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Human-Robot Teaming Configurations: A Study of Interpersonal Communication Perceptions and Affective Learning in Higher Education

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Abstract: Technology encourages collaboration in creative ways in the classroom. Specifically, social robots may offer new opportunities for greater innovation in teaching. In this study, we combined the established literature on co-teaching teams with the developing field of machine actors used in education to investigate the impressions students had of different team configurations that included both a human and a robot. Participants ($N = 215$, age: $M = 24$, $SD = 8.67$, range 18–69) saw one of three teams composed of a human and a social robot with different responsibilities present a short, pre-recorded lecture (i.e., human as lead teacher-robot as teaching assistant, robot as lead teacher-human as teaching assistant, human and robot as co-teachers). Overall, students rated the human-led team as more appealing and having more credibility than the robot-led team. The data suggest that participants would be more likely to take a course led by a human instructor than a social robot. Previous studies have investigated machine actors in the classroom, but the current findings are unique in that they compare the individual roles and power structures of human-robot teams leading a course.

Teaching is inherently collaborative. The input teachers receive from colleagues, students, and administrators can influence curriculum choices and alter classroom dynamics. A teaching team is a group of professionals who choose to actively collaborate for a common instructional purpose (Cook & Friend, 1995). The model of shared teaching responsibilities, or co-teaching, has been widely applied

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in the K-12 setting, particularly related to special education (Scruggs et al., 2007). Austin (2001) found that educators appreciated the availability of "another teacher's expertise and viewpoint" (p. 251) in a co-teaching situation. Within higher education specifically, research argues collaboration, or co-teaching, is difficult as questions surrounding power dynamics, shared responsibility, and individual expertise often emerge (Ferguson & Wilson, 2011; Morelock et al., 2017). Co-teaching essentially doubles resources available to students and allows instructors to give more attention to classroom dynamics, but the paradigm is still largely centered on individual teachers. In this study, we investigate an alternative to the traditional way of thinking about expertise in the classroom. Specifically, when one member of a teaching team is a social robot there may be additional interpersonal affordances and opportunities that enhance the learning experience.

Robots in the Classroom

Robots offer access to information and assistance in the classroom. A *social robot* mimics human interaction to communicate autonomously or semi-autonomously with others (Bartneck & Forlizzi, 2004). The field of robotics has grown rapidly, resulting in the emergence of robots designed for specific purposes, including teaching (Belpaeme et al., 2018). As team members, robots offer promising developments related to eldercare (Chang & Šabanović, 2015), industrial labor (Sauppé & Mutlu, 2015), and the military (Carpenter, 2016). Although the skill sets of humans and robots are often complementary, studies that compare the two groups in specific settings such as the classroom are limited (Belpaeme et al., 2018). However, robots have been used in supportive roles including tutors for language training (Alemi et al., 2014; Kennedy et al., 2016), supplementing math instruction (Kennedy et al., 2015), and working with autistic children (Kim et al, 2015; Szafir & Mutlu, 2012).

Social robots can also lead instruction. Compared to other technologies (e.g., web-based applications), researchers found that a social robot increased concentration levels and academic performance of users learning English (Han et al., 2008). Additionally, A. Edwards et al. (2016) found that different types of robots leading a course generated different perceptions of credibility and assessments of learning potential among students. While there have been calls for instructional communication researchers to examine social robots in the college classroom (A. Edwards & Edwards, 2017; C. Edwards et al., 2018; J. Kim et al., 2020), there have not been studies examining the role of co-teaching with human and machine actors. The human-to-human interaction script research involving human-robot interaction argues that initial encounters with robots will produce decreased levels of attraction/liking and social presence, and greater uncertainty (C. Edwards et al., 2016; A. Edwards et al., 2019; Spence et al., 2014). As such, it is vital to understand how the presence of a person teaching with a social robot will impact interpersonal impressions and attitudes toward course content, particularly if the teaching teams involve humans and robots with different levels of positional authority.

Interpersonal Impressions

Typically, human and robot instructors are examined individually. Those isolated performances often contribute to generalized impressions about that type of instructor.

However, teaching is not always a solo endeavor. Instructors may rely on teaching assistants or form teaching teams where multiple instructors present material. In this study, we focus on teaching teams that involve a social robot as one of the members. Across three scenarios (i.e., human as lead teacher-robot as teaching assistant, robot as lead teacher-human as teaching assistant, human and robot as co-teachers), we investigated perceptions of interpersonal impressions (i.e., credibility, interpersonal attraction, and social presence) and learning outcomes (i.e., affective learning).

