
Technology with Embodied Physical Actions: Understanding Interactions and Effectiveness Gains in Teams Working with Robots

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Abstract

Robots transform teamwork and create new dynamics among team members that are unprecedented in human teams. Little research has focused on how robots reshape teamwork dynamics and how teams can enhance outcomes when incorporating robots into their teamwork. My research will investigate several ways to improve the effectiveness of teams working with robots by conducting experiments in which teams will consist of multiple robots and individuals. Various psychological

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CHI'17 Extended Abstracts, May 06-11, 2017, Denver, CO, USA
ACM 978-1-4503-4656-6/17/05.

<http://dx.doi.org/10.1145/3027063.3027122>

dimensions in team processes, including trust and team efficacy, will be measured to test their impacts on team outcomes such as performance, viability, and satisfaction. My research will develop an understanding of interactions among team members as well as between humans and robots in order to find ways to improve team effectiveness. Directions for designers of robots and for managers of human-robot teams will be provided.

Author Keywords

Human-robot interaction, teamwork, robots, trust, team efficacy, performance, embodied physical actions

ACM Classification Keywords

H.5.2 [User Interfaces and Presentation (e.g., HCI)]: Theory and Methods; H.1.2 [Models and Principles]: User/Machine Systems – human factors.

Motivation of Research

Robots have been increasingly adopted by teams in different domains and contexts. For instance, first-responders such as urban search-and-rescue teams deploy remote-controlled robots to save human lives without risking the lives of team members. Special weapons and tactics teams operate with multiple robots

when encountering deadly situations. Teams working with robots have showcased a type of teamwork that is distinguishable from teamwork seen in traditional human-only teams. As such, the use of robots in teams is a topic that has significant importance to research and practice in teams using technologies [5].

Despite the potential implications for team processes and outcomes, we do not fully understand how robots change teamwork. To date, it is widely assumed that teams working with robots, which are often referred to as human-robot teams, consist of only one person and one robot. Therefore, research still lacks evidence of teamwork with multiple individuals using more than one robot and impacts of social and psychological interaction among the individuals. The existing research cannot inform how teams work using robots when there is more than one person on the team. My dissertation builds on research on teamwork and interaction with robots in order to develop a better understanding of how robots influence processes in teams working with them and how robots can be used to promote the effectiveness of such teams.

Theoretical Background

Although human-computer interaction (HCI) research has examined teams using different technologies, including communication technologies and group support systems, robots should be understood in their own right, distinguishable from other technologies that teams employ. The term *robot* is commonly used across different domains, but its definition varies by field of study. However, scholars seem to agree that physical embodiment and representation of embodied behaviors are major characteristics that make robots unique among technologies [2]. Thus, in my research, I focus on the physical embodiment of robots and define

robots as “technologies that manifest physically embodied actions.”

The physical embodiment of robots plays an important role in understanding how robots reshape teamwork. Research shows that physical embodiment invokes strong emotional and psychological phenomena that lead individuals to treat these technologies differently from non-embodied technologies [1]. For instance, researchers in human-robot interaction (HRI) have found that individuals often show higher levels of engagement and enjoyment when interacting with robots that manifest physical actions [3]. According to HCI research, increased engagement with and enjoyment of a technology lead to better performance on tasks utilizing the technology. Therefore, it is likely that robots with physically embodied actions produce different interactions with team technologies and thus result in distinct team outcomes. This warrants an investigation into whether robots transform teamwork by introducing new interactions with team technologies.

Research in HCI and HRI suggests that individuals’ interactions with robots are unique [6]. People tend to project identities and personalities onto robots and treat them as embodied entities rather than merely technological artifacts [4]. Robots can also evoke strong emotional connections from humans and lead to in-group attachments. The projection of identities and personalities, along with in-group attachments, could cause teamwork with robots to be qualitatively different from teamwork involving other technologies. However, the current literature cannot provide information about how teams operate using robots or what leads to more effective teamwork involving robots. This is mainly because 1) prior literature on interaction with robots is

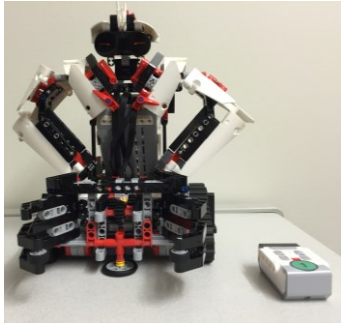


Figure 1: Robot used in the experiments.

