Driving Success: Virtual Team Building Through Telepresence Robots

Lisa Keller(✉), Oliver Gawron, Tamin Rahi, Philipp Ulsamer, and Nicholas H. Müller

University of Applied Sciences Würzburg-Schweinfurt, Sanderheinrichsleitenweg 20, 97074 Würzburg, Germany
lisa.keller.it@gmx.de

Abstract. Since the corona pandemic, the demand of remote communication solutions has increased significantly. A more uncommon platform to communicating remotely is given through telepresence robots. Telepresence robots are used by schools and universities for giving lectures or for students attending classes. In human-robot teams or at university, robots are also used for teamwork. However, the use of telepresence robots in virtual team building exercises has not been investigated immensely. Therefore, this work examines if telepresence robots are suitable for virtual team building exercises. Moreover, it is investigated whether an overall team building effect can be achieved. Thereby, subjects are divided in smaller telepresence robot groups (communicating via video conferencing). In turn the smaller telepresence robot groups communicate with the overall group through their telepresence robot. As team building exercises Pictionary as well as a QR code scavenger hunt were performed. The study took place as part of the virtual freshmen week at the faculty of computer science and business information systems. Team building was measured through a quantitative questionnaire. The results show that an overall team building effect could be achieved and that telepresence robots can be used successfully for virtual team building. However, the team building effect was significantly higher in the small telepresence robot groups than in the overall group.

Keywords: Telepresence robots · Virtual team building · Remote communication

1 Introduction and Background

Since the ongoing COVID-19 pandemic, the need of remote communication solutions has increased immensely. Moreover, since teamwork and collaboration are facing challenges as nearly every activity takes place digitally, universities mostly use Zoom or other video conferencing platforms for lectures and other activities. These platforms offer a great opportunity for discussing and conducting activities virtually. However, the part of motion we usually have in activities such as moving freely in the lecture room or the building is missing. Building connections

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with fellow students in virtual classes is harder compared to face-to-face classes as there is less opportunity to talk and most students leave the virtual room straight after the lecture ends. This is especially hard for freshmen as they are not familiar with the university system and they do not know any of their fellow students. Also, getting to know fellow students is aggravated. In order to enable freshmen to get to know each other, we designed, conducted, and evaluated a virtual team building event by means of telepresence robots. We used telepresence robots as a novel approach for team building, as online games might be too ubiquitous these days. As telepresence robots have not been used frequently for team building, related work could not give insight whether they are suitable for team building in bigger groups or not. Therefore, we examined if telepresence robots are suitable, and if an overall team building effect can be achieved. Thereby, in each iteration around 20 participants (overall group) where divided into four smaller groups (called robot group in this work). Within the smaller groups the participants communicated with each other through video conferencing, while the smaller groups communicated through telepresence robots with the other smaller groups (refer to Sect. 2). All in all, 184 subjects participated. In the following we will discuss related work regarding telepresence robots, virtual teams, and robots in team building.

Telepresence Robots

Apart from more common remote communication platforms such as Zoom, also robots can be used in communicating remotely. Telepresence robots are mobile robots which are especially designed for communicating remotely. They are equipped with cameras, microphones, a screen as well as motion control. Thereby, telepresence robots enable their operators to feel more present at the remote location. Moreover, operators can move freely and are not dependent on another person to turn camera view.

This element of moving freely was also positively stated by subjects participating in a study which examined the influence of using telepresence robots in long distance relationships [1]. Also, in what way telepresence robots impact human perception as well as conversations, was examined. In a study by Tsui et al., subjects visited an art gallery at first through a telepresence robot and afterwards in person. Conversations with a person in the gallery as well as the gallery itself were perceived fairly akin [2]. The work of Keller et al., systematically investigated this aspect further with respect to human affinity. The results of the study show, that there is no significant difference regarding perceived human affinity towards a person, whether a guided tour in a university is undertaken in person or through a telepresence robot [3]. This pleads for further successful usage of telepresence robots in social interactions. Moreover, Keller et al. also measured human affinity towards a humanoid robot interlocutor. The results indicate that there is no significant difference regarding human affinity, whether it is interacted with a humanoid robot in person or through a telepresence robot [4]. This suggest that telepresence robots cannot only be applied successfully in human-human interactions but also in human-robot interactions. Moreover, that there seems to be no difference in perceived human affinity in both cases, also benefits the use of telepresence robots in collaboration and virtual team building. Furthermore, the results of a study investigating the potential use of telepresence robots in German homes, indicate that people could imagine to have one at home [5].

