Title
Telepresence Robots Outperform Traditional Videoconferences in Higher Education: A Longitudinal Study

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Abstract: This paper presents the results of an evaluation study on the use of telepresence robots in higher education. For the first time, in four seminars, 35 teacher trainees took part both via telepresence robot and via Skype videoconference. Overall, we found that students showed a high acceptance of using telepresence robots in higher education. Students' acceptance was already high at the beginning of the seminars, increased further during the seminars, and exceeded the acceptance of using conventional videoconferences at the end of the seminars. In addition, students did not find the presence of the robots very disturbing. Telepresence robots thus represent a promising option for enabling students to participate interactively in courses if physical participation is not possible for them.
Keywords: corona-virus; digitization; higher education; remote learning; telepresence robots; videoconferences.

Telepresence robots are Segway-like machines on wheels equipped with a webcam, a microphone, a screen and a loudspeaker (see Figure 1). They can be remote-controlled over the Internet and enable interactions between the person operating the robot and people within the robot's radius via videoconferencing. In the educational context, they have so far been used in traditional K-12 schools. For example, telepresence robots are made available to students who cannot go to school for long periods of time for health reasons, such as for an increased susceptibility to infection after a serious illness. The robots enable these students to interactively participate in class and social life at school (e.g., Newhart & Eccles, in press; Newhart & Olson, 2019).

As in K-12 schools, there are also students in higher education who cannot or may not be physically present at courses for long periods. Apart from medical reasons (e.g., quarantine), adult students may also need the robots due to geographical (e.g., physical distance) or economic (e.g., childcare) barriers to equitable access for higher education opportunities. We therefore asked ourselves whether telepresence robots could also be successfully integrated into higher education to enable students to digitally participate in courses from which they would otherwise be excluded. To investigate this question, we tested and evaluated the use of telepresence robots for the first time in four seminars in the Master of Education at a German university. In these seminars all students participated in one session via telepresence robot. Moreover, for comparison purposes, all students took part in another session via traditional Skype videoconferences, where a notebook was placed at a fixed spot in the classroom. Both at the beginning and at the end of the seminars the students were asked about their expectations and experiences regarding the use of the robots and videoconferences. This present paper summarizes the main findings of our evaluation. In particular, we addressed three central questions: (1) How do students evaluate the use of telepresence robots in higher education in general? (2) Do students prefer to participate in a seminar via robot instead of via traditional videoconference? (3) How does the experience of attending a seminar with telepresence robots changes attitudes towards this technology?

Given the high usefulness of telepresence robots for implementation in university teaching and its ease of use, we assumed that the robots would meet with an overall high level of acceptance among students. For example, numerous studies that investigated Davis' (1989) technology acceptance model have shown that the acceptance of technical products depends on their perceived usefulness and ease of use (King & He, 2006). Nevertheless, we considered it possible that students might feel disturbed by the presence of robots in their courses because the robots might, for example, distract students or block their view. To examine this question, we asked the students in our study to what extent they felt disturbed by the presence of the robots.

With regard to the development of students' acceptance of the robots, we assumed that their acceptance would be higher at the end of the courses than at their beginning. Since telepresence robots represent a novel technology that most students are unlikely to be familiar with, we considered an initial skepticism towards this technology plausible (e.g., Richter, Naumann, & Horz, 2010). However, if students make their own (positive) experiences with telepresence robots, their potential skepticism should turn into increasing acceptance. For instance, numerous studies from clinical psychology show that anxiety can be reduced by confrontation with the feared stimuli (e.g. Neudeck & Lang, 2011). In a similar vein, we suspected that perceived disturbances would decrease over the courses due to habituation effects and increasing familiarity with the robots.

Hypotheses

Based on our deliberations, we tested five hypotheses:

Absolute evaluation: At the end of the seminars at the latest, the students will show a high acceptance of the use of telepresence robots in higher education (*H1*).

Relative evaluation: At the end of the seminars at the latest, the students will show a higher acceptance of the use of telepresence robots than of traditional videoconferences in higher education (*H2*). Moreover, at the end of the seminars at the latest, the majority of students will prefer to participate in the seminars via robot, instead of conventional videoconferences (*H3*).

