2016

Robots in the classroom: Differences in students' perceptions of credibility and learning between "teacher as robot" and "robot as teacher"

Autumn Edwards, *Western Michigan University*

Chad Edwards, *Western Michigan University*

Patric R Spence, *University of Kentucky*

Christina Harris, *University of Kentucky*

Andrew Gambino, *Pennsylvania State University - Main Campus*

Contents lists available at ScienceDirect

Computers in Human Behavior

journal homepage: www.elsevier.com/locate/comphumbeh

Full length article

Robots in the classroom: Differences in students' perceptions of credibility and learning between “teacher as robot” and “robot as teacher”

Autumn Edwards^{a,*}, Chad Edwards^a, Patric R. Spence^b, Christina Harris^b, Andrew Gambino^c^a Western Michigan University, USA^b University of Kentucky, USA^c Penn State University, USA

ARTICLE INFO

Article history:

Received 1 April 2016

Received in revised form

6 June 2016

Accepted 7 June 2016

Available online xxx

Keywords:

Robot

Credibility

CASA

Human-machine communication

Telepresence

Learning

Teaching

MAIN model

ABSTRACT

Advancements in technology are bringing robotics into interpersonal communication contexts, including the college classroom. This study was one of the first to examine college students' communication-related perceptions of robots being used in an instructional capacity. Student participants rated both a human instructor using a telepresence robot and an autonomous social robot delivering the same lesson as credible. However, students gave higher credibility ratings to the *teacher as robot*, which led to differences between the two instructional agents in their learning outcomes. Students reported more affective learning from the *teacher as robot* than the *robot as teacher*, despite controlled instructional performances. Instructional agent type had both direct and indirect effects on behavioral learning. The direct effect suggests a potential machine heuristic in which students are more likely to follow behavioral suggestions offered by an autonomous social robot. The findings generally support the MAIN model and the Computers are Social Actors paradigm, but suggest that future work needs to be done in this area.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Advancements in technology are bringing robotics into interpersonal aspects of life. No longer are robots confined to factories, laboratories, or battlefields. Robotic technologies are moving towards interpersonal relationships in everyday life, and as such, into higher education (Heo & Kim, 2013; Li, Kizilcec, Bailenson, & Ju, 2016). In addition to robotics, computer software and networks have advanced to a point where displacing technology (e.g., Skype) is a feasible option for instruction (Allen & Seaman, 2010; Garner & Buckner, 2013). The benefits of displacing technologies are convenience for students and instructors, as well as cost and time effectiveness. For example, Borup, West, and Graham (2012) demonstrated that students in displaced instruction situations

felt more connected when video was used than when video was not used. Li et al. (2016) argued that social robots and virtual agents might “improve the accessibility of pedagogical content” (p. 1223). The use of robots for displacing technologies is relatively new.

A robot is a machine that can do the work of a person and that works automatically or is controlled by a computer (Merriam-Webster.com). There are several ways robots can be used in the classroom. Uses are dependent on the capabilities of the robot technology, as well as the pedagogical needs of the instructional situation. Currently, robots in the classroom are being used in four basic ways: (a) robot as classroom teacher, (b) robot as companion and peer, (c) robot as care-eliciting companion, and (d) telepresence robot teacher (Sharkey, 2016). The present study focuses on the first and last scenarios, as they pertain directly to the use of robots in the role of instructor.

Robots can be used to enable computer-mediated communication (CMC) between an instructor and students. For instance, a physically remote instructor can operate a telepresence robot (videoconferencing on a mobile platform) to interact with the class.

* Corresponding author. School of Communication, Western Michigan University, 300 Sprau Tower, 1903 W. Michigan Avenue Kalamazoo, MI 49008, USA.

E-mail address: autumn.edwards@wmich.edu (A. Edwards).

Alternatively, robots can be used to enable human-machine communication (HMC) between students and a robot instructor. For example, an autonomous social robot can be placed in the position of information source and provide direct instruction to students. The two scenarios may be considered *teacher as robot* and *robot as teacher*, respectively. The former uses “displacing” technologies by enabling mediation of a distant human instructor through a robot. The latter involves “replacing” technologies by substituting a robot instructor for a human.

An important difference between the two types of classroom robots is agency. Is the source of instruction a human or a machine? The source of instruction with a telepresence robot is a human operator who uses the robot as a medium through which to interact with students. On the other hand, a social robot is autonomous, meaning it can act within bounds to achieve goals without any explicit human control. Therefore, a social robot is an agent, or source of instruction in its own right. The question that arises is whether students find these technologies credible and effective in the classroom. And, in a direct comparison, do students perceive the human or the machine robot agent more favorably?

The current study will compare differences in perceptions of credibility and learning between a human instructor using a telepresence robot (teacher as robot) and a social robot acting as a teacher (robot as teacher). Because robot technology is already being used in teaching-learning contexts, it is important to identify and understand students’ reactions and educational experiences. Ultimately, studies like this may help develop best practices for integrating robots into higher education classrooms. The following sections will discuss telepresence robots and social robots in the classroom, using the MAIN model (Sundar, 2008) and Computers are Social Actors paradigm (Reeves & Nass, 1996) to frame the research questions.

1.1. Telepresence robots in the classroom

Although many definitions exist for the term *telepresence*, this concept can be conceptualized as “a sense of transportation to a space created by technology” that “occurs when a user perceives that he or she is physically present in a remote environment” (Lee, 2004, p. 29). Whereas one can communicate *to* and *with* a social robot, one communicates *through* a telepresence robot. A telepresence robot is a device that allows a person to videoconference on a moveable platform from a remote location. The user has remote control of the robot’s movement and can interact through the screen. Factors such as distance learning and the attempt to keep students engaged in the classroom have led to a push for the incorporation of telepresence robotic forms of instruction (Smith & Mader, 2016). Although few studies have examined telepresence robots in the classroom, empirical work surrounding the use of other forms of telepresence and CMC in education is more plentiful.