Furthermore, multiple studies have examined the use of telepresence robots in a learning environment. They concluded, that telepresence robots can be effectively deployed for students, that are medically not able to visit a classroom [6]. In addition, a study showed, that this form of distant learning is more effective as more common screen-based video-conferencing solutions [7]. Mobility was also a highly valued feature for students attending classes through telepresence robots [8]. Also, having teachers using this displacing technology indicated to create positive learning attitudes [9]. Moreover, it has been shown, that the usage of telepresence robots is not affected by the users' size regarding spacial awareness at the distant location [10]. This allows school children and graduate students alike to use the same robots.

Virtual Teams

As other challenges occur in virtual teams compared to face-to-face teams, the literature review of Morrison-Smith and Ruiz deals with these challenges of collaboration. Moreover, they developed remedial strategies to illuminate and categorize these challenges [11]. Since collaboration tools are used in the sense of communication, studies also examined on which communication level information is ultimately processed in virtual teams and compared with face-to-face teams. For this purpose, a subdivision of the meaning was created on three levels [12]. In addition, researchers also dealt with the design and construction of team-building games in virtual worlds. The development of these games are based on principles from social psychology such as in Ellis et al.'s work [13]. This helps team members to develop better communication and cooperation skills [14]. Moreover, the study of Lin et al. has shown that factors of social dimensions need to be taken into account at an early stage in the formation of virtual teams. A research design within this study has been developed that includes the factors that affect the effectiveness of virtual teams [15]. Moreover, they developed a questionnaire to measure the effectiveness of virtual teams on multiple dimensions such as relationship building and cohesion. They designed their questionnaire based on a conducted literature review. We developed our questionnaire to measure the effectiveness of telepresence robots in virtual team building based on Lin et al.'s questionnaire.

Robots in Team Building

In order to examine human-robot collaboration, a study conducted a trial to investigate the effect of team building activities on humans when team building took place between humans and robots. It was found that human perception of robots improved after the team building activities were carried out [16]. Furthermore, the performance of a human-robot team has been investigated and it has been found that when a robot takes over the coordination tasks, the performance is improved [17]. Using robots in education, students were also brought closer to the topic of teamwork and were made aware of coordination mechanisms that should help to clarify and manage conflicts [18]. Furthermore, studies have shown that the usage of robots impacts students' motivation positively [19–21].

Also, telepresence robots were applied in teamwork activities. In the study of Tsui et al., they investigated the use of a telepresence robot in teamwork when one team member of the company is based at another location. The results show that some robot drivers felt more engaged with their team compared to regular video calls [22].

2 Research Questions and Hypothesis

As outlined in Sect. 1, research on virtual teams has been widely undertaken, mostly from a company working situation. Also, games have been proofed for successful team building. Likewise, robots involved in teamwork showed positive effects. Nevertheless, only little research has been undertaken regarding telepresence robots in virtual team building. Mostly interactions between humans and how they are influenced by the use of a telepresence robot were investigated. However, whether multiple telepresence robots can be used successfully in team building especially involving a bigger group had not been investigated immensely. Therefore, this work investigates the following questions:

RQ1: Are telepresence robots suitable for virtual team building exercises?
RQ2: Can a team building effect be achieved in the robot groups?
RQ3: Can an overall team building effect be achieved with subjects divided in smaller groups that communicate with each other by means of telepresence robots?

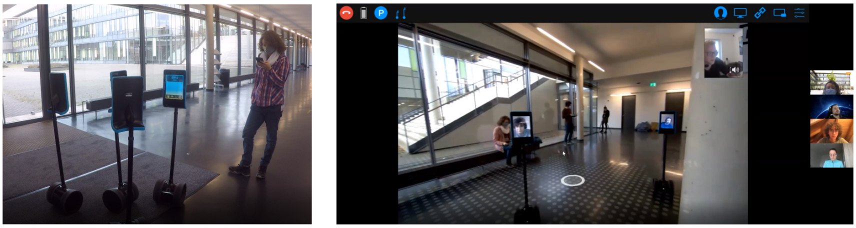
Thereby, it is assumed that a higher team building effect is present within the robot groups (which communicate via video conferencing) compared to the overall group (communicating through telepresence robots with other telepresence robot groups). This might be the case as communication in the robot groups themselves is simpler and less influenced by possible technical issues. Therefore, the following hypothesis will be examined:

H1: If subjects are divided in smaller groups that communicate with each other through telepresence robots, then a greater team building effect is present within the small groups as in the overall group.