Credibility. Perceptions of an instructor's credibility involve far-reaching implications. *Credibility* is the appraisal of a specific message or speaker (McCroskey & Young, 1981) and consists of competence, trustworthiness, and goodwill (McCroskey & Teven, 1999). Appraisals of an instructor's credibility are linked to their communication with students (Myers, 2001), impact engagement, and retention of course material (Teven & McCroskey, 1997). When the instructor is a social robot, A. Edwards et al. (2016) found that participants rated a telepresence teacher presented as a robot (i.e., human face on a telepresence robot) as more credible than a robot that was presented as a teacher (i.e., animated face on a telepresence robot). Sometimes referred to as "trust" in human-robot interaction literature, credibility can impact a person's desire to work with the robot (You & Robert, 2018), and by extension, may influence appraisals of the whole team. What remains to be seen is how the combination of a human and robot in different roles on the same instructional team (i.e., lead instructor, teaching assistant, co-instructor) will influence appraisals of credibility from students.

Interpersonal Attraction. *Interpersonal attraction* involves individual, positive assessments related to three specific dimensions that people form when they interact with others (i.e., social, task, and physical—not used for the current study; McCroskey & McCain, 1974). Specifically, *social attraction* is the degree to which one envisions a potential, future relationship with another person. *Task attraction* refers to the anticipated ability, or success, associated with working alongside another person. Previous research on interpersonal attraction in the classroom suggests that social and task attraction are particularly salient when working with peers or interacting with instructors (Rocca & McCroskey, 1999; Tatum et al., 2017).

Students view social robots as acceptable interactants in a classroom setting (Park et al., 2011), yet that relationship seems to be unique compared to human instructors. For example, Park et al. found that students rated their robot instructors higher on interpersonal attraction when the robot offered a favorable assessment of their work, but their ratings of the human instructor did not change regardless of their feedback. Coupling these assessments to be reflective of a mixed instructional team (i.e., human and robot) is increasingly important as human-robot collaborations increase outside the classroom (Hinds et al., 2004). However, there are few studies that examine attraction when a person and social robot are working together within the classroom.

Social presence. In this study, we define *social presence* as the perceived connection to a particular person in a mediated interaction (Short et al., 1976). Social presence has received a great deal of attention in the literature specifically related to online instruction (e.g., Dunlap & Lowenthal, 2014; Garrison et al., 1999). For example, Richardson et al. (2017) conducted a meta-analysis and found that across 3 decades of studies there was a positive correlation between social presence, or sense of connection, and how students rated the quality of the course. Research involving social presence related to technology suggests that people consider both the interaction they have with the machine (Goble & Edwards, 2018; Lee et al., 2006), as well as the medium, or the machine itself (Lombard & Ditton, 1997; Xu & Lombard, 2017), when forming impressions. As people develop relationships with machine actors, understanding social presence will help address the potential unpleasantness and uncertainty related to increased interaction (A. Edwards et al., 2017; C. Edwards et al., 2016; Spence et al., 2014).

Inviting social robots into the classroom may include notable challenges as well as creative affordances. For example, Gleason and Greenhow (2017) found that robot-mediated communication (RMC) actually enhanced social presence for students by linking those in the online section and those in the face-to-face section of the same course by providing a conduit for interaction. In a co-teaching situation, however, the literature is not clear on how students will rate their interpersonal impressions of a teaching team that involves a human as well as a social robot occupying different positions.

> **RQ1:** Does the configuration of roles in a human-robot instructional team influence interpersonal perceptions including credibility, interpersonal attraction, and social presence?

Affective Learning

In addition to interpersonal impressions of the instructor(s), student assessments of the subject and content are relevant to understanding effective teaching strategies. *Affective learning* refers to the "positive attitudes toward the content or subject matter" that students form about a given course or experience (Kearney, 1994, p. 81). More broadly, affective learning has been linked with cognitive learning (Rodriguez et al., 1996), motivation to learn (Frymier & Houser, 2000), higher teaching evaluations (Teven & McCroskey, 1997), and instructor impressions (Myers, 2002). In relation to robotics, A. Edwards et al. (2016) found that when social robots were used in the classroom as instructors, they influenced assessments of affective learning. In that study, however, the researchers focused on a single instructor model and not a co-teaching setup. So, it remains unclear how the configuration of roles will impact student appraisals of affective learning.

> **RQ2:** Does the configuration of roles in a human-robot instructional team influence perceptions of affective learning?