Earlier work on telepresence examined the medium of television and how it impacted student-teacher interaction (Hackman & Walker, 1990). Students viewed real-time televised lectures and had access to phones so they could call-in to the lecture with questions or comments if they chose. The researchers found positive correlations among instructor immediacy behaviors (e.g., instructors who prompted student participation, engaged in feedback by taking student phone calls, and portrayed nonverbal behaviors such as smiling, speaking in an engaged voice, and having an open body posture) and overall student satisfaction and learning. In addition, aspects of the chosen system such as the clarity of audio and video transmission were also positively related to satisfaction and learning.

Other research has found interesting, but somewhat conflicting, results. Two meta-analyses conducted by Allen et al. (2002, 2004)

found that overall, distance learners (i.e., students who were not physically present with an instructor and engaged in various forms of mediated learning) were less satisfied than their traditional student counterparts, but scored higher on exams and course grades. As Allen et al. (2004) noted, “the use of any means of communication in an educational setting may have a differential impact that favors or disadvantages different persons” (p. 404). Further, the type of telepresence (e.g., television, online-only) may also have an impact on factors such as student satisfaction and learning. Li et al. (2016) demonstrated that a human instructor could be effective in a MOOC (Massive Open Online Course) context using video presence.

Although research investigating the effects of telepresence robots in the classroom is limited, some studies have indicated positive learning experiences and outcomes. For example, researchers at Carnegie Mellon developed a telepresence robot that allowed a user to virtually attend meetings, classes, and lectures at a distance (Clark & Root, 2011). Based on their case studies, Clark and Root observed that although the interaction was unfamiliar for both parties, participants were able to overcome the unique situation and focus on the tasks at hand. Yun et al. (2011) examined the deployment of EngKey telepresence robots in South Korea. Teachers in the Philippines provided English instruction to elementary students, whose performance was found to improve. Although initial research has indicated there may be potential benefits in regards to telepresence in the classroom (in terms of enabling instruction that would otherwise be prohibited by interactional distance), further research is needed to better identify the possible effects it has on student learning and perceptions of instructor credibility.

1.2. Social robots in the classroom

A *social robot* is an autonomous, physically embodied robot that interacts and communicates with humans by following social behaviors and rules attached to its role. Social robots overlap in form and function with human beings to the extent that their locally controlled performances occupy social roles and fulfill relationships that are traditionally held by other humans. In the context of education, social robots have chiefly been used to provide or supplement instruction in three content areas: (a) language development and acquisition, (b) science education, and (c) technology and computer programming (Mubin, Stevens, Shahid, Al Mahmud, & Dong, 2013).

Several studies have demonstrated the benefits of social robot use in the classroom. For example, children have performed better in math when tutored by a robot (Brown, Kerwin, & Howard, 2013). Social robots have been used to reinforce social behaviors in children with autism (Kim et al., 2013) and to improve student retention rates by incorporating gestures and increasing vocal volume (Szafr & Mutlu, 2012). Park, Kim, and del Pobil (2011) found that robot instructors were perceived as more socially attractive when delivering positive feedback instead of negative feedback to college students.

In the context of robotics, virtual agents have been used in conjunction with mechanical bodies to produce social robots capable of performing tasks. A virtual agent is an animated computer-generated character that can utilize text-to-speech capabilities. Al Moubayed, Beskow, Skantze, and Granström (2012) argued that robots with human-like faces could better display complex information. Baxter, a ‘collaborative robot’ employed in industrial and manufacturing fields, combines two arms with an animated screen for a face. Baxter’s abilities to express emotion and signal intention while simultaneously loading, lifting, and packing enhance social interaction and workplace safety (see

rethinkrobotics.com).

Research that examines the use of virtual agents in the classroom has produced mixed results. Berry, Butler, and de Rosis (2005) demonstrated that information retention was lower for participants who viewed a virtual agent versus a video of a human. Li et al. (2016) found that although human video lecturers were preferable to virtual agents, virtual agents could be used in the classroom if designed well for student learning. Although the development of robots capable of serving the role of teacher or teaching assistant is in the beginning stages, the use of robots in the classroom is likely to increase dramatically (Park, Kim, & Pobil, 2011).

1.3. Instructor credibility and student learning

The success of robot use in the college classroom—whether *teacher as robot* or *robot as teacher*—will depend on the degree to which students find the agents of instruction credible and are able learn from them. A long-running and extensive line of instructional communication research has demonstrated the importance of teacher credibility in fostering positive educational outcomes. Credibility is defined as “the attitude toward a source of communication at a given time by a communicator” (McCroskey & Young, 1981, p. 24) and is the degree to which students consider their teachers to be competent, have character, and demonstrate caring (McCroskey & Teven, 1999). Student perceptions of credibility can have a tremendous impact on the effectiveness of the instructor (Frymier & Thompson, 1992). McCroskey and Young (1981) stated that “[r]esearch generally has supported the proposition that source credibility is a very important element in the communication process, whether the goal of the communication effort be persuasion or the generation of understanding” (p. 24).

