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Robomorphism: Examining the effects of telepresence robots on between-student cooperation

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ABSTRACT

The global pandemic has stressed the value of working remotely, also in higher education. This development sparks the growing use of telepresence robots, which allow students with prolonged sickness to interact with other students and their teacher remotely. Although telepresence robots are developed to facilitate virtual inclusion, empirical evidence is lacking whether these robots actually enable students to better cooperate with their fellow students compared to other technologies, such as videoconferencing. Therefore, the aim of this research is to compare mediated student interaction supported by a telepresence robot with mediated student interaction supported by videoconferencing. To do so, we conducted an experiment ($N = 122$) in which participants pairwise and remotely worked together on an assignment, either by using a telepresence robot ($N = 58$) or by using videoconferencing ($N = 64$). The findings showed that students that made use of the robot (vs. videoconferencing) experienced stronger feelings of social presence, but also attributed more robotic characteristics to their interaction partner (i.e., robomorphism). Yet, the negative effects of the use of a telepresence robot on cooperation through robomorphism is compensated by the positive effects through social presence. Our study shows that robomorphism is an important concept to consider when studying the effect of human-mediated robot interaction. Designers of telepresence robots should make sure to stimulate social presence, while mitigating possible adverse effects of robomorphism.

1. Introduction

Schools have various technologies at their disposal to facilitate virtual participation when students are not able to attend school due to illness or medical conditions. These technologies range from simple chat-based computer-mediated communication (CMC) tools to more advanced videoconferencing equipment which allows for real-time rich interactions that stimulate student-teacher and student-student interactions. Especially in these times of a global pandemic, which forces many of us to work and interact with each other while not being physically present, these technologies may foster a sense of belonging and academic well-being by stimulating interpersonal and social awareness of others (Abbott, Austin, Mulkeen, & Metcalfe, 2004; Hopper, 2014; Riva et al., 2020; Wiederhold, 2020).

An upcoming development is the use of telepresence robots to offer academic services for those who cannot attend school and participate in class due to illness (Newhart et al., 2016). Telepresence robots enable robot-mediated human interaction, in which people interact with each other mediated by a robot (e.g., Edwards, Edwards, Spence, Harris, & Gambino, 2016; Wang & Schwager, 2015). In classroom settings, absent students, can communicate and work together with other students and the teacher, as if they are present in the classroom, facilitated by the communication modalities provided by the robot, which may be audio only or audiovisual. In contrast to videoconferencing equipment, which is also widely used in classroom collaboration, telepresence robots offer several advantages over more traditional audio- and videoconferencing tools. Usually, the absent student has agency over the robot and can, for example, turn the robot's head, communicate basic emotions, and make simple gestures. Moreover, these robots usually have anthropomorphic characteristics that elicit affective emotional reactions similar to

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human-to-human interactions (Newhart et al., 2016). In sum, by controlling the telepresence robot absent students remain physically embodied and socially connected to their class. The telepresence robot thus may be used to support in-class participation (Fitter, Chowdhury, Cha, Takayama, & Matarić, 2018).

Up to now, there is limited research on the value of telepresence robots to foster communication and in-class participation. Most studies that have investigated the use of telepresence robots is conceptual, usually providing proof-of-concepts or small-size case studies in which a robot is tested in a single classroom (Newhart, 2016; Weibel, 2020). It is not known whether these robots can actually stimulate group cooperation and communication in comparison with other, more readily available, and cheaper technologies, such as videoconferencing. Moreover, empirical research is lacking about the underlying process that may explain group cooperation and communication via telepresence robots. Research suggests that telepresence robots may enhance social presence between students and that the anthropomorphic characteristics of the robot may stimulate affection (Adalgeirsson & Breazeal, 2010). Yet, to the best of our knowledge, this has not been tested in an experimental study.

Therefore, the goal of this study is to experimentally compare mediated student interaction supported by a telepresence robot with mediated student interaction supported by videoconferencing. We specifically posit that interacting via a telepresence robot can have both advantageous and adverse effects on group communication and cooperation. Advantageous, because both telepresence itself (Oh, Bailenson, & Welch, 2018) and telepresence robots may stimulate social presence between communication partners (Choi & Kwak, 2017; Vetere et al., 2012). Disadvantageous, because communicating via a robot may take away some of the human-like qualities of the interaction, which could potentially cause students to imbue robotic characteristics onto the robot controller (i.e., the person who is communicating through the telepresence robot). To investigate this, we introduce the concept of robomorphism in this paper, which we define as the projection of robot-like qualities onto a human (cf. Haslam, 2006). We posit that, due to these opposing mechanisms, it is important to gain more insight in the question whether telepresence robots are more effective than videoconferencing as a communication technology, and why this is (not) the case. Disentangling these opposing forces may facilitate a better understanding of telepresence robots' full potential to promote inclusive education.