Development: Students' acceptance of the use of telepresence robots in higher education will be higher at the end than at the beginning of the seminars (*H4*). Furthermore, at the end of the seminars, the students will report fewer disturbances due to the presence of the robots than they had expected at the beginning (*H5*).

Method

Sample

The sample consisted of $N = 35$ teacher trainees in the Master of Education at a German university (age: $M = 25.9$, $SD = 3.60$; 63% female). These students attended one of four seminars on educational psychology. In each seminar, all students took part in the study. None of the participants reported any previous experience with telepresence robots.

Variables

We measured students' acceptance of the robots and videoconferences using three items (e.g., "In general, I consider the use of telepresence robots / videoconferences in university teaching to be useful"; $.83 \leq \alpha \leq .87$). For the assessment of students' experienced disturbance by the robots and videoconferences, we used six items (e.g., "I felt disturbed by the presence of the telepresence robots / videoconferences"; $.91 \leq \alpha \leq .97$). We adapted these items for the assessment of students' expected disturbance (e.g., "I assume that I will feel disturbed by the presence of the telepresence robots / videoconferences"; $.80 \leq \alpha \leq .89$). The students responded to all items on a 7-point Likert scale (1 = *strongly disagree*, 7 = *strongly agree*). For the assessment of students' preference of one medium to participate in the seminar, we asked them whether they would take part via robot or videoconference if they had the choice, and which of these media they would choose for their fellow students.

Procedure

The data was collected in four parallel seminars held by the same lecturer. In the first sessions, the lecturer introduced the Double 2 telepresence robot (Double Robotics, 2020). Moreover, he explained the course of the seminar: In some sessions 1-2 students would present a topic from the field of educational psychology through a 35-minute moderation, which should contain at least 15 minutes of lecture and thus would mainly consist of interactive elements. Up to four other students would participate in each moderation from adjoining rooms via Double 2 telepresence robots or Skype videoconferences. At the end of the seminar, all students would thus have given their own moderation in person and attended one moderation via robot, one moderation via videoconference, and all other moderations in person (i.e., physical presence). Following this explanation, the students worked through the initial questionnaire, which included the acceptance and expected disturbances scales and the questions about the preferred medium. In the last session, they worked on the final questionnaire, which included the acceptance and experiences disturbances scales and the questions about the preferred medium. Since we collected most of the data collection via an online questionnaire, there were no missing values.

Results

Table 1 shows the means, standard deviations, and correlations of the continuous variables. At both measurement points, the students showed a high acceptance of the robots and videoconferences (all $5.34 \leq M \leq 6.01$). All four means on the acceptance scale were significantly above the theoretical mean of 4 (all $t(34) \geq 5.91$, $p < .001$). Thus, Hypothesis 1 found support. The expected and experienced disturbances by the robots and videoconferences were low (all $1.77 \leq M \leq 2.41$). All four means were significantly below 4 (all $t(34) \geq 11.55$, $p < .001$).

We examined the development of students' acceptance of and perceived disturbances by the media on behalf of one-way ANOVAs with repeated measures (see also Figure 2). The ANOVA with the dependent variable acceptance (with Greenhouse-Geisser correction) became significant ($F(2.11, 71.63) = 4.16$, $p = .02$, $\eta_p^2 = .11$). Contrast tests showed a different development of students' acceptance of the two media: Whereas the students showed a higher acceptance of the videoconferences at the beginning of the seminars ($\Delta M = 0.32$, $SE = 0.15$, $p = .04$, $\eta_p^2 = .12$), they showed a higher acceptance of the robots at the end ($\Delta M = 0.63$, $SE = 0.22$, $p < .01$, $\eta_p^2 = .20$). This finding war in accord with Hypothesis 2 and can be explained in particular by an increase in the acceptance of the robots during the seminars ($\Delta M = 0.67$, $SE = 0.20$, $p < .01$, $\eta_p^2 = .25$), as predicted in Hypothesis 4. The decrease in the acceptance of the videoconferences over time was not significant ($\Delta M = 0.29$, $SE = 0.25$, $p = .26$).

