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The Potential of Telepresence in Libraries: Students' Perspectives

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Abstract: The paper presents a study of library and information science students' perceptions and experiences related to the use of telepresence robots (TPRs) in libraries, with a specific focus on students assuming the role of library consultants. The study explores the innovative application of TPRs, such as Double, Ohmni and Temi, within library settings. The findings of the research reveal a positive perception of TPRs, emphasising their potential for fostering innovation, increasing engagement, providing flexibility and overcoming geographical constraints. The study also identifies distinct advantages of TPRs, including remote accessibility, enhanced communication, flexibility, a personalised user experience and cost savings. However, concurrent challenges, such as limitations in nonverbal communication, pointing accuracy, connectivity issues, space requirements, costs, safety, security concerns and varying levels of user acceptance emerge as crucial areas for refinement. While the results may not be generalisable due to the limited sample size, the study underscores the transformative potential of TPRs in libraries and the necessity of addressing these challenges to optimise their application. Further research, technological advancements and user feedback can help refine and optimise the use of TPRs in libraries to provide innovative and accessible assistance.

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1 Introduction

Throughout history, libraries have traditionally served as physical spaces that grant people access to knowledge, fostering diverse educational and social pursuits and safeguarding the collective wisdom and cultural heritage of humanity for the benefit of future generations (Virkus and Metsar 2004; White 2012). However, with the rapid advancements in technology and the growing demand for remote access to information and services, libraries are faced with the challenge of providing inclusive services that cater to users beyond their physical boundaries. In this regard, telepresence offers a solution for libraries.

The term "telepresence", first introduced by Marvin Minsky in 1980, pertains to the use of multimedia components, including sound, vision and touch, to reproduce the sensation of being physically present in a distant location (Shen and Shirmohammadi 2006). The deployment of telepresence relies on various technologies, notably videoconferencing software applications such as Zoom, Teams, Skype and Webex (Gillies 2008; Lawson et al. 2010; Suduc and Bizoi 2022). Furthermore, the integration of virtual reality (VR) and augmented reality (AR) technologies enhances telepresence by immersing users in interactive virtual environments (Cipresso et al. 2018). Holographic telepresence takes this concept further, projecting three-dimensional representations and effectively creating the illusion of physical coexistence (Ramirez-Lopez et al. 2021). Additionally, wearable devices like smart glasses, headsets or accessories with built-in cameras, microphones and displays enhance telepresence by elevating the user's sensory experience and enabling remote interaction (Nasiopoulos et al. 2015).

Moreover, telepresence robots (TPRs), characterised as mobile wheeled devices manipulated from a distance, come equipped with a range of interactive functionalities, including cameras, speakers, microphones, screens and sensor-assisted motion control, all of which enhance seamless communication and support collaboration from remote locations] (Kristoffersson, Coradeschi, and Loutfi 2013; Tuli, Terefe, and Rashid 2021; Vaughn, Shaw, and Molloy 2015; Virkus et al. 2023). TPRs empower the human operator not only to perceive, listen and interact through the technology but also to navigate and investigate the surroundings of the remote location (Boudouraki et al. 2022; Decker 2015; Winterstein et al. 2021). Typically, a TPR comprises a video conferencing system affixed to a remotely operated mobile base, with the operator managing its movements through a computer, tablet or smartphone interface while engaging with individuals who are physically co-present with the TPR. Consequently, the user experiences a level of physical autonomy and embodiment that distinguishes TPRs from conventional videoconferencing systems (Boudouraki et al. 2021).

Interest in TPRs has expanded across diverse domains, including healthcare, elderly assistance, office work, museums and education (Almeida, Menezes, and Dias 2022; Virkus et al. 2023). Moreover, TPRs find application in industrial contexts, undertaking tasks considered perilous for humans (Hernandez, Waechter, and Bullinger 2021; Johansson and De Vin 2009; Trevelyan, Hamel, and Kang 2016), while experimental applications like geocaching and collaborative shopping reveal additional promising possibilities (Björnfot 2022; Heshmat et al. 2018). The growing appeal of TPRs can be attributed to their potential for cost and time savings, alongside their capacity to enhance communication, social presence, equity and accessibility (Davey 2021; Lei et al. 2022). By eliminating geographical barriers, TPRs enable remote participation, benefiting those with chronic illnesses, limited mobility, hospitalisation or disabilities, thus introducing novel solutions for remote communication and collaboration (Vaughn, Shaw, and Molloy 2015; Zhang 2021).