3 Approach

In the study were five Double 3 robots (seen in Fig. 2) from the company Double Robotics used [23]. Four of them were in use with an additional robot as a backup in case of technical difficulties. Double 3 robot is a telepresence robot consisting of a head and a base part. The base consist of two electric engines allowing the robot to move freely around and self balances the rest of the robot. In the head are two 13MP Cameras integrated, allowing the user to access the robot's view with different zoom levels. In order to see the operator's face on the robot it also has a 9.7" LED-backlit Multi-Touch LCD screen. The robot can either be controlled by using arrow keys, WASD keys, or by clicking on the desired spot to which the robot automatically navigates with the help of multiple sensors.

The participants ($N = 184$) of this study were all freshmen participating in the university's orientation week of the computer science and business information systems department. One day before, they met in person during the orientation week. The group consisted of 20 participants maximum plus 4 guides. All participants were constructed to meet up in a Zoom video conference meeting [24] at a set time. After a brief explanation from one of the guides about the following steps, all participants were randomly divided into four smaller groups consisting of 5 participants maximum and one guide. These smaller groups communicated in so-called breakout sessions, small video conference meetings with the ability to share your screen with others present in the meeting. After all participants joined these, the guide of each group explained how to use a previously generated link to connect to the telepresence robot. Limitations to do so, like the necessity to use the Google Chrome Browser and the inability to control the robot with a mobile phone were communicated the day before, so participants had enough time to setup the needed software and hardware. Since each group only got to control one robot each, the driver of the telepresence robot had to share his or her screen, so the other participants could also hear and see the robot's actions. To allow every participant to control the robot at least once, multiple tasks were given between which the participants exchanged the driver.



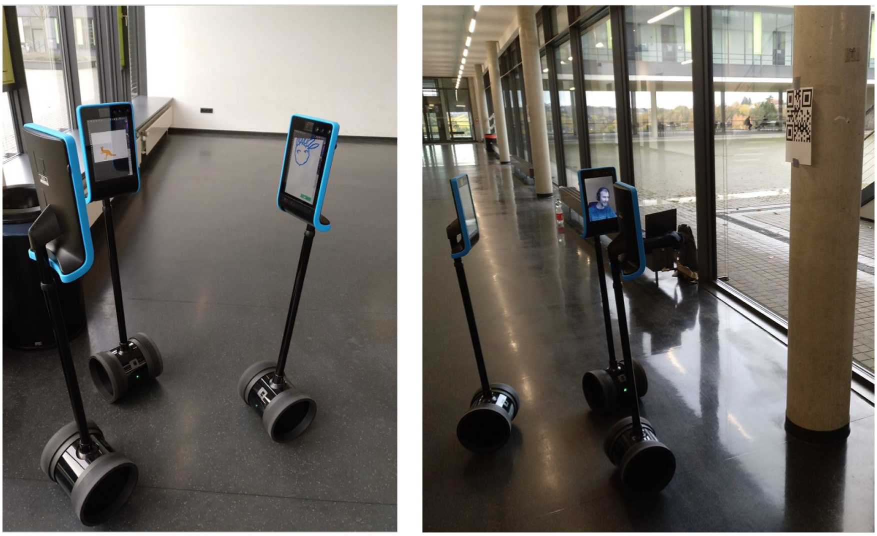
(a) One of the guides (b) Zoom call

Fig. 1. Guide and Zoom call

The first task, which allowed the participants to get used to the interface and the controls, was to drive from a starting point along a hallway to the cafeteria. This environment was familiar to the participants, since they were there shortly the day before. On their way they met the guides, they were communicating with, as they were onsite with the telepresence robots. Since all groups had the same tasks, all telepresence robots would meet each other there, allowing the robot drivers to talk to each other. At the same time, the rest of the groups could follow the action through the shared screen of the driver while talking to him or her and with each other.