2. Theory & hypotheses

Since their introduction in classrooms, telepresence robots have been heralded for their potential to keep ill students virtually included (Newhart et al., 2016; Tanaka, Takahashi, Matsuzoe, Tazawa, & Morita, 2013; Weibel et al., 2020). Telepresence robots physically represent a student in the classroom, thereby making it possible to attend class, participate in group work and interact with peers and lecturers, even when they suffer from prolonged absence due to illness or medical problems. This is considered critical for their social and academic well-being. Students who are out of touch with their school for a prolonged period of time, experience social, psychological, or school related problems (Weibel et al., 2020).

The main goal of telepresence robots is to stimulate social interaction and cooperation in classroom settings (Newhart et al., 2016). Prior research on telepresence robots in an educational setting has shown that telepresence robots are beneficial for social interaction between classmates (Cha, Chen, & Mataric, 2017; No Isolation, 2020; Soares, 2017). For example, Weibel et al. (2020) explored the effects of a telepresence robot (AV1) controlled by adolescents to attend school from a distance. The results show that the adolescents perceived the robot as a facilitator for social interaction with classmates and learning activities. More generally, cooperation and communication in a team is one of the key success factors to successful performance in virtual teams (Dennis et al., 2008; De Vries, van den Hooff, & de Ridder, 2006; Maynard & Gilson, 2013). Avatar-based interaction in teams has also been shown to increase these socio-emotional communication processes in online interactions (Bente, Rüggenberg, Krämer, & Eschenburg, 2008). Therefore, in this study, we focus specifically on how the use of a telepresence robot may support group-based cooperation between students.

Despite its promises, it remains unclear how telepresence robots perform in terms of communication and cooperation, also in comparison to other communication technologies that are widely used in classroom collaboration, such as videoconferencing. Although these communication technologies have some qualities in common, they also differ in some important aspects, which may produce different results in terms of communication and social outcomes. Similar to traditional videoconferencing, which is widely used in classroom collaboration, the robot controller usually has access to an audio-video stream using the built-in webcam and microphone of the robot. However, in contrast to videoconferencing equipment, depending on the type of robot, the controller usually can exert control over the robot, by making certain gestures (e.g., head tilting, nodding, smiling, raising eyebrows) or movement. Therefore, the main characteristic of communication that sets telepresence robots apart from videoconferencing is the embodiment of the controller into the robot. That is, the controller uses the body and facial expressions facilitated by the robot, to communicate with others.

This robotic embodiment of the controller may affect two important social processes in CMC that, in turn, may affect cooperation of people interacting via telepresence robots. First, communicating via a telepresence robot may enhance feelings of social presence in both the controller and the interaction partner (Cha et al., 2017; Lee & Takayama, 2011). In general, the concept of social presence refers to the "degree of salience of the other person in a mediated communication and the consequent salience of their interpersonal interaction" (Short, Williams, & Christie, 1976, p. 65). In other words, the "realness" of the feeling of being together with another "human" in a mediated environment (Nowak & Biocca, 2003; Nowak, Watt, & Walther, 2009). Other research extended this definition beyond physical awareness or the medium's capabilities to includes people's sense of access to the other's internal state (Kang & Watt, 2013), which relates to the feeling of awareness of other's presence (Biocca & Nowak, 2001).

Considering that telepresence robots allow people to be physically present with others (Fitter et al., 2018), we expect that participants interacting via the telepresence robot will experience a higher degree of social presence than participants interacting via videoconferencing. Both videoconferencing and telepresence robots are high in social presence, as both allow rich synchronous communication using audio and/or video channels. However, compared to videoconferencing, telepresence robots may elicit a greater sense of social presence. The robot controller is physically present together with the interaction partner, albeit embodied by a robot. This may increase the salience of the interaction partner, both for the robot controller and for the person interacting with the robot. This will result in a greater sense of being together, and being together in the same room (Newhart et al., 2016; Nowak & Biocca, 2003). We therefore pose:

H1. Compared to videoconferencing, participants interacting via a telepresence robot will experience more social presence.

Although telepresence robots may allow the robot controller to be "present" with others, the robot controller is always physically represented by a machine (i.e., a robot). To increase the acceptance of human-robot interaction, robots are often designed to bear a human resemblance (Bartneck, Kulić, Croft, & Zoghbi, 2008). For example, they are given physical features similar to those of humans, such as a body, a face, and/or a pair of eyes. These characteristics are believed to promote anthropomorphism: a psychological process responsible for the human tendency to attribute human-like qualities onto lifeless entities and objects such as robots (Duffy, 2003; Nowak & Biocca, 2003). Anthropomorphism reduces feelings of discomfort with things that are unlike us

(Guthrie, 1995), and hence is stimulated by robot designers. Although interaction with humanlike robots may promote anthropomorphism, we pose that the inverse may also happen when this interaction takes place via a telepresence robot. The robotic embodiment of the robot controller blurs the traditional boundaries between human and machine. Consequently, people may attribute robot-like qualities onto their interaction partners; a process that we call robomorphism.