Method

Participants

The sample was composed of 215 undergraduates (age: $M = 24$, $SD = 8.67$, range 18–69) at a large Midwestern research university. Participants included 134 women (62.32%), 77 men (35.81%), one listed as non-binary (0.4%), and two who did not indicate gender (.9%). Most participants self-identified as White/Caucasian (76.7%, $n = 165$).

Procedures

Following IRB approval and informed consent, participants were randomly assigned to view one of the three conditions: (1) human-led class ($n = 71$) with social robot TA, (2) robot-led class ($n = 73$) with human TA, and (3) co-teachers ($n = 69$) between human and social robot. Participants were instructed to watch a small video lecture on the definition of communication. Each video was about 3 minutes long. The lecture slides appeared on the screen with a picture of each member of the instructional team (larger pictures for instructors and smaller pictures for teaching assistants) and their position (i.e., instructor, teaching assistant, co-instructor) at the beginning of the lecture. During the human-led and the robot-led conditions, the lead instructor spoke for over 90% of the video. For the co-instructor teaching condition, the human and the social robot were introduced on the screen together and spoke for equal time. After participants watched the video lecture, they completed the measures regarding their impressions of the teaching team, received research credit, were debriefed, and thanked.

Instruments

Participants responded to four measures, a demographic section, an open-ended question, and a series of quantitative measures not analyzed for the current study. Across measures, participants were asked to rate the instructional team as a whole. We used an 18-item measure of Source Credibility (McCroskey & Teven, 1999) to evaluate perceptions of credibility across three dimensions: competence (six items; e.g., "intelligent/unintelligent"), trustworthiness (six items; e.g., "trustworthy/untrustworthy"), and goodwill (six items; e.g., "cares about me/doesn't care about me") on a series of 7-point semantic differential scales. Westerman et al. (2014) argued that the measure can be treated as a second-order unidimensional scale for overall credibility. Our own analysis found the same second-order unidimensional scale to be reliable and appropriate (overall credibility = .93, *Scale Item M* = 5.13, *Scale Item SD* = .96).

To measure task and social attraction, we modified McCroskey and McCain's (1974) scale. Participants reported their answers across eight (four: social and four: task) Likert-type scale items ranging from 1 ("strongly disagree") to 5 ("strongly agree"). The measure for social attraction had a reliability coefficient of .81 (*Item M* = 2.91, *Item SD* = .87), and the measure for task attraction had a reliability coefficient of .72 (*Item M* = 3.91, *Item SD* = .62).

Social presence was measured with five items adapted from an established instrument (Walther & Bazarova, 2008). Each social presence item (e.g., close/distant) was assessed on a 7-point semantic differential. This measure had a reliability of .91 (*Item M* = 3.72, *Item SD* = 1.54).

Affective learning was assessed using an 8-item instrument measuring a person's affect for a subject and content (McCroskey, 1994) along a series of 7-point semantic differential scales (e.g., "I feel that the content in this lesson is: valuable/worthless"). For the current study, we obtained a reliability coefficient of .91 (*Item M* = 5.06; *Item SD* = 1.24).

Results

To address the research questions, a one-way K-group multivariate analysis of variance (MANOVA) was conducted to determine the effects of the type of instructor configuration (human-led, social robot-led, and co-teachers) on the dependent variables of the credibility (i.e., competence, trustworthiness, and goodwill), social attraction, task attraction, social presence, and affective learning. Correlations among the dependent variables ranged from .35 to .77 ($p < .001$). Results of the omnibus MANOVA show a significant main effect of team configuration, Wilk's Lambda = .83, F (10, 412) = 4.14, $p < .001$, $\eta^2 = .09$. As a follow-up to the MANOVA, we used a series of univariate analysis of variance (ANOVAs) to test the influence of team configuration on each dependent variable. To help control for Type 1 error, we utilized the Bonferroni method (.05/5) and each of these ANOVAs was tested at the .01 level. ANOVAs were statistically significant for the dependent variables of: credibility [F (2, 210) = 14.64, $p < .001$, $\eta^2 = .12$], social attraction [F (2, 210) = 13.92, $p < .001$, $\eta^2 = .12$], social presence [F (2, 210) = 5.09, $p = .007$, $\eta^2 = .05$], and affective learning [F (2, 210) = 8.37, $p < .001$, $\eta^2 = .07$]. An ANOVA was marginally significant for task attraction [F (2, 210) = 3.95, $p = .02$, $\eta^2 = .04$]. Post hoc tests showed there was a significant difference between the human-led and robot-led teacher conditions for all dependent variables; the human-led teacher was perceived as higher in credibility, social and task attraction, social presence, and affective learning. See Table 1 for means, standard deviations, and other significant post hoc differences.