Double 3 telepresence robots have the ability, besides displaying the operator's face, also to show a given website on its screen. The current robot driver was now asked to let the robot show an instance of the aggie.io website [25]. Aggie.io is a collaborative drawing space, allowing multiple users to draw together on the same canvas. The whole robot group was now asked to also open said website and draw a given object. Each team had a different object to draw. The possible objects were: forklift truck, dwarf, a native American, and a kangaroo. Since all robots were now showing different paintings of the different groups, the drivers task was to position each other in a way that allows the robots to see each other so that the groups could play a game of Pictionary though the telepresence robots.

The next task was to find and scan four hidden QR codes in the previously mentioned hallway. Since the robot itself has no build in QR code scanner, the participants used their mobile phones to scan these codes. The difficulty in this task was the QR code being captured by the robots camera, streamed to the controller's device and again streamed to the other participants in the group through the screen share, which deteriorated the image quality in every step, making the code hard to scan. To overcome this obstacle, the driver had to drive as close and straight on to the codes as possible, to allow his or her teammates an easy scan. The codes itself contained a letter each. With the letters being B, I, T and S the participants had to assemble them into the right code word BITS.



(a) Pictionary (b) QR code scanning

Fig. 2. Tasks

The experiment always lasted an hour maximum, though some groups finished earlier than others. In the end, all participants were asked to fill in a questionnaire (refer to Sect. 4).

4 Methods

In order to examine the research questions (refer to Sect. 2), a quantitative questionnaire was designed which participants filled in at the end of the experiment. Additionally, the participants had the opportunity to give qualitative feedback by evaluating the freshmen orientation week.

Questionnaire
The designed questionnaire (listed below) consists of five categories: relationship building, cohesion, communication, coordination, and satisfaction. Each category consists of four quantitative questions. Therein, two questions relate to the subjects' robot group (question 1 and 3) and the other two questions to the whole group (question 2 and 4). Moreover, a 7-point Likert scale is applied where 1 means "not at all" and 7 "very". The questionnaire is based on the work *A model to develop effective virtual teams* by Lin et al. [15]. Therein, also a 7-point Likert scale and the five categories are applied. As the sixth category "performance" did not suit entirely to our experiment, this category was not applied. Moreover, two questions per category of Lin et al.'s work were chosen and adjusted towards the study settings and the use of telepresence robots.

Relationship Building

1. I had the feeling that my robot group had a common goal.
2. I had the feeling that the whole group (all robot groups together) had a common goal.
3. I have the feeling that I have established a connection to my robot group.
4. I have the feeling that I have established a connection with the whole group.

Cohesion

1. I had the feeling that my robot group was working together.
2. I had the feeling that the whole group was working together.
3. I had the feeling of being integrated in my robot group.
4. I had the feeling of being integrated in the whole group.

Communication

1. I had the feeling that we communicated effectively in my robot group.
2. I had the feeling that we communicated effectively throughout the group.
3. I had the feeling that my robot group was listening to me.
4. I had the feeling that the whole group was listening to me.

Coordination

1. I had the feeling that the coordination within my robot group worked well.
2. I had the feeling that the coordination within the whole group worked well.
3. I knew what I had to do within my robot group.
4. I knew what I had to do within the whole group.

Satisfaction

1. I was satisfied with the commitment of my team members in my robot group.
2. I was satisfied with the commitment of my team members throughout the whole group.
3. I felt comfortable in my robot group.
4. I felt comfortable in the whole group.

Qualitative Feedback
During the whole experiment, participants gave feedback about the experiment itself. Also, qualitative feedback was collected through the freshmen orientation week evaluation by means of a questionnaire about the complete orientation week. Therein, participants had the opportunity to write about what they especially liked and disliked about the week. Thereby, only feedback that could be specifically linked to the experiment was used in the virtual team building's evaluation.

5 Results and Analysis

For analysing data, IBM's SPSS was used. As the samples are from the same population and conducted Kolmogorov-Smirnov tests showed that the data is not normally distributed, Wilcoxon signed-rank tests were applied for each category. Thereby, the applied tests were two-tailed at the significance level of $p \leq 0.05$.

Demographics
Participants ($N = 184$) were aged 17 to 36. Moreover, 134 (72.8%) were male, 37 (20.1%) female, and 13 (7.1%) did not specify their sex. 74 (40.2%) subjects started studying e-commerce, 55 (29.9%) computer science, and 55 (29.9%) business information systems. The average participant was male, 20.85 years old ($\sigma = 2.82$), and started studying e-commerce.