However, TPRs have limitations, including slow and cumbersome movement, challenging navigation, inability to handle stairs or doors and reliance on a stable network connection. These devices lack audio feedback and complicating conversational engagement, while their limited sensing capabilities impede situational awareness, often necessitating local assistance (Boudouraki et al. 2021; Lee and Takayama 2011).

Despite their advantages, TPRs remain a novelty, primarily embraced by early adopters (Reis et al. 2019). Mainstream adoption in professional settings lags behind videoconferencing, largely due to perceived limitations in usefulness (Lei et al. 2022). Successful adoption requires public familiarity with TPRs, understanding of their functions and a willingness to interact with and assist them as needed (Boudouraki, Fischer, and Reeves 2020).

TPRs offer libraries a myriad of perspectives, however, this topic remains largely unexplored in the scientific literature. Searches of the Web of Science and Scopus databases yielded only five publications addressing the use of TPRs in a library context, with Guth and Vander Meer (2017) providing some early cases of academic libraries adopting TPRs.

One of the earliest examples is from Baylor University in 2012, which used the VGo TPR to allow Texas K-12 students to tour the library (Logan, Orr, and Holgersson 2012). Elsewhere, the University of Texas – Arlington Central Library hosted a robot petting zoo in 2015, where distance users were also able to meet people and explore the library through TPR (Martin 2015). A third example was the Grand Valley State University's library, which gave students and faculty a chance to experiment with Double TPRs and evaluate their educational potential (Raths 2015). Decker (2015) describes several advantages of incorporating TPRs into an academic library to improve library operations, including staffing and security, virtual reference and distance learning services and public relations. She discusses using VGo TPR at the Atlanta University Center as a mobile library tour guide and ambassador for library visitors, a teleconferencing device for virtual reference and distance education students and a robot for students to experiment with. Elsewhere, a study conducted at the King Library on the Oxford, Ohio campus of Miami University implemented the Double TPR to investigate its effectiveness in providing remote services, which revealed librarians' positive view of TPRs but recommended the traveling librarian model for more effective task management (Guth and Vander Meer 2017; Hartsell-Gundy, Johnson, and Kromer 2015). Guth and Vander Meer (2017) also described a collaboration between the Western Michigan University Library and the Western Michigan University Communication and Social Robotics Lab to introduce TPRs in high-traffic settings by students around 2015.

While many examples are from the United States, De Sarkar (2023) highlights Chulalongkorn University in Thailand's adoption of a TPR for user engagement, concluding that TPRs effectively facilitate communication, enabling subject librarians to guide researchers in proper search procedures and resource identification. Elsewhere, Nguyen et al. (2022) demonstrated TPR use at Eastern International University in Vietnam, where a guide robot assisted students with various inquiries, from COVID-19 updates to book searches and freshman quizzes. While one article (Tella and Ogbonna 2023) provides an extensive account of TPR applications in libraries, the majority of its references appear to lack authenticity, with the cited case studies lacking verifiable evidence. Consequently, the materials cited in that article have not been utilised in this paper.

This study examines the utilisation of TPRs in libraries, focusing on the perspectives of library and information science (LIS) students. The study is guided by the following research questions: (1) What are students' perceptions about TPRs?; and (2) How could TPRs be used in libraries from the point of view of LIS students?

The structure of this paper is organised as follows: after an introduction to the topic, the following section provides the theoretical background which underpins the study, with the third section describing the research methodology and the fourth section presenting the findings. Finally, the fifth section presents discussions, conclusions and suggestions for future research.