The idea that people interacting via a robot may feel themselves more robotlike is not new (Kuwamura, Minato, Nishio, & Ishiguro, 2012; Straub, Nishio, & Ishiguro, 2010; Sumioka, Nishio, & Ishiguro, 2012). For example, Kuwamura et al. (2012) already showed that perceptions of someone's personality may be distorted when interacting via a robot. As the authors explain, the personality imagined from the neutral appearance of the robot is mixed with the personality of the user transmitted through the telepresence robot, thereby leading to perceptions of personality distortion. Likewise, we argue that the mechanic identity of the telepresence robot can be mixed with the human identity of the user transmitted through the telepresence robot, thereby leading to perceptions of identity distortion.

The literature on infrahumanization provides initial evidence that robomorphism may be at work in interpersonal settings (Haslam, 2006). This field considers humanness as a dynamic, social judgment, meaning that we can attribute more or less humanness to (groups of) people and even deny it. Denying human nature in people leads people to equate human beings with robots or machines, and is marked with a lack of interpersonal warmth, prosocial concern, cognitive openness (e.g., curiosity, flexibility), and individual agency (Haslam, 2006). When this mechanistic form of dehumanization is active, people are instead seen as cold, emotionally inert, rigid, and passive, or in other words, as robots.

In this paper, we argue that people may also be equated with robots as a result of robot-mediated communication. However, differently from what infrahumanization theory proposes, we argue that these perceptions occur not because human nature is denied in interaction partners, but also because robotic qualities are attributed to interaction partners. This perspective relies on research demonstrating the presence of so-called machine heuristics. The machine heuristic refers to attributions of randomness, objectivity, and other mechanical characteristics to technological artefacts (Sundar, 2008, p. 83). Thus, technological interaction partners may automatically prompt associations of stereotypical machine- or robotlike characteristics (Sundar, 2008. p.83). In this paper, we propose that such robotlike qualities can spill over to the human controlling and therefore that are communicating through telepresence robots, thereby leading to perceptions of robomorphism. This would be mostly pronounced for the interaction partner because she interacts with the person embodied by the robot. The sense of embodiment may instill a certain sense of robotlike qualities onto the robot controller. However, the robot controller may also experience a sense of robomorphism in the interaction partner, as she may unconsciously project her robot embodiment onto the interaction partner (Kuwamura et al., 2012; Straub et al., 2010; Sumioka et al., 2012). This may also reduce the sense of realness of both controller and interaction partner, as they may be seen less as a human and more as a robot (Straub et al., 2010). We therefore pose:

H2. Compared to videoconferencing, participants interacting via a telepresence robot will experience more robomorphism.

We expect that social presence and robomorphism will differentially affect the ability of people to communicate with each other and work together. In this study, we define cooperation in terms of satisfaction, warmth, and social identification. Satisfaction is usually defined in terms of both satisfaction with the group process and the outcome (Chidambaram, 1996). The former relates to the degree to which participants are satisfied with the group process, such as the overall satisfaction with the cooperation and the effective participation of each group member. The latter relates to the degree to which participants are satisfied with the outcome, such as whether the team members feel they have been able to provide adequate solutions to an issue (Green & Taber, 1980; Hinds & Weisband, 2003; Lowry, Roberts, Romano, Cheney, & Hightower, 2006). Second, the extent to which communication is perceived as warm and personal is paramount for effective cooperation (Walther, 1995), especially in learning situations (Gunawardena, 1995). Warmth is one of the universal dimensions and comprises a feeling or trust, friendliness, and personalness (Cuddy, Fiske, & Glick, 2008). Finally, social identification relates to the sense of cohesion and the feeling of being part of a team. Social identification makes team members more willing to cooperate with each other and is an important factor in successful team collaboration (Chan, 2004; Webster & Wong, 2008).

There is ample evidence that a sense of social presence positively affects team interaction and cooperation (e.g., Altschuller & Benbunan-Fich, 2010; Lowry et al., 2006; Sallnäs, 2005), with teams experiencing more social presence, also experiencing more warmth in team interactions, more satisfaction, and a stronger communal bond, leading to more social identification (Schouten, Van den Hooff, & Feldberg, 2016; Slater, Sadagic, Usoh, & Schroeder, 2000). A number of studies have indicated that social presence is a predictor of perceived learning outcomes and learner satisfaction (Gunawardena, 1995; Weinel, Bannert, Zumbach, Hoppe, & Malzahn, 2011; Whipp & Lorentz, 2008). We therefore expect that social presence is positively related to cooperation.

However, we do expect that robomorphism may decrease the ability of a group to cooperate. First, the interaction may be perceived as less warm, as the interaction is mediated by a robot. This is supported by infrahumanization theory, showing that mechanistic dehumanization involves emotional distancing and perceiving the subject of robomorphism as lacking in warmth (Haslam, 2006). Furthermore, research suggests that the coldness and lifelessness of the robot could affect perceptions of the controller of the robot and perceptions of the interaction as a whole (Kuwamura et al., 2012; Straub et al., 2010). Moreover, team members may be less able to identify with each other and form a common bond, as it may be less easy to feel part of a team when one member is represented by a robot (Haslam, 2006). Finally, this may also affect satisfaction, as increased feelings of talking with a robot instead of a real human may hamper the group process. As Haslam (2006) explains, perceiving someone in robotic terms stimulates feelings of indifference, which could stand in the way of reaching satisfactory group outcomes. We therefore expect robomorphism to be negatively related to cooperation. In sum, we pose the following hypotheses.