The ANOVA with the dependent variable Disturbance also became significant ($F(3, 102) = 5.54$, $p < .01$, $\eta_p^2 = .14$). Contrast tests demonstrated that the students experienced less disturbances than expected, both by the robots ($\Delta M = 0.53$, $SE = 0.18$, $p < .01$, $\eta_p^2 = .20$) and by the videoconferences ($\Delta M = 0.45$, $SE = 0.20$, $p = .03$, $\eta_p^2 = .13$). Thus, Hypothesis 5 was also supported. We found no significant difference between the two media with regard to expected or experienced disturbances (all $\Delta M \leq 0.19$, $SE \leq 0.16$, $p \geq .16$).

Table 2 presents students' preferences for a medium to participate in the seminars. Whereas the students reported a slightly higher preference of participation via videoconference at the beginning, at the end almost three quarters of the students preferred to participate via robot. This pattern was shown with respect to both students' own participation and the participation of a fellow student, and was in line with Hypothesis 3.

Discussion

The findings of the present study illustrate the great potential of the use of telepresence robots in higher education. For the first time, students temporarily participated in four seminars on educational psychology via telepresence robot. In accordance with our assumptions, these devices met with high acceptance.

It is interesting, however, that the robots outperformed the videoconferences only at the end of the seminars. Whereas we found higher acceptance values for the use of videoconferences at the beginning of the seminars, the acceptance of the robots significantly exceeded the acceptance of the videoconferences at the end due to a strong increase in the acceptance of the robots during the seminars. Similarly, at the end of the seminars a clear majority of students showed a preference of digital participation in the seminar via robots, although most students at the beginning of the seminars would have decided to digitally participate via videoconference. The experienced disturbances by the robots were low and comparable to the disturbances by videoconferences. However, although the students did not expect any serious disturbances by the robots, the experienced disturbances were still below their expectations.

The extent to which students' positive attitude towards the robots continued to grow during the seminars is remarkable. The strong effects of the longitudinal analysis illustrate that even a relatively short experience with telepresence robots in university teaching can reduce possible reservations and contribute to a high acceptance of this the technology. Together with students' overall positive evaluation of the robots, this finding is also of high practical relevance. This is especially true in times of COVID-19. Although the problem that students are excluded from courses due to a lack of opportunities for physical participation already existed before the pandemic, the number of these students is likely to significantly increase in the near future. This is because of the high number of students for whom contact with other people may represent a significant health risk as long as there is currently no mediation to treat COVID-19. Telepresence robots could effectively enable these students to digitally participate in their courses from home.

We hope that our paper will inform improved educational practices by demonstrating the potential of using telepresence robots in educational settings and enhance the awareness of the challenges students face when they encounter inequitable access to learning opportunities.

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Table 1

Means, Standard Deviations, and Correlations

Scale	***M***	***SD***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1 Acceptance of telepresence robots T1	5.34	1.29	1							
2 Acceptance of telepresence robots T2	6.01	0.91	.49**	1						
3 Acceptance of videoconferences T1	5.67	0.91	.74***	.42*	1					
4 Acceptance of videoconferences T2	5.38	1.38	.23	.44**	.24	1				
5 Disturbance by telepresence robot T1	2.41	0.81	–.55***	–.14	–.35*	–.27	1			
6 Disturbance by telepresence robot T2	1.88	0.89	–.33	–.58***	–.51**	–.14	.21	1		
7 Disturbance by videoconferences T1	2.22	0.88	–.50**	–.18	–.36*	–.17	.58***	.30	1	
8 Disturbance by videoconferences T2	1.77	1.00	–.10	–.40*	–.18	–.51**	.17	.49**	.21	1

Note. T1 = initial questionnaire. T2 = final questionnaire. $N = 35$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 2

Preference of a Medium for Participation in the Seminar

	Own person		**Other person**	
Measurement point	Telepresence robot	Video conference	Telepresence robot	Video conference
T1	15 (43%)	20 (57%)	17 (49%)	18 (51%)
T2	26 (74%)	9 (26%)	25 (71%)	10 (29%)

Note: Absolute (relative) frequencies. T1 = initial questionnaire. T2 = final questionnaire. *N* = 35.