2 Theoretical Background

Telepresence intersects with several areas of research including computer-mediated communication (CMC) and human-computer interaction (HCI). While CMC research has focused on the differences between interpersonal and mediated communication – how computing tools afford and influence social interactions and how CMC differs from face-to-face interactions – research in the HCI field also examines the psychological similarities between interaction with humans and with media (Sundar et al. 2015; Xu and Liao 2018). In addition, with the rapid proliferation of diverse computer technologies, including mobile phones, tablets and robots, the scope of CMC and HCI research has expanded significantly beyond traditional computers. The term "computer" now encompasses a broader, more inclusive concept, encompassing all digital devices that facilitate connectivity between individuals in different locations (Xu and Liao 2018; Zhao 2006). HCI plays a pivotal role in ensuring machines' usability, like robotic systems, and the success and effectiveness in targeting end-users (Gulliksen 2017; Søgaard Neilsen and Wilson 2019). By analysing the dynamic relationship between humans and digital devices, HCI researchers aim to develop technology that seamlessly integrates with human capabilities, enhances user experience and effectively caters to user needs. This holistic approach recognises that successful interactive systems must not only be functional but also user-friendly, taking into account the various human factors during their design and development process (Edmonds 2014). By placing users at the forefront of design and development processes, HCI ensures that technology aligns with their goals, preferences and expectations (Xu 2019).

Today, the rapid diffusion of cutting-edge media technologies, such as chatbots, TPRs, voice agents and virtual and augmented reality technologies, are blurring the traditional boundaries between CMC and HCI. The integration of CMC and HCI thus becomes essential in explaining users' social responses to TPRs which allow users to simultaneously interact with physical bodies and communicate with distant partners (Xu and Liao 2018). By facilitating seamless interactions with digital social actors and through computer systems, these innovative technologies are reshaping the way users engage in the digital realm and fostering the emergence of new theories; the notion of Cyborg coupling thus goes beyond mere integration of cutting-edge technologies with our physical bodies, transcending the boundaries between technology and our minds (Biocca 1997; Haraway 1985). This transformative synergy has the power to fundamentally reshape and redefine our understanding of CMC and HCI (Xu and Liao 2018), with robotic telepresence thus becoming an important research topic in HCI (Beer and Takayama 2011; Björnfot 2022; Herring et al. 2016; Rae, Mutlu, and Takayama 2014; Tsui and Yanco 2013).

Human-robot interaction (HRI) is another area that focuses on interactions between humans and robots (Zhang 2021), aiming to understand, design and evaluate robotic systems for human use (Goodrich and Schultz 2008). Key focus areas include human perception and seamless integration of robots into human environments (Bartneck and Moltchanova 2020; Henschel, Hortensius, and Cross 2020), and telepresence can thus be used as a tool for HRI by allowing users to remotely control robots and interact with their environment in real-time (Tuli, Terefe, and Rashid 2021). Boudouraki, Fischer, and Reeves (2020) note that from the perspective of a bystander the TPR might look like a social robot or other electronic equipment, however, a TPR is more accurately conceived of as the robotic extension of a real person. It has been found that local users are at times confused about whether to treat a TPR as a person or as an object, for example with regards to touching and personal space (Boudouraki, Fischer, and Reeves 2020; Lee and Takayama 2011). Considering that these behaviours are intricately tied to users' mental models of TPRs – what they are and how they should be utilised – it becomes evident that these mental models exhibit variations among individuals and across different situations (Boudouraki, Fischer, and Reeves 2020).

Widespread acceptance of TPRs is crucial for seamless integration into library services. The successful implementation of new technology is closely linked to social and human factors, explored through technology acceptance models (Davis, Bagozzi, and Warshaw 1989; Savela, Turja, and Oksanen 2017; Venkatesh and Davis 2000), with notable models including the technology acceptance model (TAM), unified theory of acceptance and use of technology (UTAUT) and innovation diffusion theory (Davis, Bagozzi, and

Warshaw 1989; Malhotra and Galletta 1999; Venkatesh et al. 2003; Rogers 1995). Social cognitive theory by Albert Bandura (1986) explains how technology use intentions, often integrated with usability theories. These models address user concerns, aiding successful technology implementation (Kasuk and Virkus 2023).