Team Building
In each category of the applied questionnaire, question 1 and 3 refer to the small robot groups whereas question 2 and 4 refer to the whole group. The results of the robot group as well as of the whole group in each category are computed by adding both selected values of the 7-point Likert scale. So, a minimum of 2 and a maximum of 14 points can be achieved. Thereby, we define that if an average of 7 points is achieved, then we consider the category of virtual team building by means of telepresence robots as successful.

Relationship building was rated as $M = 9.95$ ($\sigma = 2.53$) in the robot group and $M = 7.76$ ($\sigma = 3.06$) in the whole group. The conducted test shows that there is a significant difference between relationship building between the whole group and the robot group ($Z = -9.55$, $p < 0.001$). The distribution of the ratings can be seen in Fig. 3.

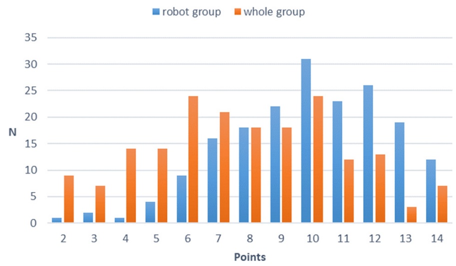


Fig. 3. Relationship building

Likewise, cohesion was rated as $M = 10.84$ ($\sigma = 2.56$) in the robot group and $M = 8.52$ ($\sigma = 3.30$) in the whole group. Moreover, a significant difference between both groups could be detected ($Z = -9.41$, $p < 0.001$). Figure 4 shows the distribution of the rated cohesion.

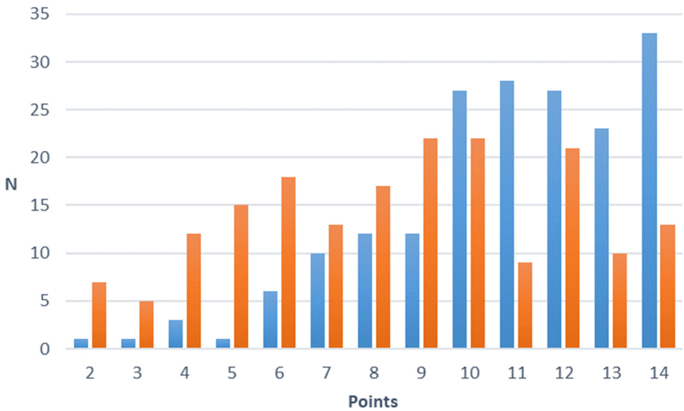


Fig. 4. Cohesion

Communication was perceived as $M = 11.01$ ($\sigma = 2.50$) in the robot group and $M = 8.02$ ($\sigma = 3.41$) in the whole group. Furthermore, a significant difference between both groups could be observed ($Z = -9.58$, $p < 0.001$). The distribution of the communication rating is illustrated in Fig. 5.

Coordination was perceived as $M = 11.31$ ($\sigma = 2.63$) in the robot group and $M = 9.66$ ($\sigma = 3.20$) in the whole group. Moreover, a significant difference

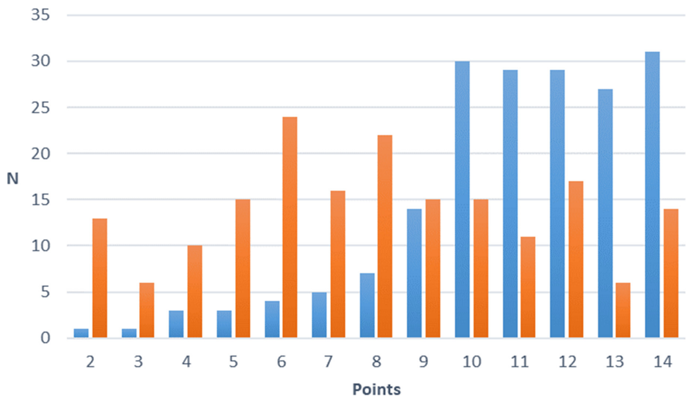


Fig. 5. Communication

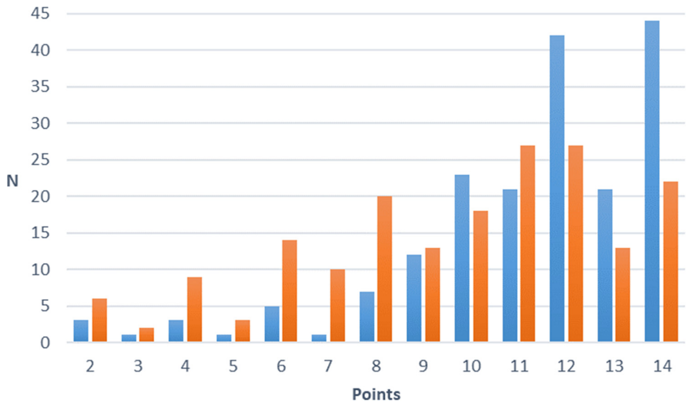


Fig. 6. Coordination

between both groups could be identified ($Z = -7.97$, $p < 0.001$). Figure 6 shows the distribution of the coordination rating.