H3. Social presence is positively related to cooperation.

H4. Robomorphism is negatively related to cooperation.

When taking the four hypotheses together, we predict a positive effect of telepresence robot interaction on cooperation mediated by social presence and a negative effect of telepresence interaction on cooperation mediated by robomorphism.

Finally, there could be a certain inequality between the robot controller and the person interacting with the robot. The robot controller may experience more social presence than the interaction partner, as the controller has an audiovisual connection to the interaction partner via the robot. Moreover, the interaction partner is physically present and interacts with a robot. Therefore, the interaction partner may experience more robomorphism and less social presence than the robot controller, who is controlling the robot but sees the interaction partner. Thus, the extent to which both robot controller and the interaction partner experience social presence and robomorphism may differ, and this may affect perceptions of cooperation between team members. We therefore ask the following research question:

RQ1. Are there any differences in experiences of social presence and robomorphism between the robot controller and the interaction partner and how do these affect cooperation between students?

3. Method

3.1. Sample

Ethical clearance for this study was obtained from the Ethical Review Board of the first author's university. In January 2020, 122 (63.1 % women) students from the Rotterdam University of Applied Sciences participated in this study. Mean age of participants was 20.66 (SD = 2.59). Of the participants, part of the sample participated as part of a course, while others were recruited informally on campus. In this experiment, most of the students were already familiar with each other (N = 113).

3.2. Design

Our experiment consisted of a one-factor experimental design with two conditions: a telepresence robot condition (N = 58) in which pairs of students communicated mediated by a telepresence robot, and a videoconferencing condition (N = 64) in which students communicated with each other using a WhatsApp video call. In the telepresence robot condition one participant controlled the robot and thus interacted through the robot while the other participant interacted with the robot.

The telepresence robot, called AV1 (see Fig. 1), is a robot designed specifically to stimulate classroom interaction and collaboration for absent children and young adults (for example due to illness).[1] AV1 is able to turn 360°, has a camera installed to look around, and a microphone so that the controller can use AV1 to speak. Furthermore, the telepresence robot is able to express four different emotions using LEDs that represent AV1's eyes: neutral, confused, happy, and sad. AV1 is controlled by the controller through a tablet which shows the controls and a video feed of AV1's camera. The audio connection is two-way, so both team members can hear and speak to each other, while the video connection is one-way: Only the robot controller can see the interaction partner, while the interaction partner only sees AV1.

3.3. Procedure

Participants were told that they would take part in a study about mediated interaction in the classroom and would have to complete a task with a fellow student via virtual collaboration software. Once two students agreed to participate, they were asked to report to two different rooms at a specific time. Upon arrival, participants were instructed about the experiment and were asked to sign the consent form.

In the telepresence robot condition, participants were told that they were about to interact with each other via a telepresence robot. One participant acted as the robot controller and was situated behind an empty desk and was given the tablet with which the participant could control AV1, of which the audio and video stream were currently muted. The participant was instructed on how to use the tablet to control AV1 and was asked to wait for the other participant to be ready. The other participant, the interaction partner, was situated in another room behind a desk on which AV1 was placed about 1 m (3 feet) away. Robot controllers were told that interaction partners could hear, but not see the robot controller, while the interaction partners were told that the robot controller could both hear and see them. In the videoconferencing condition, both participants were situated behind an empty desk and were asked to use their own smartphone to contact the other team member using WhatsApp video calling (phone number was provided if needed).

Once both participants were set up, the experimental task was explained to the participants, and they were told they could start the call and conduct the task. In the telepresence robot condition, the audio and video streams were then unmuted and in the videoconference condition, the participants could start the WhatsApp videocall.

The experimental task consisted of a collaborative task in which participants had to come up with several solutions to a problem as a team. Participants were first asked to read an article about AI & fake news and had to come up with a solution of how they thought that fake news could best be discovered with AI. After the team came up with a solution, the connection between the team members was cut off whereafter they both individually filled in a questionnaire. Finally, participants were debriefed as to the goal of the study and were thanked for their participation.

3.4. Measures

3.4.1. Satisfaction

Satisfaction was measured by combining items from several satisfaction scales and consisted of ten items that measured both satisfaction with the group outcome and with the group process (Jarvenpaa, Rao, & Huber, 1988; Swaab, Postmes, Neijens, Kiers, & Dumay, 2002). Example items were: (1) I agree with the solution we came up with, (2) I am satisfied with the result of our decision, (3) My team chose the best option, and (4) I think we have made the right decision. Answers ranged between (1) totally disagree and (7) totally agree ($\alpha = 0.904$, $M = 5.80$, $SD = 0.90$).

3.4.2. Warmth

The participants asked to judge the warmth of their interaction by answering four statements adapted from the social richness scale (Gunawardena, 1995). All statements began with "I experienced the conversation with AV1 as.", answers ranged between (1) impersonal to personal, (2) passive to interactive, (3) insensitive to sensitive, and (4) cold to warm ($\alpha = 0.848$, $M = 4.90$, $SD = 1.15$).