Traditionally, studies on credibility in the classroom have focused on human instructors. Because credibility is an attitude toward source, questions arise as to how students will perceive introducing robot technology into the role of instructor. Sundar's (2008) MAIN model is geared toward understanding technology effects on credibility by focusing on how the aspects of the technological interface (cues) may trigger cognitive heuristics. According to Sundar, technological affordances including modality (M), agency (A), interactivity (I), and navigability (N) may trigger heuristic cues that influence attributions of credibility. Numerous studies have shown that these medium-based affordances have psychological effects that often lead to increases or decreases in credibility and user behaviors (Gambino, Kim, Sundar, Ge, & Rosson, 2016; Kim & Sundar, 2012). Especially relevant to this study is the *agency affordance* of the MAIN model, which deals with how the perceived source of information may result in different perceptions of information quality. In an experiment conducted by Sundar and Nass (2001), participants who read identical news stories rated them as higher in quality when they believed “the computer” (versus news editors, other users, or the self) had selected them. Machine sources may trigger a *machine heuristic*, which leads to attributions of machine characteristics like objectivity.

The Computers are Social Actors (CASA) paradigm was developed from the many studies examining human responses and perceptions to a variety of media (Reeves & Nass, 1996). The paradigm is premised on the idea that people display social reactions to computers and other media (Reeves & Nass, 1996). According to CASA, people apply the same social scripts that guide human-human interaction to human-computer interaction, “essentially ignoring the cues that reveal the essential social nature of a computer” (Nass & Moon, 2000, p. 83). Kim and Sundar (2012) maintained that individuals use and rely on the same social rules when interacting with computers as they do with other

people.

Traditional social science theories and experiments of human-human interaction largely hold up in human-computer interaction (HCI). Similar to interpersonal relationships, HCI has significant emotional (Brave, Nass, & Hutchinson, 2005) and behavioral (Ferdig & Mishra, 2004) outcomes. Reeves and Nass (1996) argued that “people's responses to media are fundamentally social and natural” (p. 251). Bailenson, Blascovich, Beall, and Loomis (2001) demonstrated that the nonverbal behaviors of an embodied computer agent impacted the distance that individuals maintained in a virtual reality environment. In a group task situation, individuals treated computers as teammates to accomplish a goal (Nass, Fogg, & Moon, 1996). Additionally, research has demonstrated that people may assess and interact with computers differently on the basis of computer vocal qualities (Lee, 2010).

In general, research has indicated that individuals appear to apply the social scripts of human interaction to HCI in similar ways. Although the first CASA studies used a computer as the social actor, more recent studies have expanded social actors to include robots (Edwards, Edwards, Spence, & Westerman, 2016; Lee, Park, & Song, 2005; Park, Kim, & del Pobil, 2011; Spence, Westerman, Edwards, & Edwards, 2014). In the few empirical studies conducting a direct comparison between human-human interaction and HCI, social responses to both conditions have been roughly equivalent (Nass & Moon, 2000).

This study presents an opportunity to examine the unique influence of agent type (human vs. machine; or *teacher as robot* vs. *robot as teacher*) on student perceptions of instructor credibility.¹ The MAIN model suggests that a more machine-like instructor may trigger a heuristic that influences credibility. However, research on the Computers are Social Actors (CASA) paradigm might suggest students will respond to the machine and human agents in the same way. Therefore, we present the following research questions:

RQ1. Will participants rate both *teacher as robot* and *robot as teacher* as credible?

RQ2. Will instructional agent type (teacher as robot vs. robot as teacher) influence ratings of credibility?

Learning is a critical outcome and one closely associated with credibility (Schrodt et al., 2009). Previous research demonstrates that students learn more from teachers perceived as credible (see, e.g., Pogue & Ahyun, 2006). Students may experience affective learning, defined as the positive attitudes an individual holds towards the subject matter (Kearney, 1994). In addition, students may experience behavioral learning, which Bloom (1956) defined as changes in behavior as a result of being provided alternative information. Both affective and behavioral learning have been positively related with favorable classroom environments and effective education (Christensen & Menzel, 1998; Christophel, 1990; Comstock, Rowell, & Bowers, 1995; Gorham, 1988; Plax, Kearney, McCroskey, & Richmond, 1986; Richmond, McCroskey, Kearney, & Plax, 1987; Sanders & Wiseman, 1990). In order to understand the learning outcomes associated with robot instructors, we pose two additional research questions:

RQ3. Will there be a relationship between instructional agent type (teacher as robot vs. robot as teacher) and (a) affective and (b) behavioral learning?

¹ We were able to hold constant the other affordances of the MAIN model—modality cues, interactivity cues, and navigability cues—by using the same robot, verbal script, and motion path in both the *teacher as robot* and *robot as teacher* conditions.

RQ4. Will the relationship between instructional agent type and learning be mediated by credibility ratings?

2. Method

2.1. Participants

The convenience sample was composed of 86 undergraduate students enrolled in a large lecture introductory communication course at a large Midwestern U.S. American research university. Participants included 60 females (69.80%) and 26 males (30.02%). The majority of participants self-identified as Caucasian/White (72.10%, $n = 62$). Participants' ages ranged from 18 to 30 years, with a mean of 20.63 ($SD = 2.01$). Participants received minimal extra credit points in return for taking part in the study.

2.2. Procedures

Upon securing institutional review board approval, an experimental design consisting of two treatment groups—*teacher as robot* and *robot as teacher*—was used. Each group consisted of 43 randomly assigned students (subdivided into 3 groups of approximately 15 students each to accommodate classroom size).

On the day of experiment, participants in groups of 15 were greeted at a welcome desk and taken to a classroom. In both conditions, the robot was positioned at the front of the room, about eight feet from the first row of participants. A scripted research assistant told participants that the “teacher” would instruct on the subject of business communication in a few moments (either when the teacher connected through the telepresence robot or when the social robot commenced the lesson, depending on the condition). Participants were told that their teacher could move its camera/eyes and physically move around the room. After 90 s, the research assistant departed and the teacher began the lesson on business communication. Afterward, participants were asked to rate the teacher using (a) McCroskey and Teven's (1999) Measure of Source Credibility, (b) the Affective Learning Measure (McCroskey, 1994), (c) a Behavior Learning Scale, and to complete a (d) brief demographic survey.