Satisfaction was rated as $M = 11.73$ ($\sigma = 2.38$) in the robot group and $M = 10.67$ ($\sigma = 2.67$) in the whole group. Also, a significant difference between both groups could be identified ($Z = -6.78$, $p < 0.001$). Moreover, the distribution of the satisfaction rating is shown in Fig. 7.

Considering the distributions of the robot groups and the whole group, it can be seen that a higher team building effect (point score) could be achieved in the robots group regarding all categories. Also, the applied statistical tests support this significant difference as all $p < 0.001$. Therefore, evidence supporting H1 is found.

Nevertheless, an overall team building effect could be achieved as the means of the whole group in each category are above the average of 7 points. Therefore, telepresence robots can be successfully applied for virtual team building, especially in the robot groups.

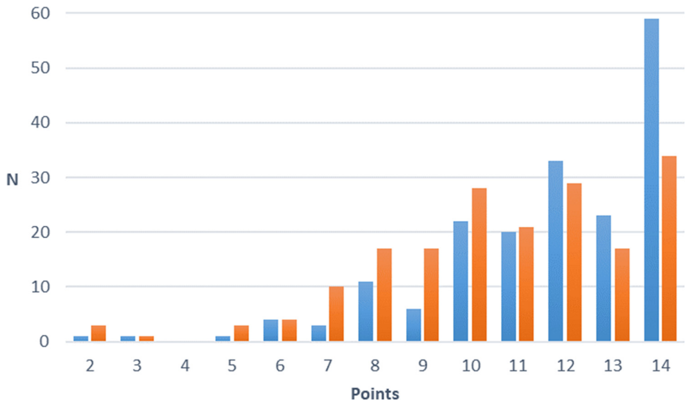


Fig. 7. Satisfaction

Qualitative Feedback
During the experiment, as well as in the freshmen orientation week evaluation, participants stated, that they had fun driving the robots and solving the challenges. Also, that it was an event and something new to them was stated. Moreover, some of them wished for more time to spend with the robots and the exercises. In cases, where technical difficulties (see Sect. 6) hindered the operation of the robot, some participants stated to not like the experiment. Still, the overall feedback was predominantly positive.

6 Discussion

The results of the study show that telepresence robots can be used successfully in virtual team building (RQ1). Moreover, a team building effect could be achieved in the robot groups (RQ2) as well as an overall team building effect (RQ3). Thereby, all research questions (see Sect. 2) could be answered. Furthermore, evidence supporting H1, that the team building effect in the robots groups is higher compared to the overall group, is given.

Furthermore, the quantitative feedback was mostly positive. Some participants stated that it was special and totally new to them. Moreover, they enjoyed controlling the robot and taking part in the exercises. However, some subjects stated that they did not like the experiment as technical difficulties hindered controlling the robot.

Moreover, other factors which might have influenced participants' rating and may limit the study's results occurred. Due to technical difficulties such as disturbed audio transmission, communication between the robot groups was affected. Therefore, instructors helped coordinating occasionally. Moreover, some subjects faced difficulties controlling the telepresence robot due to software or hardware issues. Therefore, less time for team building exercises was available in some groups, as those issues needed to be fixed in order to continue. All in all, this might have influenced participants' ratings.

Finally, not only online games [13,14], robots on-site [18–21], or robots as team colleagues [16,17] but also telepresence robots can be applied successfully in team building exercises as this work indicates. Moreover, the results of this study go hand in hand with findings of other studies which showed that telepresence robots can be successful used in education and company teamwork [6–9,22]. Nevertheless, future work has to evaluate telepresence robots in virtual team building in more depth. Also, measures increasing the overall team building effect need to be researched further. Moreover, it would be good to enhance audio transmission between the robot groups.

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