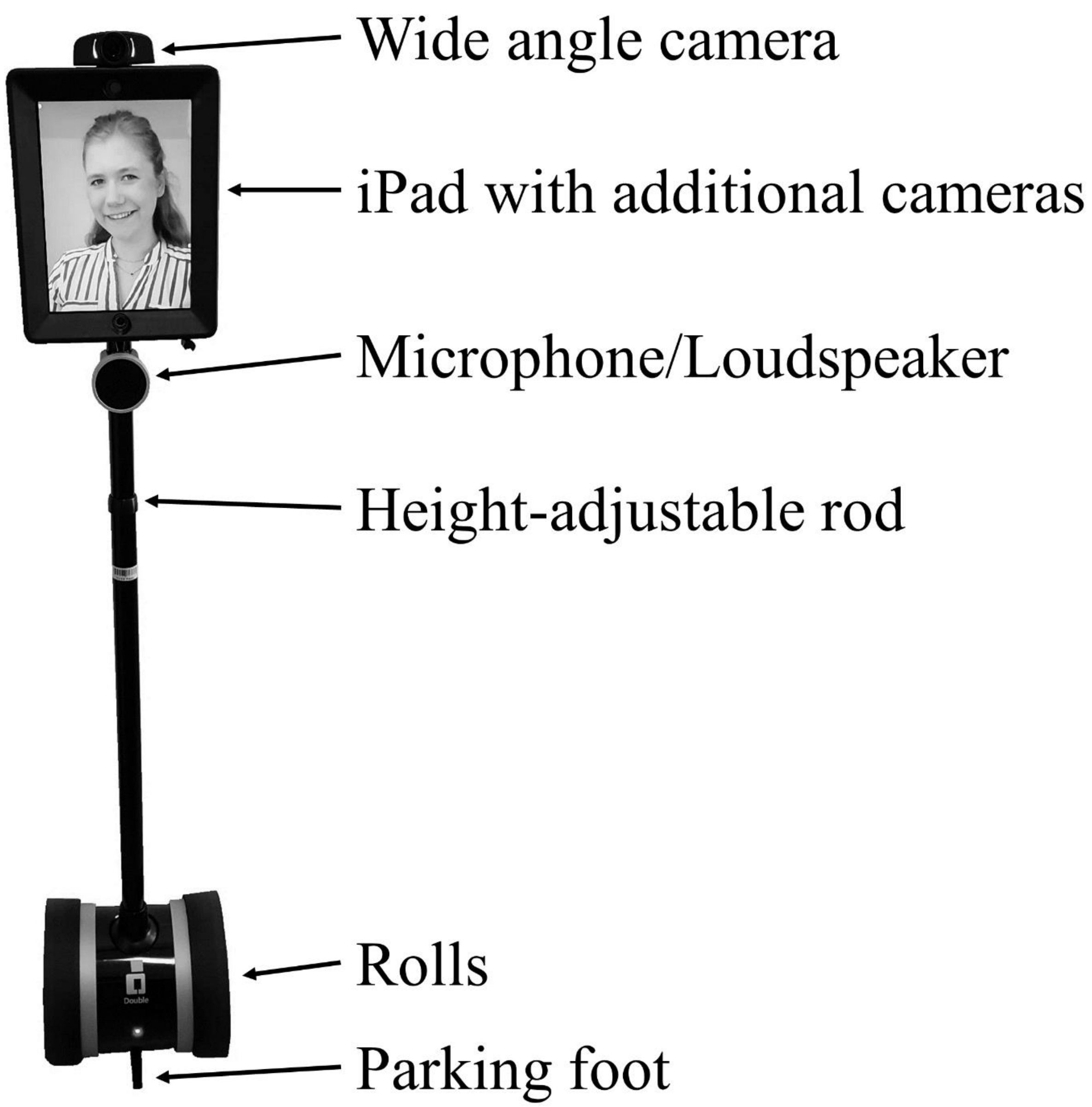

Figure 1: A telepresence robot of the type Double 2.