2.3. Stimulus materials

The robot was a MantaroBot Classic telepresence robot. The robot is controlled over a WIFI network and utilizes a pan and tilt camera mounted on a 14" LED monitor. The body and monitor are atop a wheeled base navigated by a user. For this experiment, the robot was set to move at a slow pace (<1 fps). The monitor displayed either the human instructor's face via video conferencing software (*teacher as robot*) or an animated virtual agent face modeled in appearance after the same instructor (*robot as teacher*).²

2.3.1. Robot screen and audio

In both conditions, participants were exposed to a 5-min lecture (either by *teacher as robot* or *robot as teacher*). The robot moved to each side of the classroom at some point, but stayed at the front of the room. The robot also scanned the student audience throughout by panning its camera. Although the lectures were pre-recorded

and the movements were choreographed to control all differences between conditions except for the independent variable of instructor robot type, participants were led to believe that the performances were unfolding live.

We synced the audio of the human instructor used for the *teacher as robot* condition to the movement of the talking avatar used for the *robot as teacher* condition. This resulted in identical audio feeds for both conditions. For both conditions, the teacher on “live” videoconference and the avatar was prerecorded for experimental control.

To convince participants that the lessons were being given in real time, we scripted interaction between the research assistant and robot that appeared two-way and spontaneous. For the *teacher as robot* condition, the research assistant said “hi” to the instructor, who responded with a (taped) in kind greeting. For the *robot as teacher* condition, the research assistant “activated” the robot in front of participants by asking the robot to move its onboard laser to the right and then to the left. This technique left participants with the impression that the robot was autonomous and responding to requests in real time.

2.3.2. Robot controls

In the research lab of the first and second authors, two robot drivers controlled the robot in the classroom during the experiment. These robot drivers were trained on robot operations for a total of 25 hours over the course of the semester. They were taught to quickly diagnosis and fix problems that may arise (e.g., losing a signal to the robot). Additionally, they practiced driving the robot one foot every 30 seconds so that the movement seemed like a walking behavior that might occur in a lecture environment. Robot drivers practiced panning and tilting the robot's camera to appear as if the instructor/robot was looking at students in the class. For each condition, the movement of the robot was as identical as possible.

2.4. Wizard of Oz simulation

The current study used a Wizard of Oz (WOZ) design. A WOZ design is a technique used to simulate human-robot interaction that is convincing to participants (Steinfeld, Jenkins, & Scassellati, 2009). The chief advantage for this design is that it allows human-robot interaction studies to occur without the necessary programming of a robot to complete complex interactions in an autonomous manner. Fraser and Gilbert (1991) argued that in order to conduct a valid WOZ design study several conditions must be met. First, it must be possible that the simulation in the study is possible in the near future. Second, the simulation must be convincing. And third, it must be possible to demonstrate the future behavior of the robot. For the present study, these three standards were used to create the stimulus materials. Through the use of a commercially available robot, an off-the-shelf avatar program, and carefully scripted action, participants believed the simulations were real. No participant indicated in debriefing that they did not believe the stimulus. Additionally, this study uses a simulation that in many respects is far below that of the capabilities of current HRI (e.g., Goodrich & Schultz, 2007). In other words, any participant familiar with social robots or exposed to popular media about robots would believe that the current real-world capabilities of educational robots exceed the technology used in this experiment.

2.5. Dependent variables

2.5.1. Source credibility

To measure the hypothesized mediator of source credibility, we used the Measure of Source Credibility (McCroskey & Teven, 1999),

² The virtual agent face was constructed by loading a photo of the instructor into an off-the-shelf program that allows users to create talking, moving avatars. We conducted a small manipulation check to make sure participants could identify the difference between the telepresence display of the human instructor's face and the virtual agent's face. Six participants at the third author's lab accurately labeled the *teacher as robot* versus *robot as teacher* conditions.

which is an 18-item instrument designed to assess perceptions of an individual's credibility across the three dimensions of competence (6 items each for competence, character, and caring) along a series of 7-point semantic differential scales. Overall credibility achieved an internal consistency coefficient of 0.88 ($M = 4.61$, $SD = 0.82$).

2.5.2. Affective learning

The Affective Learning Measure is an 8-item instrument measuring an individual's feelings for a subject and content (McCroskey, 1994). It is assessed using a series of 7-point semantic differential scales (e.g., "I feel that the content in this lesson is: valuable/worthless"). Past studies have reported acceptable reliability coefficients (McCroskey, 1994). For the current study, a reliability coefficient of 0.91 was obtained ($Item\ M = 4.21$; $Item\ SD = 1.48$).

2.5.3. Behavioral learning

Behavioral learning was measured using two items on a 7-point scale ranging from not likely to very likely. The questions asked about the participants' willingness to engage in the behaviors presented in the lecture and to recommend those behaviors to others. In this study, a reliability coefficient of 0.74 ($M = 3.44$; $SD = 1.66$) was obtained for behavioral learning. Affective and behavioral learning were significantly and moderately related, $r(84) = 0.37$, $r^2 = 0.14$, $p < 0.001$.

3. Results

To answer RQ1, which asked whether *teacher as robot* and *robot as teacher* were perceived by students as credible, a one-sample t -test was conducted to evaluate whether the mean rating in each condition was significantly higher than the scale midpoint of 4.0 (1–7 semantic differential scale). For the *teacher as robot* condition, the mean credibility score ($M = 87.63$) was significantly above the scale midpoint [$t(42) = 40.64$, $p < 0.001$]. For the *robot as teacher* condition, the mean credibility score ($M = 78.26$) was also significantly higher than the scale midpoint [$t(42) = 33.35$, $p < 0.001$]. Thus, both the telepresence instructor and the autonomous social robot teacher were rated by students as "credible." Table 1 presents the means and standard deviations on the dependent variables by experimental condition.