3.4.3. Social identification

Social identification was measured with an adapted form of the self-identification scale (Ellemers, Kortekaas, & Ouwerkerk, 1999). Students were asked to rate the following statements: (1) I see myself as a member of this group, (2) I identify with this group, (3) I'm happy to belong to this group, and (4) I feel connected with this group. Answers ranged between (1) totally disagree and (7) totally agree ($\alpha = 0.945$, $M = 5.70$, $SD = 1.16$).

3.4.4. Social presence

Three items from the social presence scale by Nowak and Biocca (2003) were used to measure social presence: (1) It felt like we were in the same space, (2) the conversation felt like a real face-to-face meeting, (3) I felt like I was present with my partner. Answers ranged between (1) totally disagree and (7) totally agree ($\alpha = 0.832$, $M = 4.19$, $SD = 1.44$).

3.4.5. Robomorphism

As we introduced the concept of robomorphism in this paper, there was no scale available to measure the construct. We therefore constructed our own scale to measure robomorphism. We based the items on existing scales, measuring anthropomorphism (Carpinella, Wyman, Perez, & Stroessner, 2017; Hellén & Sääksjärvi, 2013), and on concepts from descriptive studies that investigated personality distortion when interacting with telepresence robots (Kuwamura et al., 2012; Straub et al., 2010; Sumioka et al., 2012). Our robomorphism scale consisted of five items that were: (1) I felt my partner was a real person (r), (2) I felt as if I communicated with a robot, (3) I felt the other was real (r), (4) I treated my partner more like a machine than as a person, and (5) I sometimes got the impression that my interaction partner was a machine. Answers ranged between (1) totally disagree and (7) totally agree ($\alpha = 0.857$, $M = 2.20$, $SD = 1.12$).

[1] https://www.noisolation.com/global/av1/.

Fig. 1. AV1. © marius vabo/wikimedia commons/CC BY-SA 4.0.

4. Results

As participants participated in dyads in the experiment, the data from the two participants in each dyad may not be independent from each other. To check for non-independence of the data, we calculated the Intraclass Correlation Coefficients (ICCs) between the dyads for the three dependent variables, as well as for social presence and robomorphism. ICCs turned out to be low; 0.09, 0.08, and 0.20 for satisfaction, warmth, and social identification, respectively, and 0.09, and 0.27 for social presence, and robomorphism, respectively. As ICC's were low, we analyzed the data at the individual (participant) level.

To examine the first two hypotheses, in which we expected that the telepresence robot condition leads to higher perceptions of social presence (H1), and robomorphism (H2) than the videoconferencing condition, we conducted an independent sample *t*-test. The results showed a significant effect of the CMC condition on social presence, t (120) = −2.59, $p = .011$, $d = 0.47$. Social presence was higher in the telepresence robot condition (M = 4.54; SD = 1.28) than in the videoconferencing condition (M = 3.88; SD = 1.51), supporting H1. Moreover, robomorphism was higher in the telepresence robot condition (M = 2.64; SD = 1.24) than in the videoconferencing condition (M = 1.81; SD = 0.82), t (120) = −4.38, $p < .001$, $d = 0.79$, which supported H2.

To test the effects of social presence and robomorphism on cooperation, and the accompanying mediation role of social presence and robomorphism between condition and cooperation, we conducted mediation analyses using Hayes' (2017) process macro (model 4, 5000 bootstrap samples, 95 % bias-corrected CI's). Social presence was positively related to warmth, $b = 0.34$, $p < .001$, and social identification, $b = 0.32$, $p < .001$, and marginally related to satisfaction, $b = 0.10$, $p = .072$, as shown in Fig. 2. Hence, H3 is partly supported. Indirect effects confirmed the positive and significant indirect path between the use of a telepresence robot and satisfaction, $b = 0.07$, 95 % CI [0.00, 0.15], the use of a telepresence robot and warmth, $b = 0.22$, 95 % CI [0.05, 0.42], and the use of a telepresence robot and social identification, $b = 0.21$, 95 % CI [0.05, 0.41], through social presence. In other words, participants in the telepresence robot condition experienced more social presence than participants in the videoconferencing condition, resulting in them being more positive about the communication process in terms of satisfaction and warmth, and identified more with each other.

Robomorphism was negatively related to satisfaction, $b = -0.28$, $p < .001$, and social identification, $b = -0.26$, $p = .005$, and marginally related to warmth, $b = -0.18$, $p = .059$, partly supporting H4. Indirect effects revealed a negative and significant indirect path via robomorphism between the use of a telepresence robot and satisfaction, $b = -0.23$, 95 % CI [-0.39, −0.10], and the use of a telepresence robot and social identification, $b = -0.22$, 95 % CI [-0.40, −0.07]. The indirect effect of the use of a telepresence robot and warmth was not significant, $b = -0.14$, 95 % CI [-0.33, 0.00], though hovered around significance as the CI indicated. Thus, using a telepresence robot was negatively related to cooperation via robomorphism.