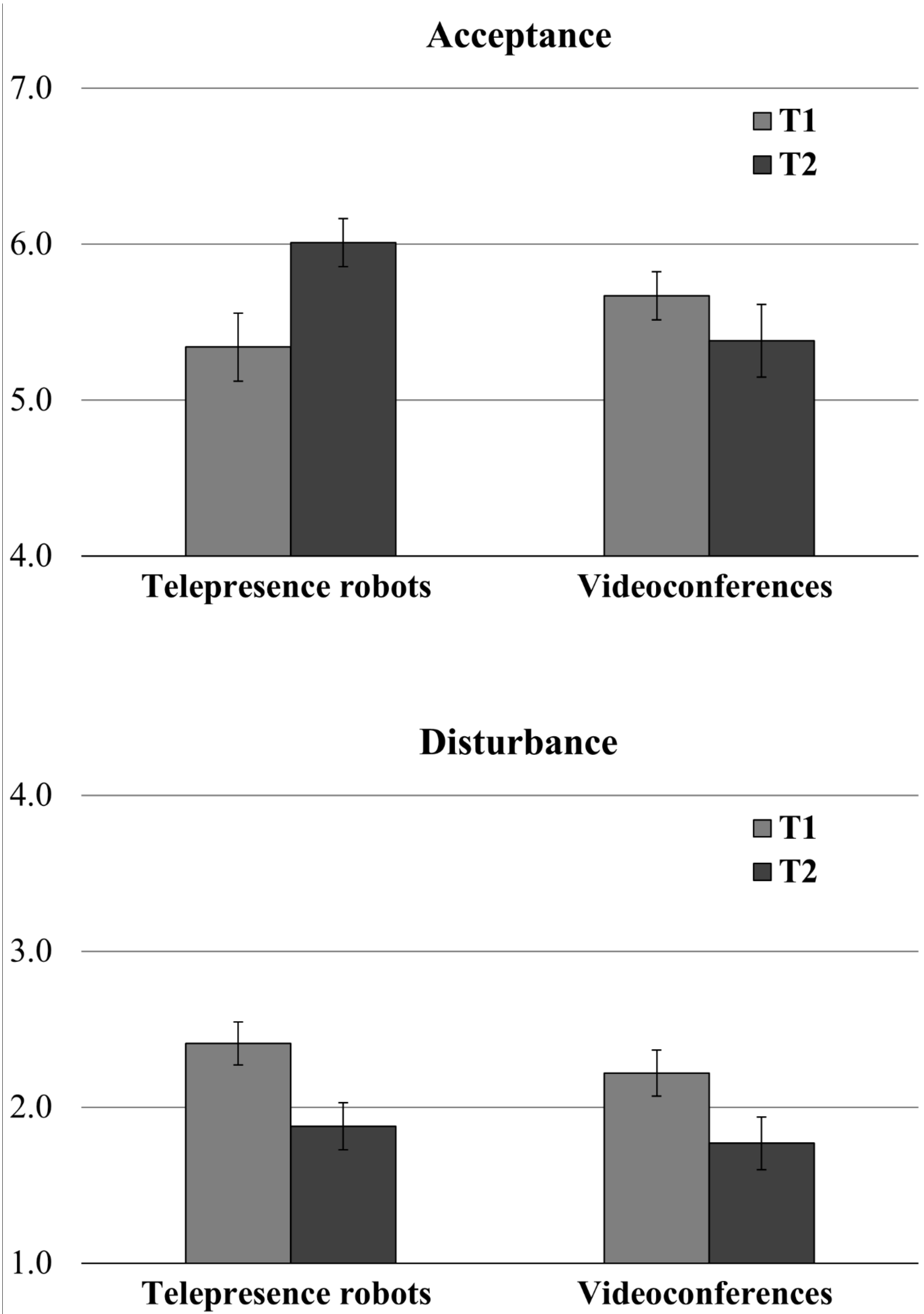

Figure 2: Acceptance of telepresence robots and videoconferences as well as expected/experienced disturbances by the telepresence robots and videoconferences at the beginning (T1) and at the end (T2) of the seminars. The error bars depict the standard errors of the means. $N = 35$.