Proceedings of the International Conference on Human-Robot Interaction. pp. 237–244. ACM (2015)
9. Miller, B.C.: Quick activities to improve your team: How to run a successful teambuilding activity. Journal for Quality and Participation 30(3) (2007)
10. Mutlu, B., Forlizzi, J.: Robots in organizations: the role of workflow, social, and environmental factors in human-robot interaction. In: Proceedings of the International Conference on Human Robot Interaction (HRI). pp. 287–294. ACM New York, NY, USA, Amsterdam, The Netherlands (March 2008)
11. Nagavalli, S., Chien, S.Y., Lewis, M., Chakraborty, N., Sycara, K.: Bounds of neglect benevolence in input timing for human interaction with robotic swarms. In: Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction. pp. 197–204. ACM (2015)
12. Newell, S., David, G., Chand, D.: An analysis of trust among globally distributed work teams in an organizational setting. Knowledge and process management 14(3), 158–168 (2007)
13. Nikolaidis, S., Ramakrishnan, R., Gu, K., Shah, J.: Efficient model learning from joint-action demonstrations for human-robot collaborative tasks. In: Proceedings of the International Conference on Human-Robot Interaction. pp. 189–196. ACM (2015)
14. Ponda, S., Choi, H.L., How, J.P.: Predictive planning for heterogeneous human-robot teams. AIAA Infotech@ Aerospace (2010)
15. Reeves, B., Nass, C.: The media equation: how people treat computers, television, and new media like real people and places. Cambridge Univ. Press, NY, NY (1996)
16. Rivas, O., Jones, I.S.: Leadership: building a team using structured activities
17. Unhelkar, V.V., Siu, H.C., Shah, J.A.: Comparative performance of human and mobile robotic assistants in collaborative fetch-and-deliver tasks. In: Proceedings of the International Conference on Human-Robot Interaction. pp. 82–89. ACM (2014)

18. Xu, A., Dudek, G.: Optimo: Online probabilistic trust inference model for asymmetric human-robot collaborations. In: ACM/IEEE Int. Conf. on HRI (2015)