Developed by Davis in 1989, TAM is a widely recognised framework explaining users' acceptance and adoption of new technologies. Rooted in the theory of reasoned action (Fishbein and Ajzen 1975), TAM focuses on specific beliefs about technology use shaping behavioral intentions and serves as a pivotal tool for predicting user behavior, offering a theoretical framework for successful technology implementation (Davis, Bagozzi, and Warshaw 1989; Marikyan and Papagiannidis 2023). Davis, Bagozzi, and Warshaw (1989) identified perceived usefulness and perceived ease of use as fundamental determinants of user acceptance, reflecting beliefs in how technology enhances performance and the perceived effortlessness of use, respectively; TAM, in turn, suggests that the trade-off between these factors influences technology usage decisions (Davis 1993; Davis, Bagozzi, and Warshaw 1989; Marikyan and Papagiannidis 2023). The perceived usefulness and acceptance of TPRs have been studied with various groups, including faculty and students (Herring 2013; Lei et al. 2022; Wernbacher et al. 2022), healthcare professionals (Turja et al. 2020), older adults (Mascret and Temprado 2023; Wu et al. 2017) and pre-service teachers (Han and Conti 2020).

Several studies have also shown that the acceptance of TPRs may be low due to their poor ease of use (Berisha, Kölle, and Griesbaum 2015; Hartsell-Gundy, Johnson, and Kromer 2015; Herring 2013; Lei et al. 2022; Park 2013; Wu et al. 2017). Although the TAM framework shows that perceived ease of use is a positive predictor of use intention, the empirical results vary (Turja et al. 2020; Lei et al. 2022). However, TAM is a theoretical framework that helps to explain and predict individuals' acceptance and usage of technology. Although it is primarily a quantitative model, its underlying concepts and constructs can be adapted for qualitative studies to investigate the utilisation of TPRs.

In summary, the integration of insights from the fields of CMC, HCI, HRI and TAM informed the study's design, contributing to a holistic understanding of the dynamics, challenges and factors that shape the acceptance and effectiveness of library consultants utilising TPRs.

3 Methodology

This study investigated LIS students' perceptions of TPRs and their use in libraries. Three models of TPRs were used in the pilot: Ohmni by OhmniLabs, Double 3 by Double Robotics and Temi by temi USA inc.

These TPRs have a lot in common: they all have a wheeled base with a heavy battery section, a screen on top of the robot for video communication, Wi-Fi and Bluetooth connectivity and are equipped with microphones, speakers and cameras that facilitate two-way communication. TPRs allow users to remotely control their movements and interact with their surroundings using a computer, tablet or smartphone.

Double 3 has two 13 Megapixel cameras (wide angle and superzoom lenses) that can tilt upward and downward to adapt to different scenarios, such as perusing documents on a desk or zooming in on specific points of interest. Of these models, the Double 3 has the shortest battery life; according to the specification it can last up to four hours on a single charge, with a two-hour recharge time. This TPR has a built-in obstacle avoidance technology displaying navigational guidelines in the form of floor markings to aid the driver in guiding the TPR along secure paths; the driver can click anywhere on the floor and the TPR will go there, avoiding obstacles along the way. It is also the only TPR that can adjust its height, with a range from 120 to 152 cm. Moreover, the Double 3 TPR offers the capability of accommodating multiple individuals within a single robotic unit; while only one person assumes a leading role, appearing prominently on the TPR's display, others can also participate and engage through this technology (Double Robotics 2023; Nichols 2022).

Ohmni TPR has a single camera for communication: a 13 Megapixel module with 4K resolution that offers digital zoom. The camera is fixed firmly on top of the screen, but the screen itself can tilt vertically, allowing the operator to look up and down. Ohmni has a height of 142 cm, with its batteries lasting up to four to five hours in a call and around eight to ten hours on standby (OhmniLabs 2023). Ohmni is also the only robot to offer user-controlled variable speed and can go as fast as 3.5 km/h.