RQ1 asked whether there would be any differences in experiences of social presence and robomorphism between the robot controller and the interaction partner and how these would affect cooperation between participants. We found a significant effect for the role of social presence, t (56) = 2.19, $p = .033$, $d = 0.57$. The robot controller (M = 4.90; SD = 1.08) experienced higher social presence than the interaction partner (M = 4.18; SD = 1.38). There was no significant effect of robot controller vs. interaction partner on robomorphism, $t\ (56) = -1.74$, $p = .146$, $d = 0.40$. Participants talking to the robot (M = 2.88; SD = 1.28) experienced equal feelings of robomorphism than ones talking through the robot (M = 2.40; SD = 1.17).

With social presence as a mediator, we did find significant indirect effects of controller vs. interaction partner on warmth, $b = -0.19$, 95 % CI [-0.46, −0.01], and social identification, $b = -0.21$ 95 % CI [-0.48, −0.02], but not for satisfaction, $b = -0.05$, 95 % CI [-0.22, 0.08]. This indicates that the person controlling AV1 experienced more social presence then the one interacting with the robot, which in turn led to a higher experience of warmth and social identification. Robomorphism did not mediate the relationship between controller vs. interaction partner and satisfaction, $b = -.10$, 95 % CI [-0.32, 0.03], warmth, $b = -0.03$, 95 % CI [-0.23, 0.07], or social identification, $b = -0.07$, 95 % CI [-0.28, 0.03].

Because we observed several differences between the robot controller and the interaction partner, we also conducted mediation analyses in which we separately compared the robot controller with the videoconferencing group and the interaction partner with the videoconferencing group.

Comparing the robot controller with the videoconferencing group, we did find significant indirect effects via social presence of robot controller vs. videoconferencing group on satisfaction, $b = .14$, 95 % CI [0.03, 0.30], warmth, $b = 0.36$, 95 % CI [0.15, 0.61], and social

