Does Robotic Telepresence Make the Classroom Accessible?

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Telepresence robots are meant to provide physical access to digital remote spaces. However, they have a range of limitation that make spaces less accessible for remote participants. In this study we reveal, catalogue, and examine telepresence limitations in the context of the classroom. Based on ongoing field study results from participatory observations, surveys and interviews with 22 participants we discuss the extent to which telepresence robots make the classroom accessible and whether the telepresence robots are "disabled."

CCS Concepts: • **Computer systems organization → Robotics**; • **Human-centered computing → Empirical studies in collaborative and social computing**; **Collaborative and social computing design and evaluation methods**.

Additional Key Words and Phrases: Robotic telepresence, remote participation, classroom, articulation work, accessibility, disability

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1 INTRODUCTION

Robotic telepresence offers a promising solution for making classrooms accessible to students who are unable to attend in-person [2, 17] due to various reasons, such as illnesses, injuries, physical disabilities, and COVID infections. When compared to online courses and video conferencing, robotic telepresence better emulates face-to-face interactions by providing access to social cues such as facial expressions, intonation, and physical movement. This enables remote students to move around the classroom and interact with their classmates and instructors, enhancing learning.

Studies have explored the support of robotic telepresence for office work [3, 19, 24, 25], attending conferences [8, 14], hospitals [18], home [4, 15] and education [9, 12, 13, 16], including classrooms accessibility [16, 17]. While the majority of these studies are motivated by making the remote environment accessible, the focus has been on the usability and user experience, adoption, quality of interaction, embodiment, and interaction aspects and often contributed design recommendation. The novelty of this paper lies in exploring the accessibility of the telepresence robots in an educational context and discussing it in a theoretical context. Telepresence robots often embody corporate values like identity, privacy, prioritizing company ownership of information. However, genuine education focuses on individual growth and human development [7], necessitating students and teachers to navigate this socio-technical divide [1].

As the accessibility issues surrounding telepresence in the classroom are understudied, we first aim to identify and categorize accessibility challenges faced by non-disabled students. Only once this broader accessibility issues were addressed do we feel it appropriate to incorporate vulnerable disabled students. By accessibility here we mean ensuring students can see and hear adequately, as well as move unencumbered around the classroom. We analyzed screen recordings, notes, photos, and interviews with 22 participants to understand the challenges related to accessibility and how they can be mitigated. Our study contributes to the theoretical discussion surrounding the limitations of humans using technology-mediated communication and how to address them.

2 RELATED WORK: ROBOTIC TELEPRESENCE

Various mobile robotic telepresence platforms (e.g. Beam, Double, GoBe) each have known accessibility considerations. They typically consist of video conferencing systems in addition to being physically embodied, granting remote users, the *operator*, the ability to move and navigate a remote space [11]. The COVID-19 pandemic increased the perceived importance of remote participation [22] and robotic telepresence [6]. Unlike video conferencing applications (e.g. Zoom) telepresence is especially useful in contexts where the participant is the only person participating remotely, as it helps to mimic face-to-face interactions between the operator and interlocutor [20] (e.g. facial expressions, human-sized embodiment, and mobile control), and act as physical embodiment of the operator in order to maintain social interactions with peers [10], but the technology is not without flaws which we hope to investigate.

Work related to educational Robotic Telepresence provides numerous benefits to remote students, especially in comparison to videoconferencing [17]. Studies overall focused on students' experience [13, 23], acceptance and adoption [13], interaction [23] and engagement [12]. Similar issues to what we present in our findings are mentioned in some of the above studies but are often framed as UX, usability or as purely technical problems to be solved. We argue that there is a need for studies that frame the issue in terms of accessibility as this frame allows for new insights in meeting classroom needs. We contribute to this gap by identifying and cataloguing the accessibility limitations of the telepresence robots and discussing the disability in a telepresence context.

3 RELATED THEORY: ROBOTS' DISABILITY

Williams [26] and Rode [21] have both examined the connection between cyborgs and disability. Williams [26] argues that "All robots are disabled," highlighting the deficit lens used when discussing disabled people using robotic limbs as everyday cyborgs. Williams [26] suggests that disabled robots and people could work together to solve common problems for differently-abled cyborgs. Rode [21]'s autoethnography discusses her experiences as a disabled person using a telepresence robot, emphasizing that the cyborg is neither a fix nor a deficit but a unique combination of abilities. She highlights the ways in which the robot compensated for her disability, giving her increased stamina and enhanced abilities, but also had limitations such as battery life and difficulties moving the robotic self. Rode [21] advocates for conscious manipulation of abilities and limitations and embracing her cyborg self-mediated through a telepresence robot. Williams [26] and Rode [21] explore articulation work/labor around human-mediated robot interactions, with Rode [21] focusing on the disabled person's experience as a mixture of power and limitation, and Williams [26] focusing on others' perceptions of the robot and arguing that only deficits are recognized. These theories can coexist, though one wonders if telepresence robots might eventually be recognized by others as both a liability and a strength. In this paper, we attempt to understand they ways students without disabilities find telepresence disabling.