To perform the two mediation analyses necessary to test RQs2–4, we used a product of coefficient approach as suggested by Hayes (2013). In particular, we used Hayes's PROCESS Macro model 4 to examine the relationships among our variables. Instructor agent type (*teacher as robot* versus *robot as teacher*) was dummy coded 1 and 0, respectively, to enable regression analyses and entered as the independent variable (X). Credibility was treated as the mediator variable (M) on the dependent variables of affective learning (Y_1) and behavioral learning (Y_2). See Table 2 for model coefficients.

RQ2 asked whether the type of instructional agent influenced

credibility ratings. As shown in Fig. 1, the unstandardized regression coefficient between agent type and credibility was statistically significant and indicated that the *teacher as robot* was rated more credible than the *robot as teacher*. In terms of RQ3a, agent type did not directly influence student affective learning, but did so indirectly through its influence on credibility (*teacher as robot* → credibility → affective learning). We tested the significance of direct and indirect effects using bootstrapping procedures. Unstandardized effects were computed for each of 1000 bootstrapped samples, and the 95% confidence interval was computed by determining the effects for the 2.5th and 9.7th percentiles. The unstandardized indirect effect was 3.253 (LLCI = 1.034, ULCI = 6.315) and the unstandardized direct effect was -2.204 , ($t = -0.932$, $p > 0.05$, LLCI = -6.909 , ULCI = 2.500). Students rated the *teacher as robot* as more credible, which led to more affective learning.

In terms of RQ3b, instructional agent type exerted both a direct and indirect effect on behavioral learning. The indirect effect parallels the results to RQ3a, with the *teacher as robot* being rated more credible, which led to higher behavioral learning (*teacher as robot* → credibility → behavioral learning). The unstandardized indirect effect = 0.415, LLCI = 0.028, ULCI = 0.972. However, the significant direct effect indicated that the *robot as teacher* led to more behavioral learning (unstandardized direct effect = -1.479 , $t = 0.725$, $p < 0.05$, LLCI = -2.921 , ULCI = -0.036).

RQ4 asked whether credibility would mediate the relationship between instructional agent and learning outcomes. As reported above, credibility ratings accounted fully for the influence of agent type on affective learning and partly for behavioral learning. The *teacher as telepresence robot* was rated as more credible than the autonomous social robot teacher, which predicted an increase in student affective and behavioral learning. However, the significant direct effect of instructional agent type on behavioral learning indicates that when credibility is allowed to vary as it would in a control condition, the *robot as teacher* produces greater behavioral learning.

4. Discussion

The purpose of this study was to determine whether *robot-as-teacher as robot* and *robot as teacher*—would be perceived as credible sources of instruction resulting in student learning (affective and behavioral). In terms of RQ1, results indicated that students perceived both types of robot instructor as credible. The attribution of credibility to both machine and human instructional agents generally aligns with the CASA paradigm (Reeves & Nass, 1996).

The two teaching performances and robot appearances were identical in all ways except the nature of the agent: human instructor operating as a telepresence robot versus autonomous social robot independent of explicit human control. However, the two types of instructional robots were not rated as equally credible (RQ2). Rather, the *teacher as robot* was perceived as most credible. Sundar's (2008) MAIN model posits that differences in the credibility assigned to various sources result from different technological affordances, which trigger cognitive heuristics. According to Sundar (2008), interface agencies may influence credibility perceptions through a *social presence heuristic*, or by giving the idea that the user is communicating with a social entity versus an inanimate object. To the extent that source credibility is composed of dimensions linked to traditionally human traits (caring, character, competence), the increased social presence of the human teacher operating a telepresence robot would result in higher credibility ratings.

Alternatively, or perhaps in tandem, the *robot as teacher* may have cued the machine heuristic and resultant attributions about

Table 1
Means and standard deviations for the experimental conditions on the dependent variables.

	Robot as Teacher (Social robot)	Teacher as Robot (Teacher operating robot)
Variable	M (SD)	M (SD)
Credibility	78.26 (14.51)	87.63 (13.49)
Affective learning	32.67 (12.20)	34.63 (11.49)
Behavioral learning	7.30 (3.21)	6.47 (3.40)

Table 2
Model coefficients for the instructional robot agent mediation analyses.

Antecedent	Consequent											
	M (Credibility)			Y ₁ (Affective learning)			Y ₂ (Behavioral learning)					
	Coeff.	SE	p	Coeff.	SE	p	Coeff.	SE	p			
X (Agent)	a_1	9.371	3.022	<0.01	c_1	-2.057	2.342	>0.05	c_2	-1.479	0.725	<0.05
M (Credibility)	—	—	—	b_1	0.428	0.080	<0.001	b_2	0.068	0.025	<0.01	
	$R^2 = 0.103$			$R^2 = 0.261$			$R^2 = 0.099$					
	$F(1, 84) = 9.616, p < 0.01$			$F(2, 83) = 14.666, p < 0.001$			$F(2, 83) = 4.549, p < 0.05$

Fig. 1. Perceived credibility mediates the influence of instructional robot agent on student learning.

the characteristics machines typically possess. Machines often are perceived as more “objective” than human actors, but also less capable of feeling and relating. The machine heuristic may help explain why the autonomous social robot was perceived as somewhat less credible in a teaching context, and also why students experienced heightened levels of a specific type of learning from the *robot as teacher* when credibility was allowed to statistically vary.