Temi TPR is the smallest of three robots used in the pilot, with its height 100 cm (Temi 2023), and it has the most sophisticated set of sensors, including LIDAR with 360 degrees reach, two built-in depth cameras and five proximity sensors. Temi can create a map of the surroundings and navigate independently between user-created reference points.

The cost of TPRs varies greatly and is often divided into several parts, such as the robot itself, software license, cloud environment, technical support, etc. In addition, the manufacturers do not often specify the price on the company's website, instead providing a contact form for communication.

The study was conducted in November 2022 as part of the elective course "Library Didactics" of the bachelor of LIS curriculum at Tallinn University. The research comprised four LIS students, consisting of two females and two males, all in their third year pursuing bachelor's degrees in LIS, with their ages ranging from 21 to 40. In addition, the pilot involved one physically present adult library visitor and two adult library visitors remotely connected via Ohmni and Temi TPRs.

A pilot deployment of TPRs took place at the TalTech faculty library over a three-hour period. Initially, students received a concise 15-minute introduction to TPRs and their functionalities. Subsequently, they had the opportunity to hone their skills in operating TPRs, before then taking on the role of library consultants using two Double 3 TPRs. TPRs provided an opportunity to navigate the library space, interact with physical objects and provide two-way communication experience between TPR-mediated student library consultants, a physically present visitor and two TPR-mediated library visitors. All three library visitors, who performed tasks such as searching and finding resources in the library, were advised by student library consultants who served visitors through TPRs. During the pilot phase, the researchers refrained from engaging with the participants.

Beyond the pilot, qualitative methods, including student essays and a 90-minute focus group interviews, were employed. After the pilot, students wrote essays on TPR applications in memory institutions, complemented by insights gathered from the focus group session.

The four students participating in the pilot took part in a focus group interview conducted by one of the researchers in the research group, which investigated participants' perceptions of TPRs through ten probing questions. The inquiry covered their overall perspectives on TPRs, including advantages, limitations, opportunities and challenges, while participants were also prompted to share insights into potential applications of TPRs within the GLAM sector, emphasising opportunities, limitations, challenges and contextual benefits. The focus group interview was conducted via Zoom, recorded and transcribed for analysis. This rich qualitative dataset about participants' experiences and perceptions of TPRs proved invaluable in exploring and understanding various aspects of using TPRs in libraries.

The study's data analysis phase employed a combination of robust qualitative techniques, including thematic analysis and content analysis, to examine the qualitative data collected via student essays and a focus group interview. Through this process, key themes, patterns and relationships within the data were identified, facilitating an understanding of the advantages, limitations and challenges pertaining to the implementation of TPRs in libraries.

The researchers drew on the conceptualisations of CMC, HCI, HRI domain and the TAM model to design the study, comprehend the data and derive insights into the benefits and challenges associated with this innovative approach to library services. The study involved investigating users' perceptions, attitudes and interactions with TPRs, analysing aspects such as acceptance of TPRs, ease of use, their comfort levels, satisfaction, learning curve, challenges encountered and perceived usefulness of TPRs in enhancing the efficiency of library services. Understanding the user experience can help identify areas for improvement and optimise the design and implementation of TPRs in the library context.

4 Results

In this section, the answers to the research questions are presented in two main themes: (1) Students' perceptions of TPRs; and (2) Potential of TPRs for libraries from the students' point of view.

4.1 Students' Perceptions of Telepresence Robots

Three students rated their TPR-related skills as novice, while one student considered theirs advanced. Additionally, three students had no prior TPR experience while one had previous experience with robots. For example, one student said: "It was a first-hand experience for me, but I've seen photos and videos of telepresence robots." Another student noted: "As I work in Starship Technologies, I was familiar with driving robots like that. But interaction aspect was new to me. But I thoroughly enjoyed it and thought it's a fantastic invention." Starship Technologies is a company that produces autonomous delivery robots designed to make food and package deliveries more efficient (Starship 2023).