Preliminary Results of Trust Study

Results of the experiment with 110 participants in 55 teams working with robots showed that trust in robots only increased team performance, not team satisfaction, whereas trust in human teammates increased only team satisfaction but not performance.

mostly about interaction between a single individual and a single robot and 2) outcomes of collaboration using robots are rarely examined.

Research Questions

I propose research questions to examine core social-psychological constructs in processes of teams working with robots and their impacts on team outcomes.

- 1) Trust: What are the impacts of trust in robots and in other team members on team outcomes?
- 2) Efficacy: Can all teams benefit from using robots? More specifically, how do team efficacy and diversity result in better or worse outcomes in teams working with robots?

Trust, Team Performance, and Satisfaction

This study examines different impacts of trust in teammates and in robots on team performance and satisfaction in teams working with robots. Specifically, in order to examine dynamic aspects of trust in teams involving robots, an individual's trust in another team member and trust in the individual's robot were measured separately by treating trust as a network construct.

In an experiment in a controlled lab experiment, individuals in teams delivered water bottles from one location to another location using robots made of LEGO Mindstorms (see Figure 1 for robot and Figure 2 for task design). While one individual team member worked with one robot to deliver water bottles from point A to point B, another team member used another robot to deliver the water bottles from point B to point C. Team performance was measured by recording the total time it took to deliver the five water bottles from point A to point C. The task was designed to represent

some essential aspects of tasks fulfilled by teams working with robots in real life, such as removing hazardous materials or rescuing injured humans. Variables were measured using self-report questionnaires after the experimental task.

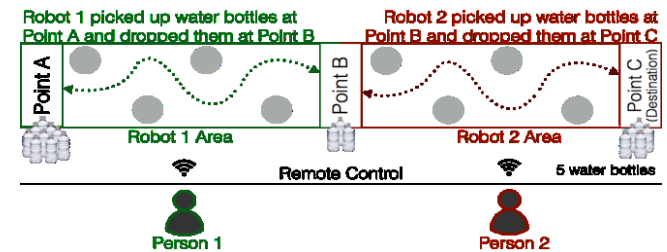


Figure 2: The task setting and the robot for the experiments. The two robots used for a team were identical.

Remote-controlled robots were chosen for two reasons. One, robots used for this research should solely instantiate physical embodiment and actions, so variables of intelligence and appearance needed to be ruled out. Two, although many autonomous robots are used in the public sector and in some workplaces, remote-controlled robots have been the most widely adopted in teamwork domains ranging from urban search-and-rescue to construction.

Efficacy in Diverse Teams Using Robots

The second study investigates boundary conditions for team efficacy to be beneficial for improving outcomes among teams working with robots. This study posits that team efficacy of using robots may increase performance and viability in teams working with robots only when diversity is high.

In this experiment, a team's diversity is ascertained and thus the team's ethnicity, gender, education level, nationality, and age heterogeneity are calculated. The

Results of Efficacy Study

I am currently collecting data for the second study. However, preliminary results show tendencies that suggest that team efficacy has a positive relationship with the performance of robot operators only when the team is ethnically diverse. On the other hand, team efficacy increased viability of teams working with robots when the teams were heterogeneous, while it decreased viability in diverse teams.

same experimental setting as in the first study is used, but team efficacy is manipulated by the presence of team training prior to the team task. Individual performance is measured by recording the average time it takes to make five trips to deliver a bottle to point B for the first team member and to point C for the second team member.

Contributions

I believe that my studies have great potential to make significant contributions to research on human-robot teams. First, my research will be the first to investigate emotional and psychological impacts of using robots and subsequent outcomes in teams working with robots. Second, I will examine multilevel phenomena in teams working with robots. This will allow a better understanding of not only interactions between individuals in teams but also of teamwork as a whole, which can inform both dyadic human-robot interaction and team interaction involving multiple individuals and robots.

My research is expected to improve guidelines for designers of robots working closely with humans in teams, as well as for managers of teams working with robots in dangerous and high-stakes environments. As a result of my dissertation, several guidelines will also be produced for designing effective team processes involving both humans and robots.

Conclusion

My research investigates how robots reshape teamwork and how to improve outcomes among teams working with robots. Teamwork with robots is a topic that is important to both research and practice. Because teams are using robots to accomplish goals such as

saving human lives, my research has the potential to have a broader impact on society.

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