Type of instructional robot influenced levels of student affective and behavioral learning (RQ3). Affective learning (positive regard for the instructional content) was higher in the *teacher as robot* condition, but the relationship was indirect in the sense that affective learning was increased via enhanced perceptions of instructor credibility (RQ4). Although the relationship between behavioral learning (intent to enact recommended actions) and type of instructional robot was similarly mediated by credibility ratings (teacher as robot → credibility → behavioral learning), there was also a direct effect of instructional agent on behavioral learning that favored the opposing experimental condition. Students instructed by the autonomous social robot teacher (*robot as teacher*) reported higher behavioral learning. Like Sundar and Nass's (2001) participants who rated news stories as higher in quality when they believed a computer had selected them, our

participants reported greater likelihood to follow the behavioral suggestions offered by a machine instructor versus a telepresent human instructor. The significant direct effect linking instructional agent to behavioral learning suggests the operation of a machine heuristic connecting machine-generated content with trustworthiness and authority.

But, how are we to reconcile the seemingly contradictory findings that affective learning from a fully machine instructional agent is *lower*, whereas behavioral learning is *higher*? Sundar (2008) maintained that the social presence heuristic may “toggle with the machine heuristic,” insofar as the former heuristic would be more influential on judgments about socio-emotional information, whereas the latter would be more influential on judgments about objective content (p. 84). Computer-mediated instruction (“displacing technologies” like the human instructor operating a telepresence robot) may be more effective for creating positive attitudes about subject matter, whereas human-machine instruction (“replacing technologies” like the autonomous social robot teacher) may be more effective for influencing behavior adoption or modification.

Future studies should explore the extent to which personological variables (e.g., attitudes about robots or AI) could influence perceptions of and interaction with instructional robots (Bartneck, Suzuki, Kanda, & Nomura, 2007). Additionally, future studies should directly compare learning between a face-to-face condition and both CMC and HMC conditions, and explore other important instructional outcomes (e.g., motivation, cognitive learning). Because our results suggest that some instructional robot agents may outperform others on the basis of fit between affordances, instructional content, and desired learning outcomes (affective vs. behavioral), research identifying the instructional conditions under which it may be better to choose a displacing versus replacing technology would be beneficial. Finally, given the central role of source credibility in predicting learning outcomes, instructional design research on the technical features associated with perceptions of robot competence, character, and caring should be conducted.

4.1. Limitations

One limitation of the current study is that the stimulus material (video lecture) was prerecorded and played via the robot's screen “face.” Even though there was scripted interaction and movement behaviors intended to give the appearance of a “live” performance, it is possible that some participants did not believe that this lecture was happening in real time. However, during the debriefing session, participants seemed genuinely surprised to learn of the WOZ design and none expressed disbelief or doubts about realism.

Moreover, the current study did not allow for actual two-way interaction to occur between the robot and the participants (only the perceived interaction that was controlled). Thus, our *robot as teacher* was decidedly less “social” than it could have been. Future studies should test how students respond to an interactive robot.

The final limitation is based on the WOZ design. Bertel, Rasmussen, and Christiansen (2013) state, “due to high technological complexity and cost combined with low system stability and usability, the majority of research on educational service robots is still based on highly controlled experiments in lab settings which cause certain limitations to the transferability and applicability of the results to real-world learning environments” (p. 438). Because much of the classroom environment was controlled, it is possible that different results might occur in a more naturalistic setting, which would include a lengthier exposure to the instructional agent.

5. Conclusion

This study examined college students' perceptions of two types of robot instructors—a human teacher operating a telepresence robot and an autonomous social robot teacher—and their learning outcomes. Both a *teacher as robot* and a *robot as teacher* were rated as “credible” college instructors. However, the *teacher as robot* was rated as most credible. Students of the *teacher as robot* experienced more affective learning (liking of the content) because of enhanced perceptions of source credibility. Students of the *robot as teacher* experienced more behavioral learning (intentions to act differently). CMC (“displacing technologies”) may be more effective for enhancing social presence to create positive learning attitudes, whereas HMC (“replacing technologies”) may be more effective for influencing behavior adoption or modification.

The findings are generally supported by CASA and the MAIN Model, but suggest that future work needs to be done in this area. Instructor credibility, affective learning, and behavioral learning are important parts of successful classroom environments (Schrodt et al., 2009). Based on present rates of development and adoption, it seems inevitable robots will increasingly be used in instructional contexts (Chang, Lee, Chao, Wang, & Chen, 2010; Clark & Root, 2011; Kim et al., 2013; Szafrir & Mutlu, 2012). At one point in the past, course management software was viewed with disbelief and dismay. Yet now, many instructors utilize this technology with great success. Students are already familiar with Skype and other video conferencing systems, and consequently, human interaction with robots can provide an interesting occasion to test communication variables and theories (Lee, 2004). Autonomous social robots that can be utilized as the information source and provide direct instruction to students is a natural place to advance the study of HMC.