4.1.1 Perception of Telepresence Robots

The students' general perception of TPRs was positive. One student found the experience with TPRs to be impressive, exciting and interactive, describing it as "very cool", despite the TPR being smaller in size than expected. She found the ability to remotely control and interact with the environment and other participants to be engaging. Another student found it enjoyable, while a third found it innovative and interesting. One participant also highlighted the novelty of the social situation they encountered when using TPRs. All students saw TPRs as a unique and thrilling opportunity, finding the experience of conversations with individuals mediated by different types of TPRs to be enriching. They expressed their experience of using TPRs as remarkable, exhilarating, uncommon, enriching, enjoyable as well as significant and practical, and also highlighted how they gained new insights and knowledge about TPRs. According to their feedback, TPRs would be excellent tools in many fields.

Here are a few illustrative responses that exemplify their reactions. One student remarked: “I had an incredibly thrilling experience using TPRs. It was a joy to navigate the room and engage with library visitors.” Another student enthusiastically expressed, “Telepresence robots offer the freedom to access any location, no matter where you are. They provide a remarkable level of flexibility and convenience.” A third student added: “Compared to the usual Zoom and Teams, it is much more efficient, you can move to the interlocutors and see the remote environment as you wish and more spatially.” However, one student noted: “I think it would need more development towards driving around and moving without human help. But as a robot in general I think it has a lot to offer in the years to come.”

All participants perceived TPRs as tools that enhanced communication and interaction possibilities. In addition, they often referred to the technology simply as a “robot” rather than a “telepresence robot”. Focusing on the differences between human and TPR-mediated communication, the students found that while TPR-mediated communication can provide visual and auditory representation, it still lacks all the human physical cues and nonverbal communication that occurs during in-person communication, such as body language and gestures, and can lead to misunderstandings or misinterpretations during communication. Technical glitches, delays or malfunctions can disrupt communication and cause frustration that is less likely to occur in face-to-face interactions, while TPRs also have limitations in navigating certain physical spaces, which can hinder the natural flow of communication. However, students still found that there are psychological similarities between interactions with humans and TPR-mediated interactions that stem from shared elements of social interaction, communication and emotional connection; although the medium of interaction may differ, basic principles of human psychology still play a role in shaping the nature of these interactions.

In sum, the use of TPRs offered a number of benefits, including novelty and excitement, enhanced communication and promising future applications. The experience was clearly considered unique, leading to speculation that its utility may become even more pronounced in the future, with all students reporting a growing interest in learning more about TPRs after using them. There were no significant differences found in participants’ perceptions of TPRs, based on their gender, although the sample was too small to make such generalisations.

4.1.2 Perceived Usefulness

All the students understood the potential of TPRs and found that they offer many opportunities in different sectors of society, including the GLAM sector (galleries, libraries, archives and museums), particularly in enhancing customer support experiences. Students noted that TPRs offer various opportunities for remote customer consultations, meetings, conferences or seminars, facilitating effective communication and engagement, enhancing interaction quality and providing a personalised experience where visual presence and mobility are important.

Participants found that TPRs enable remote work and learning, creating an immersive experience of connection and presence in remote locations that video conferencing tools often lack. One student said: “They add mobility and adaptability to traditional video conferencing tools like Zoom and MS Teams.” Another student added: “With Zoom and Team, you only see the surroundings that the host wants you to see, but with the telepresence robot you can direct your focus and see what interests you at the moment.” A third student noted that the TPR allows the user to zoom in on specific items and explore them closely without the need to physically approach the object.

It was also found that instead of having to physically travel to another location, individuals with busy schedules can use TPRs to attend meetings, workshops and other events, which saves travel costs and time, allowing people to be more productive. A student noted: “Instead of wasting time waiting at airports and waiting for luggage and dealing with jet lag, telepresence robots allow you to save a lot of time and organise your work more productively.”

Participants also mentioned that TPRs allow people with mobility impairments or disabilities to interact with others in ways that might otherwise have been difficult, such as participating in studies and events, experiencing new places and socialising remotely. Some participants also emphasised that the opportunities of TPRs are more social in nature, allowing individuals to have more human contact and connection, particularly during extended periods of illness or other restrictions, and thus providing a way to alleviate feelings of isolation and enhance social interactions beyond regular phone calls. One student said: “I feel like the opportunities of telepresence robots are more social than practical, at least for now. For example, telepresence robots would be great during long stretches of illness or other restrictions when a person is not able to visit the facility and is craving for more human contact than a regular phone call.”