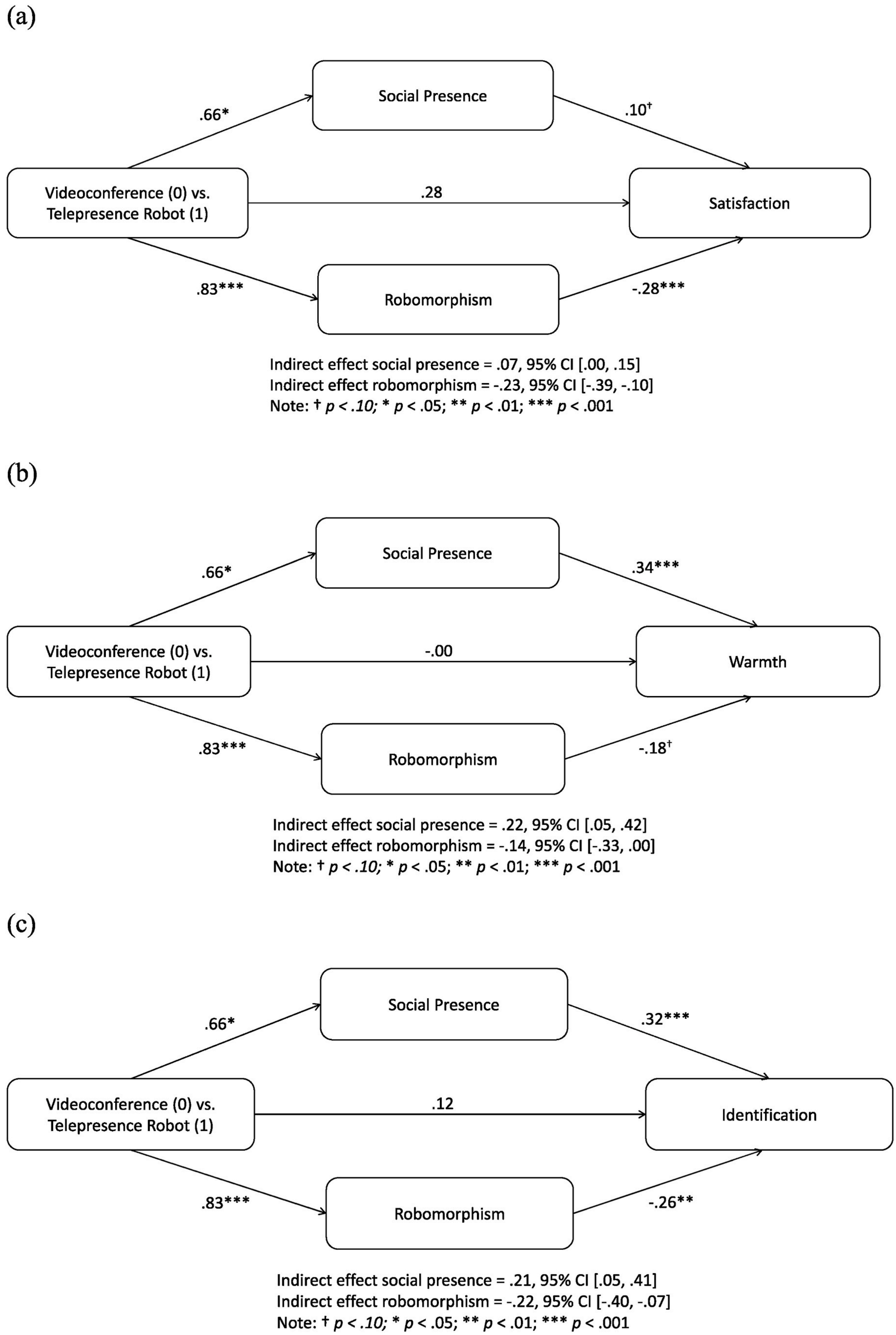

Fig. 2. Mediation analyses for examining the effects of using telepresence robot versus using WhatsApp video through social presence and robomorphism on (a) satisfaction, (b) warmth and (c) identification.

identification, $b = 0.34$, 95 % CI [0.13, 0.61]. However, when comparing the interaction partner with the videoconferencing group, we find no significant indirect effects on satisfaction, $b = .03$, 95 % CI [-0.04, 0.11], warmth, $b = 0.10$, 95 % CI [-0.11, 0.33], and social identification, $b = 0.10$, 95 % CI [-0.11, 0.34]. Comparing the robot controller with the videoconferencing group, we did find significant indirect effects via robomorphism of robot controller vs. videoconferencing group on satisfaction, $b = -.21$, 95 % CI [-0.43, −0.04], social identification, $b = -0.21$, 95 % CI [-0.48, −0.03], but not on warmth, $b = -0.11$, 95 % CI [-0.30, 0.03]. Comparing the interaction partner with the videoconferencing group, we also find significant indirect effects on satisfaction, $b = -.32$, 95 % CI [-0.57, −0.13], warmth, $b = -0.28$, 95 % CI [-0.62, −0.03], and social identification, $b = -0.33$, 95 % CI [-0.61, −0.10]. When comparing these results with the overall comparison between the telepresence robot condition and the videoconferencing condition, we find that the mediating positive effect of social presence is mostly due to the robot controller experiencing more social presence. Robomorphism mediates the relationship between the telepresence robot condition and cooperation for both the robot controller and the interaction partner.

5. Discussion

The purpose of this study was to experimentally examine mediated student interaction supported by a telepresence robot compared to mediated student interaction supported by videoconferencing. The assumption was that interaction via a telepresence robot can have both advantageous and adverse effects on cooperation, in such a way that telepresence robots may prompt social presence between communication partners on the one hand, whereas communicating via a robot may decrease the human-like qualities of the interaction on the other hand, the latter phenomenon we dubbed robomorphism. Accordingly, we conducted an experiment in which students pairwise and remotely worked together on an assignment, either by using a telepresence robot or by using videoconferencing.

The findings showed that students that made use of the robot experienced stronger feelings of social presence compared to using videoconferencing, and this effect was even stronger when the participant controlled the robot. At the same time, participants in the telepresence robot condition experienced higher feelings of robomorphism than in the videoconferencing condition. Interestingly, there were no differences between the robot controller and the interaction partner in experienced robomorphism. Taken together, the results revealed two opposing mediating effects of communicating via telepresence robot vs. videoconferencing on cooperation. Communication via telepresence robot positively affected cooperation via perceptions of social presence, but this was counterbalanced by the negative indirect effect of the use of a telepresence robot on cooperation through robomorphism.

The findings contribute to the literature in several ways. First, this study is one of the first to investigate the use and effects of a telepresence robot in an experimental setting. By doing so, this study strengthens the body of knowledge regarding telepresence robots by demonstrating that using telepresence robots in higher education enhanced social presence, and as such, had a positive effect on cooperation compared to using videoconference. This positive effect of increased social presence on communication and cooperation was mostly pronounced for the robot controller, and not for the interaction partner, for whom the results were on par with videoconferencing. This is in line with prior findings regarding the enhanced sense of connection felt by absent students, their classmates and teachers using telepresence robots (Newhart et al., 2016). Telepresence robots may thus be applicable as a tool to stimulate classroom participation of absent students, if the use can stimulate the feeling of social presence in a group, and if feelings of robomorphism can be mitigated.

Future research should examine whether our findings could be extrapolated to long-term collaborations between students via telepresence robots and whether similar results would be obtained in a classroom setting with larger groups. Telepresence robots are a relatively new phenomenon in higher education. The novelty of a new technology affects the adoption of the innovation (Wells, Campbell, Valacich, & Featherman, 2010), and as such, also might affect cooperation. Previous research showed that after the newness and interestingness of human-machine communication technology evaporates, users had lower expectations about that technology than in the beginning (Croes & Antheunis, 2020). Future research is recommended to further explore the effects of telepresence robots on a longitudinal basis.