References

- Al Moubayed, S., Beskow, J., Skantze, G., & Granström, B. (2012). Furhat: A back-projected human-like robot head for multiparty human-machine interaction. *Cognitive Behavioural Systems*, 7403, 114–130.
- Allen, M., Bourhis, J., Mabry, E., Emmers-Sommer, T., Tittsworth, S., Burrell, N., et al. (2002). Comparing student satisfaction of distance education to traditional classrooms in higher education: A meta-analysis. *American Journal of Distance Education*, 16, 83–97.
- Allen, M., Bourhis, J., Mabry, E., Mattrey, M., Bourhis, J., Tittsworth, S., et al. (2004). Evaluating the effectiveness of distance learning: A comparison using meta-analysis. *Journal of Communication*, 54, 404–420.
- Allen, E., & Seaman, J. (2010). *Class differences in online education in the United States*. Needham, MA: Sloan Consortium.
- Bailenson, J. N., Blasovich, J., Beall, A. C., & Loomis, J. M. (2001). Equilibrium theory revisited: Mutual gaze and personal space in virtual environments. *Presence: Teleoperators & Virtual Environments*, 10, 583–598. <http://dx.doi.org/10.1162/105474601753272844>.
- Bartneck, C., Suzuki, T., Kanda, T., & Nomura, T. (2007). The influence of people's culture and prior experiences with Aibo on their attitude towards robots. *AI & SOCIETY – The Journal of Human-Centered Systems*, 21, 217–230.
- Berry, D. C., Butler, L. T., & de Rosier, F. (2005). Evaluating a realistic agent in an advice-giving task. *International Journal of Human-Computer Studies*, 63(3), 304–327.
- Bertel, L. B., Rasmussen, D. M., & Christiansen, E. (2013). Robots for real: Developing a participatory design framework for implementing educational robots in real-world learning environments. In *Human-computer interaction—INTERACT 2013* (pp. 437–444). Springer Berlin Heidelberg.
- Bloom, B. S. (Ed.). (1956). *A taxonomy of educational objectives: Handbook 1: The cognitive domain*. New York: Longmans Green.
- Borup, J., West, R. E., & Graham, C. R. (2012). Improving online social interaction through asynchronous video. *Internet and Higher Education*, 15, 195–203. <http://dx.doi.org/10.1016/j.iheduc.2011.11.001>.
- Brave, S., Nass, C., & Hutchinson, K. (2005). Computers that care: Investigating the effects of orientation of emotion exhibited by an embodied computer agent. *International Journal of Human-Computer Studies*, 62, 161–178.
- Brown, L., Kerwin, R., & Howard, A. M. (2013). Applying behavioral strategies for student engagement using a robotic educational agent. In *Systems, man, and cybernetics (SMC)* (pp. 4360–4365), 2013 IEEE international conference on IEEE.
- Chang, C.-W., Lee, J.-H., Chao, P.-Y., Wang, C.-Y., & Chen, G.-D. (2010). Exploring the possibility of using humanoid robots as instructional tools for teaching a second language in primary school. *Educational Technology & Society*, 13, 13–24.
- Christensen, L. J., & Menzel, K. E. (1998). The linear relationship between student reports of teacher immediacy behaviors and perceptions of state motivation, and of cognitive, affective, and behavioral learning. *Communication Education*, 47, 82–90.
- Christophel, D. (1990). The relationships among teacher immediacy behaviors, student motivation and learning. *Communication Education*, 39, 323–340.
- Clark, M. N., & Root, D. (2011). Using mobile telepresence in academia. In *27th annual conference on distance teaching and learning* (pp. 11–20).
- Comstock, J., Rowell, E., & Bowers, J. W. (1995). Food for thought: Teacher nonverbal immediacy, student learning and curvilinearity. *Communication Education*, 44, 251–266.
- Edwards, C., Edwards, A., Spence, P. R., & Westerman, D. (2016). Initial interaction expectations with robots: Testing the human-to-human interaction script. *Communication Studies*. <http://dx.doi.org/10.1080/10510974.2015.1121899>.
- Ferdig, R. E., & Mishra, P. (2004). Emotional responses to computers: Experiences in unfairness, anger, and spite. *Journal of Educational Multimedia and Hypermedia*, 13, 143–161.
- Fraser, N. M., & Gilbert, G. N. (1991). Simulating speech systems. *Computer Speech & Language*, 5, 81–99.
- Frymier, A. B., & Thompson, C. A. (1992). Perceived teacher affinity-seeking in relation to perceived teacher credibility. *Communication Education*, 41, 388–399.
- Gambino, A., Kim, J., Sundar, S. S., Ge, J., & Rosson, M. B. (2016). User disbelief in privacy paradox: Heuristics that determine disclosure. In *Published in proceedings of SIGCHI '16 extended abstracts on human factors in computing systems (CHI EA '16)*. <http://dx.doi.org/10.1145/2851581.2892413>.
- Garner, J. T., & Buckner, M. M. (2013). Skyping class: Using videoconferencing in organizational communication classes. *Communication Teacher*, 27, 1–5. <http://dx.doi.org/10.1080/17404622.2012.730618>.
- Goodrich, M. A., & Schultz, A. C. (2007). Human-robot interaction: A survey. *Foundations and Trends in Human-Computer Interaction*, 1, 203–275.
- Gorham, J. (1988). The relationship between verbal teacher immediacy behaviors and student learning. *Communication Education*, 37, 40–53.
- Hackman, M. Z., & Walker, K. B. (1990). Instructional design in the televised classroom: The effects of system design and teacher immediacy on student learning and satisfaction. *Communication Education*, 39, 196–206.
- Hayes, A. F. (2013). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. New York, NY: The Guilford Press.
- Heo, H. H., & Kim, M. S. (2013). The effects of multiculturalism and mechanistic disdain for robots in human-to-robot communication scenarios. *Interaction Studies*, 14, 81–106. <http://dx.doi.org/10.1075/is.14.1.06heo>.
- Kearney, P. (1994). Affective learning. In R. B. Rubin, P. Palmgreen, & H. E. Sypher (Eds.), *Communication research measures: A sourcebook* (pp. 81–85). New York: Guilford Press.
- Kim, E. S., Berkovits, L. D., Bernier, E. P., Leyzberg, D., Shic, F., Paul, R., et al. (2013). Social robots as embedded reinforcers of social behavior in children with autism. *Journal of Autism and Developmental Disorders*, 5, 1038–1049.
- Kim, Y., & Sundar, S. S. (2012). Anthropomorphism of computers: Is it mindful or mindless? *Computers in Human Behavior*, 28, 241–250. <http://dx.doi.org/10.1016/j.chb.2011.09.006>.
- Lee, K. M. (2004). Presence, explicated. *Communication Theory*, 14, 27–50. <http://dx.doi.org/10.1111/j.1468-2885.2004.tb00302.x>.
- Lee, E. J. (2010). The more humanlike, the better? How speech type and users' cognitive style affect social responses to computers. *Computers in Human Behavior*, 26, 665–672. <http://dx.doi.org/10.1016/j.chb.2010.01.003>.
- Lee, K. M., Park, N., & Song, H. (2005). Can a robot be perceived as a developing creature? *Human Communication Research*, 31, 538–563. <http://dx.doi.org/10.1111/j.1468-2958.2005.tb00882.x>.
- Li, J., Kizilcec, R. F., Bailenson, J. N., & Ju, W. (2016). Social robotics and virtual agents as lectures for video instruction. *Computers in Human Behavior*, 55(B), 1222–1230. <http://dx.doi.org/10.1016/j.chb.2015.04.005>.
- McCroskey, J. C. (1994). Assessment of affect toward communication and affect toward instruction in communication. In S. Morreale, & M. Brooks (Eds.), *1994 SCA summer conference proceedings and prepared remarks: Assessing college student competence in speech communication*. Annandale, VA: Speech Communication Association.
- McCroskey, J. C., & Teven, J. J. (1999). Goodwill: A reexamination of the construct and its measurement. *Communication Monographs*, 66, 90–103.
- McCroskey, J. C., & Young, T. J. (1981). Ethos and credibility: The construct and its