4 METHOD

We observed students attending two Indiana University classes remotely through Beam Pro, now GoBe, during the Fall 2022 semester. The study received IRB approval.

- Setting: Students controlled the robot from a computer in our lab while sitting at a desk. The study took place in two 80-minute informatics classes per week. The robot had to be carried up and down half a flight of stairs by a research assistant. The classes were a mix of lecture-based and group activities.

- Participants: 22 students attended the study via telepresence robots (F=11, M=11, NB=0). Every student attended one class session. The students are a mix of undergraduate and graduate students majoring in majoring in data science, computer science, engineering, and human-computer interaction. Participants were offered 2 extra credits as an incentive —as is common practice at the PI's university. Recruitment was done through a researcher visiting the class and through postings on the class Learning Management System by the professor.

- Protocols: The observation protocol was open-ended, documenting interesting moments triggered by the telepresence robot. The after-use survey had 6 questions about demographics and overall experience. The scheduled interview was semi-structured, informed by the recordings, photos, and observation notes and aimed at gathering in-depth information about the operator's experiences and accessibility in the classroom.

- Procedure: Participants received training on how to operate the Beam 30 minutes before class. They were asked to participate as if they were attending in person and were free to position themselves as they wished. The study used a maximum of two Beams at a time (allowing a backup in case of tech issues), and assistants recorded notes and photos of interesting events. After class, operators returned the Beams to the lab and completed a short 6 questions Qualtrics survey to collect data about the users' demographics and overall experience. Participants then scheduled an interview with open-ended questions about students' experience of attending via robotic telepresence, how they compare it to Zoom and in-person attendance and their assessment of teamwork and learning as remote attendees. Data was supplemented by a review of the recordings. Interviews were audio recorded and transcribed.

- Data Analysis: Data was thematically coded [5]. The themes were organized into categories on a board and used to create a preliminary code list. The themes were receptive and expressive abilities relating to accessibility.

5 FINDINGS

Remote students using telepresence robots faced accessibility constraints, including challenges in seeing, hearing, moving, and being aware of their surrounding. We categorized these as receptive and expressive abilities limitations.

5.1 Receptive abilities limitations:

Receptive abilities concern receiving information from the classroom environment through senses. Remote attendees had limits to their visual and auditory capabilities, and a sense of 'what's going on' limitation. Here we mention a few examples from the data:

- Vision limitations: Vision limitations are the most common among our participants. 19 participants highlighted they could not see the slides, the whiteboard, or artifacts from classroom activities. For example, despite being in the first row and zooming, P12 was not able to see text on the slides: *"some of the text or annotation text and the pictures were not clear, even after zooming. I was in the front row."* Similarly P16 could see the pictures but not the small text. He mentioned he *"could not read anything."* As for P18, the issue was the color contrast on the slide. The fact that students were not able to see the small text or low contrast may be due to the size of the text and the quality of photos that the human eye can capture better that the Beam camera.

- Auditory limitations: 11 participants reported issues with hearing others. P13 mentioned she could not hear the professor because of the audio quality, consequently during the Q&A she had no questions. She said: *"I could not hear the instructor clearly. So I don't know what question I want to ask."* The inability to ask questions here could impact her overall understanding of the lecture. P16 was not able to hear his classmates even though they were right in front of him. He mentioned that he was talking to one of his classmates who decided to leave and said goodbye and left. Since P16 did not hear him he was wondering why he suddenly left. He says: *"he said bye guys. And then when he looked back, he realized that I was still here."* It is particularlly dificutl to hear people talking behind the Beam, for instance when students ask questions. This poses challenges for the remote attendees regardless of where they position their robot, as remote attendees in the front of the room can hardly hear questions from the back, and vice versa.

- Sense of "what's going on" limitations: 13 students reported not having the same sense of what was going on around them, that they would when they are in the classroom in-person. P9 compares being in the classroom in-person and using the Beam: *"I'd say you just have a better perception of everything when you're a person where there comes like what you see what you hear if you can make sense people behind or in front of you. But I guess with the Beam you're only really limited to what you can see in front of you depending on which direction your turn and then also what you can hear in general vicinity."* Similarly, P22 thought she can be aware of only what is in the front of the Beam. She mentioned things that could happen while she was not aware of them, like somebody's waiting for me, but she does not know. This could have been related to either limited field of vision or peripheral vision. Another reason could be not being able to tell where the voice is coming from and how close it is to the Beam's body. When co-located our hearing can detect spacial location of the sound, listening through the Beam does not help make such inferences.

In summary, participants reported limitations in perception that may affect the remote students' understanding, interactions with classmates, and classroom dynamics.

5.2 Expressive abilities limitations:

The expressive abilities involve all kind of movements enacted by a person to express themselves. For the telepresence robot these are limited to speaking and moving around in the remote space.