Participants noted that TPRs offer flexibility and independence as they can be controlled from any distance and are able to move around the physical environment independently. Although some situations such as riding the elevator, going up and down stairs, and charging the battery required assistance, the freedom to navigate on their own was seen as valuable. Participants also found that displaying a human face on the TPR's screen contributed to a more immediate and engaging interaction. One student said: "Having a human face on it makes it more real. I loved seeing the facial expressions of my conversation partners. It made the person more alive when compared to a robot that has just a speaker and a microphone."

Participants also recognised that although TPRs already existed before the pandemic, their usefulness became apparent especially during the conditions of the pandemic.

Overall, the students found that TPRs offer a wide range of opportunities, especially in terms of customer support in the GLAM sector. They were praised for enabling remote consulting, meetings and conferences that increased communication and personalisation, especially in visual and mobile contexts. The students found that TPRs enable remote work and learning, creating connection and immersion beyond standard video calls, saving save time and cost for events and helping people with mobility issues. Although the TPRs are promising technologies, the students acknowledged that some technical and usability improvements are needed. However, in general, TPRs increase a sense of presence and social interaction.

4.1.3 Ease of Use

The general consensus among the participants was that the TPR was easy to use. One participant praised the TPR as "extremely user-friendly," and indicated that the design and interface of the TPR were easy to interact with. Another student found that although they initially experienced a slight learning curve in understanding the navigation features, they quickly got used to the system; in addition, they emphasised the remarkable ease with which they could manipulate the TPR through the web-based interface, noting: "This web-based interface facilitated seamless remote navigation and engagement without the need for detailed instructions." Nevertheless, another participant noted that achieving skilled navigation with the TPR in a remote setting may require a certain level of practice to master the complexities of their remote navigation.

4.1.4 Challenges of Telepresence Robots

Students identified several challenges and weaknesses related to TPRs, such as limitations in pointing, safety concerns, connectivity issues, space requirements, costs and security risks.

One notable weakness highlighted was the difficulty in pointing to objects. Students suggested that incorporating a laser or some other means of indicating specific objects could enhance the user experience. For example, one student said: "One of the things that stood out to me was not having the ability to point at things. [It] could be fixed using a laser, for example."

Safety concerns regarding physical accidents or intentional misuse were also mentioned, and that TPRs were prone to physical instability. Students expressed concerns about the TPR falling down or encountering mechanical issues, or someone intentionally misusing it to drive into someone or something, all of which could pose challenges, especially if there was no on-site mechanic available for immediate assistance. For example, one student said: "Again I would think it's movability and when it falls down or won't work, then it might be difficult to fix if you don't have a mechanic on the spot." Another student mentioned: "[The] threat would be if it would fall on someone or if someone would misuse it and drive into someone or something on purpose." To mitigate these risks, participants suggested implementing automatic safety measures to prevent accidents and unauthorised use.

Connectivity issues were another weakness, with poor or unreliable internet connectivity causing communication disruptions and impacting the overall experience. One participant faced major connection problems despite having a fast and reliable internet connection, and attributed these issues to potential software compatibility problems. She said: "I had major connection problems even though my connection is fast and reliable. Everything seemed to work fine for my peers for the most part, so it was probably just a software compatibility problem that needs to be worked on." The students also found that the quality of video and audio transmission can be affected by a poor network connection.

Students also noted that the use of TPRs requires a conducive spatial environment, so that the TPRs have enough space to move and do not disturb the normal working environment with their movement. They expressed concern that TPRs may not be suitable for all environments; they can encounter difficulties navigating through narrow spaces and cannot manage climbing stairs, opening doors or getting in and out of elevators on their own. The battery life of TPRs, which is limited, can also be a problem, requiring frequent charging. One student reasoned, "Telepresence robots also need rooms with enough plugs to charge the robots and to be in places where the robots can easily access them." Participants also expressed the importance of a sense of space while operating the TPRs. Moving around floors and between different areas within a facility was noted as a challenge, and participants emphasised that modern architecture should be designed to better accommodate the smooth movement of TPRs. For example, one student mentioned: “The challenge was in moving around the floor and between floors. Modern architecture has to come along to facilitate them better.”