Another important contribution of our study is that we show the importance of studying the underlying processes that affect the outcomes of mediated interaction. Had we only focused on outcomes and not investigated social presence and robomorphism as mediators, we would have found no differences between robot-mediated interaction and videoconferencing on team cooperation. However, by taking social presence and robomorphism into account, we were able to uncover two opposing mechanism that explain the effects of using a telepresence robot on team cooperation.

Future research could investigate how to stimulate feelings of social presence in robot mediated human interactions, and how to counteract feelings of robomorphism, so that the net effect of the interaction may be positive. That is, if a telepresence robot could elicit more social presence and less robomorphism, this could positively affect cooperation. Research into personalization of robots has shown that a higher degree of personalization may indeed positively affect impressions of human-robot interaction (Westlund et al., 2016). This could possibly be achieved by adjusting the appearance of the robot to mirror the robot controller (Dautenhahn et al., 2004).

The third contribution of this study is the introduction of the concept of robomorphism and the accompanying scale we developed. Although there are some studies that have investigated robot induced personality distortion (e.g., Sumioka et al., 2012), this paper not only embeds this concept in the context of social sciences, but also provides a way to measure robomorphism. Robomorphism may explain why communication and cooperation using telepresence robots may not always have beneficial outcomes, based on two reasons. First, it may be caused by dehumanization, such that characteristics of humanness are denied to those interacting through a robot (Haslam, 2006). Second, robomorphism may also be enhanced because an interaction partners attribute part of the robot's characteristics on each other. The latter explanation also relates to what Sundar (2008) calls the machine heuristic. In this case, interaction partners may have attributed machinelike qualities onto each other (cf. Edwards et al., 2016), resulting in a sense of robomorphism. It may be an interesting venue for further research to investigate the extent to which both of these explanations could play a role in robomorphism.

The concept of robomorphism may also be applicable to interactions that go beyond robot-mediated human interactions. In our paper, we position robomorphism as the inverse process of anthropomorphism, where people attribute human traits and characteristics to nonhuman agents. Anthropomorphistic thinking does not only occur in human-robot interaction, but in many other situations as well. For example, people see human traits in all kinds of objects and entities that they encounter in the world around them: animals, trees, gadgets and even abstract concepts such as brands and nature (i.e. mother nature) (e.g., Portal, Abratt, & Bendixen, 2018; Sacchi, Riva, & Brambilla, 2013; Waytz, Cacioppo, & Epley, 2010).

Similarly, we believe that robomorphism also applies to wider interactions. Research on dehumanization describes instances in which people engage in robomorphistic styles of thinking, even in the absence of explicit robotic cues and triggers. In medicine, for example, doctors are known to see patients as mechanical objects, made up of interacting systems, rather than as human beings (Szasz, 1973). Robomorphism is also mentioned in relation to ethnicity and race (e.g., 'mechanical Asians', Bai & Zhao, 2021) and in relation to criminals (e.g., "robot killers”). Moreover, early research on computer-mediated communication also mentioned that when interacting via computers, people could see each other more as computers than as real people (Kiesler et al., 1984; Siegel, Dubrovsky, Kiesler, & McGuire, 1986).

The fourth contribution lies in the observation that although teams interacting via telepresence robot experienced more robomorphism than teams interacting via videoconferencing, there was no difference in experienced robomorphism between the robot controller and the interaction partner. We would have expected that interaction partners would attribute more robot-like qualities on the controller, as they were directly interacting with the robot. A possible explanation may be that the robot controllers may also have partly experienced the interaction as less lifelike as they were using the tablet with the robot interface to communicate. However, although there was no significant difference between the controller and the interaction partner, the means of the two groups did deviate somewhat (2.88 vs. 2.40, $p = .15$). Therefore, we suggest to further investigate the concept of robomorphism in different contexts and with different types of telepresence robots.

Although our study provides important new insights into the value of telepresence robots to foster communication and student collaboration, it does have some limitations. For instance, our study examined the effects of telepresence robots for a specific task (i.e., a cognitive learning objective), within a specific setting (i.e., dyadic setting), and a specific social context (i.e., students within the same class). Further research is needed to understand whether our findings can be generalized to a classroom setting, and to other tasks in student cooperation in the classroom. Moreover, the robomorphism scale we developed needs to be validated beyond the current study. For example, other studies could investigate whether robomorphism also occurs in other communication settings, for example when communicating via avatar in virtual reality. It also would be interesting to see how robomorphistic assessment of a human-controlled robot interaction differs from human-robot interaction (e.g., robomorphism perceptions of a chatbot).

Despite these limitations, our findings showed that interacting via telepresence robot led to stronger feelings of social presence than videoconferencing, but also made the interaction partners feel more robotlike, causing opposing effects of using a telepresence robot on team cooperation. Our study was one of the first to experimentally test the effects of robot-mediated human interaction on cooperation and communication in virtual teams. Moreover, we showed that robomorphism is an important concept to consider when studying the effect of human-mediated robot interaction. Our results have important implications for the use of telepresence robots in classroom and other collaborative settings, and designers of those systems and those responsible for implementation should make sure to stimulate social presence, while mitigating possible adverse effects of robomorphism.

Credit author statement

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Declaration of competing interest

None.

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