- Speech ability limitations: Some remote students struggled with being heard as either their audio was too loud or too quiet, they talked while their microphone was muted, or did not feel comfortable verbally attracting attention if the teacher failed to see they raised their hand to talk. 13 participants mentioned that they found it difficult to determine whether their audio volume was appropriate. P3 mentioned that he *"never figured out what's better, and how [he] could... make them hear [him] better."* Some participants mentioned that they recalled hearing the telepresence robot's volume when it was used by other students in their classroom and that it was louder than they expected, but others took note that they could not remember or gauge how it was that the robot sounded on their behalf. P2 tied knowing how loud the volume was to *"confidence"* he said *"there is no proper confidence while you're speaking because we don't know how the audio works... If we have confidence that the audio is good, we can speak properly."* This point is very important, as it suggests lack of confidence that volume was of an appropriate level discouraged a student from further interacting with their classmates. The issue of unnoticed raised hands on the Beam's screen highlights speech expression limitations, as reported by many participants. All of this suggests students struggled to express themselves verbally through the Beam, and while this could improve with practice the technology itself could be redesigned to support such interactions.

- Mobility limitations: Several students complained about the physical movement challenges such as getting stuck, not being able to rotate the Beam display alone or adjust its height, climb stairs and move faster.

Some participants expressed they could not move the Beam because they became "stuck", whereas for others fear of being stuck left them afraid to move. P12 described how the stem of the Beam snagged a chair even though the navigation camera looked all clear. Some of the students who got stuck were afraid of moving lest they get stuck again, e.g. P4 who described her hesitancy to move due to obstacles: *"I, honestly was not in a great spot... and I was like, Well, I* *gotta be in the front row, because I can't really see but I want to be behind the desk, just because I'm a student ... But I also didn't want to have to go ... I see all these chairs and obstacles galore."* If the way to what P4 thinks is the best position was clear, her receptive abilities would have improved as she will be able to see and hear the lecture better.

Students wanted to be able to rotate just the upper most display or to adjust the height of the Beam to face the speakers without moving the whole Beam's body. E.g. P1 said: *"it was kind of annoying having to turn the entire robot and I just want to turn my head..."* Many students wanted to face the speakers during Q&A time to hear them better but were afraid they would get stuck as they will have to turn the whole body of the Beam.

In addition, six students pointed to the stairs as a limitation to classroom accessibility. P5 did not like to be carried and expressed a preference for disabled access ramps and P3 thinks: *"that's when you feel a little like handicapped [person] with [regards to] movement."* Reliance on others to navigate stairs, according to P16: *"takes away of accessibility and is a challenge."*. Other students also mentioned the speed of the beam that is slower than the human speed.

5.3 Are telepresence robots "disabled"?

Although most literature highlights the accessibility advantages of telepresence, we will primarily focus on its accessibility limitations. Our findings reveal how class members implemented strategies to overcome the Beam's constraints. We will examine these strategies and discuss theoretically about whether robots can be considered "disabled."

- Strategies by the Beam operators: Participants mentioned mitigation strategies to their vision and auditory limitations. Some students moved to go closer to the front (P13, P19, P22, P4), however, others stayed where they were (P2, P20, P7) lest they distract their classmates or get stuck. The fact that the Beam operators were able to somewhat alleviate some of the limitations signifies that the telepresence robot is not disabled but differently-abled. This follows Rode [21]'s framing that "conscious trade-offs between the affordances of my corporeal body and an emergent cyborg-self" (p239).

- Classmates helping the Beam operators: In many instances classmates volunteered to help the remote students. In few instances the needed help was not received, which made the operators' task a little harder as they needed to figure out other ways to circumvent the limitations. P3 mentioned requesting a teammate to read a piece of paper as he could not read it himself for an activity, which helped them complete the task.

In few instances, the requested help was not obtained. Beam operators often need help to pick things up from their way. P4 told a story about a classmate not helping her removing a cord from the floor so she can move to a place: *"When I was trying to go to my seat, there was a charger cord. And I didn't know if I could go over it. And I was trying to talk to the guy who was sitting there. That's when I realized I was on mute. So he had no idea what I was saying."* Our video of the incident shows that P4's classmate looked up, and saw his charging cord on her way but went back to his task without moving it. P4 considered that *"a rude thing... he clearly knew what my issue was and was just kind of looking at me."* While P4 could have gotten where she wanted to be by knocking the laptop off the table, her alliance to the social contract resulted in her going the long way around to protect her classmate's laptop. However, help is not always solicited. Others help more than needed because they are unaware of the robot's features.

6 CONCLUSION AND FUTURE WORK

Our research found that telepresence robots have limitations, and users can manage for a new kind of differently-abled robot-mediated interaction. We argue telepresence robots and their users are differently-abled, and that many of the steps that would make education inclusive to telepresence robots would also improve accessibility for a host of students with disabilities and ESL. This is a significant opportunity to ensure educational equity, but requires future work to enumerate use and design recommendation which we will pursue after conducting interviews with classmates. Future work also includes conducting the study with disabled students to examine to what extent it made the classroom accessible for them. Telepresence is a promising new educational tool, but these challenges must be met lest it be used as a new means of marginalizing and disabling students.

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