- measurement after three decades. *Central States Speech Journal*, 32, 24–34.
- Mubin, O., Stevens, C. J., Shahid, S., Al Mahmud, A., & Dong, J.-J. (2013). A review of the applicability of robots in education. *Technology for Education and Learning*, 1, 1–7. <http://dx.doi.org/10.2316/Journal.209.2013.1.209-0015>.
- Nass, C., Fogg, B. J., & Moon, Y. (1996). Can computers be teammates? *International Journal of Human-Computer Studies*, 45, 669–678. <http://dx.doi.org/10.1006/ijhc.1996.0073>.
- Nass, C., & Moon, Y. (2000). Machines and mindlessness: Social responses to computers. *Journal of Social Issues*, 56, 81–103.
- Park, E., Kim, K. J., & Del Pobil, A. P. (2011). The effects of a robot instructor's positive vs. negative feedbacks on attraction and acceptance towards the robot in classroom. In *Social robotics* (pp. 135–141). Springer Berlin Heidelberg.
- Plax, T. G., Kearney, P., McCroskey, J. C., & Richmond, V. P. (1986). Power in the classroom VI: Verbal control strategies, nonverbal immediacy and affective learning. *Communication Education*, 35, 43–55. <http://dx.doi.org/10.1080/03634528609388318>.
- Pogue, L. L., & Ahyun, K. (2006). The effect of teacher nonverbal immediacy and credibility on student motivation and affective learning. *Communication Education*, 55, 331–344. <http://dx.doi.org/10.1080/03634520600748623>.
- Reeves, B., & Nass, C. (1996). *Media equation: How people treat computers, television, and new media like real people and places*. New York: Cambridge University Press.
- Richmond, V. P., McCroskey, J. C., Kearney, P., & Plax, T. G. (1987). Power in the classroom VII: Linking behavior alteration techniques to cognitive learning. *Communication Education*, 36, 1–12. <http://dx.doi.org/10.1080/03634528709378636>.
- Sanders, J., & Wiseman, R. (1990). The effects of verbal and nonverbal teacher immediacy on perceived cognitive, affective, and behavioral learning, in the multicultural classroom. *Communication Education*, 39, 341–353. <http://dx.doi.org/10.1080/03634529009378814>.
- Schrodt, P., Witt, P. L., Turman, P. D., Myers, S. A., Barton, M. H., & Jernberg, K. A. (2009). Instructor credibility as a mediator of instructors' prosocial communication behaviors and students' learning outcomes. *Communication Education*, 58, 350–371. <http://dx.doi.org/10.1080/03634520902926851>.
- Sharkey, A. (2016). Should we welcome robot teachers? *Ethics of Information Technology*. <http://dx.doi.org/10.1007/s10676-016-9387-z>.
- Smith, B., & Mader, J. (2016). Do I need a robot? *The Science Teacher*, 83(1), 8.
- Spence, P. R., Westerman, D., Edwards, C., & Edwards, A. (2014). Welcoming our robot overlords: Initial expectations about interaction with a robot. *Communication Research Reports*, 31, 272–280. <http://dx.doi.org/10.1080/08824096.2014.924337>.
- Steinfeld, A., Jenkins, O., & Scassellati, B. (Mar 2009). The Oz of Wizard: Simulating the human for interaction research. In *Human-robot interaction (HRI 2009)* (pp. 101–108). San Diego, CA, USA.
- Sundar, S. S. (2008). The MAIN model: A heuristic approach to understanding technology effects on credibility. In M. J. Metzger, & A. J. Flanagin (Eds.), *Digital media, youth, and credibility* (pp. 73–100). Cambridge, MA: The MIT Press. <http://dx.doi.org/10.1162/dmal.9780262562324.073>.
- Sundar, S., & Nass, C. (2001). Conceptualizing sources in online news. *Journal of Communication*, 51, 52–72. <http://dx.doi.org/10.1111/j.1460-2466.2001.tb02872.x>.
- Szafir, D., & Mutlu, B. (2012). Pay attention! designing adaptive agents that monitor and improve user engagement. In *CHI '12: Proceedings of the 2012 annual conference on human factors in computing systems*.
- Yun, S., Shin, J., Kim, D., Kim, C. G., Kim, M., & Choi, M. T. (2011). Engkey: Tele-education robot. In *Social robotics* (pp. 142–152). Springer Berlin Heidelberg.