TABLE 1
Item Means and Item Standard Deviations for the Four Conditions on the Dependent Variables

	Human-Led		Robot-Led		Co-Instructors	
Variable	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
Competence	5.95_a	(.94)	5.47_{bc}	(.91)	5.75_{ac}	(.90)
Trustworthiness	5.49_a	(1.01)	4.76_{bc}	(1.05)	5.12_{ac}	(1.01)
Goodwill	5.08_a	(1.05)	3.86_b	(1.29)	4.70_a	(1.11)
Social Attraction	3.30_a	(.72)	2.58_b	(.95)	2.87_b	(.77)
Task Attraction	4.00_a	(.54)	3.75_{bc}	(.65)	3.99_{ac}	(.64)
Social Presence	4.08_a	(1.51)	3.29_{bc}	(1.51)	3.79_{ac}	(1.50)
Affective Learning	5.40_a	(1.18)	4.60_b	(1.15)	5.15_a	(1.28)

Note. Means in a row with differing subscripts are significantly different at $p < .05$ in the Tukey HSD.

Discussion

In this study, we investigated the difference in interpersonal impressions (credibility, social/task attraction, social presence) and affective learning between a class led by a human teacher, a class led by a robot teacher, and a class that was co-taught by a human and robot. The experiment demonstrated a significant difference between the human- and the robot-led scenarios across most of the variables with the human-led teacher being perceived as higher in credibility, social and task attraction, social presence, and affective learning. Overall, our findings suggest that participants found the human-led team to be more credible and more appealing than the robot-led instructional team.

The results from this study support and extend research on social robots in education. Technology remains a staple in the modern classroom, but our findings suggest that the type and use of that technology is still important to students. While not a complete test of the human-to-human interaction script research (A. Edwards et al., 2019), the current study demonstrated a preference for the person over the social robot, similar to other studies (A. Edwards et al., 2016; C. Edwards et al., 2016; Spence et al., 2014). Furthermore, the current study shows that students may feel more comfortable with a person leading a class in which there is a social robot serving in the TA role. A key takeaway from the current study is that the status of the social robot in the classroom influences assessments of interpersonal impressions. In other words, it is not the involvement of a social robot in the classroom, but the absence of a human teacher at the helm.

The current study suggests that interpersonal impressions may also look different in an environment that prioritizes interaction and connection, such as a classroom. Although learning can occur across modalities, the process of teaching often involves a relationship, and the data seem to suggest this is a priority for students when judging the potential effectiveness of an instructional team. By altering the robot's standing in the team (i.e., lead teacher, teaching assistant, co-teacher), we were able to test the difference in credibility appraisals based on the role the robot enacted. Participants rated the robot-led team as the least credible, the least liked, and the least likely to teach a class they would choose to take. It could be that hearing information from a social robot in an environment that prioritizes an interpersonal connection may introduce what Sundar (2008) calls, "a confusing multiplicity of sources" that can contribute to perceptions of the message (p. 73), as well as the learning environment itself.

Our three-group study design was ideal for this exploratory study on perceptions of co-teaching teams involving social robots. Due to COVID-19 and the lack of ability to have in-person studies, we asked participants to view a short PowerPoint presentation with human and robot voice-overs. Although members of the teaching team introduced themselves and noted that they were available to students, participants did not have a chance to interact with anyone on the team. By removing the element of interaction from the scenario we may have limited people's ability to accurately translate this experience to a real classroom setting. Future research in this area could invite participants to an in-person course, or hold a synchronous, online option where students could see and potentially interact with the instructional team (see A. Edwards et al., 2016). A live version of this study may also influence interpersonal perceptions and show an even greater difference between the human and robot instructors.

Conclusion

In this study, we examined the differences in interpersonal impressions and affective learning between different teaching teams. Participants rated the robot-led team significantly lower on credibility, social/task attraction, and social presence when compared to the human-led team. Further, the students didn't feel as though they would learn as much, or be as likely to take a course from, the robot instructor. Findings suggest that it was not the practice of team-based teaching that soured students' feelings toward the class, but who was leading the course. The next steps in this line of research involve in-person testing with students as well as faculty. A study that focused on faculty participants co-teaching with social robots may reveal that the dynamic between instructors is more important than whether the lead teacher is a robot or human. Overall, the current study suggests that more research is needed to better understand the complicated dynamic within human-robot teams.

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