Students also thought that TPRs are currently still quite expensive and may hinder personal or organisational use. One student said: “The cost of telepresence robots can be high, making them inaccessible to some users.” Another student expressed doubt: “I don’t think many organisations, especially libraries, may be able to afford them at the current price.”

In addition, one student expressed concerns about the size of one of the TPRs, specifically the Temi TPR, which she described as smaller and more compact than the others. This smaller size made her feel like she was interacting with a child, possibly leading to a perception of the robot being in a less favourable position compared to the larger TPRs. She said: “I was very comfortable using it myself but as one robot was smaller than others, it made me feel that this was in a slightly worse position than others, being smaller and more compact. Like interacting with a child.”

Participants also acknowledged that TPRs, like any other connected device, could pose security risks. They expressed concerns about the potential for hacking, which could result in unauthorised access to the TPR’s functions and potentially compromise the privacy and security of the facility. One student said: “Perhaps security risks: practically everything is hackable and so are telepresence robots which could be used to snoop around the facility.”

While the two students in each Double TPR changed their roles during the experiment, there was an awkwardness in communication when someone else was controlling the robot. The participants also noticed that the image quality suffered when someone else was driving the robot and there was not the freedom to see the objects that the passenger would have liked. Another challenge mentioned was the inconvenience of starting a conversation while someone else was controlling the robot, with the students finding it strange to start talking when they knew that the face of the person controlling the robot was displayed on the screen and not that of the speaker. One student said: “Also, the picture quality was low when someone else was controlling the robot, but the sound was really clear and understandable. Also, it felt weird to start talking when someone else was controlling the robot and I knew their face was on the screen.” Another uncomfortable aspect was that while the Double robot can accommodate four more passengers in addition to the operator, the students felt that those physically present may feel uncomfortable if they do not know how many passengers there are and who else is in the TPR besides the robot operator.

Students also expressed concern that because TPRs are not yet widely used, they may be treated as physical objects rather than the people they mediate and not be involved in social interactions to the same extent as physically present people. One student emphasised that despite all the advantages, TPR-mediated communication is still not as smooth as human-to-human communication; for example, in situations where both TPRs and people are present in a room, people usually prefer to communicate with an actual person who is physically present.

These insights shed light on some aspects that require improvement to enhance the functionality and user experience with TPRs.

4.2 Potential of Telepresence Robots for Libraries

The participants found that with the help of TPRs, library consultants could successfully serve library visitors who are physically or virtually present, with it possible to guide them in the search for library resources and advise them in the search for necessary information. Students believed that there are several potential benefits of using TPRs in libraries, providing innovative solutions and enhancing user experiences. The participants unanimously found TPRs to be highly valuable when utilised as extensions of librarians’ roles.

According to student feedback, the utilisation of TPRs can lead to an enhancement in the accessibility, flexibility, efficiency and productivity of library services, with these benefits encompassing the facilitation of remote access, cost-effectiveness, heightened social presence and increased user engagement. The students highlighted several specific areas where TPRs prove exceptionally advantageous, including virtual library tours, remote access to library resources, virtual reference assistance, interactive author talks and virtual events, remote book clubs and other events. For example, one student said: “The virtual library tours allow users to explore library spaces, facilities, and resources virtually, providing a glimpse of what the library has to offer, without being physically there.” Another student added: “They can virtually navigate the library stacks, explore physical resources with the help of the telepresence robot’s camera and mobility functions.” A third noted: “Telepresence robots can also enable remote participation of book authors, regardless of their physical location, and allow them to engage with the library users in real-time,” and “Through robots libraries can bring in guest lectures, book authors, community leaders and many other prominent experts."

Additionally, TPRs can provide remote access to special collections, offering inclusive services, supporting distance learners, providing remote assistance for research and study, assisting in database searches and locating factual information, articles and books, among other pertinent library-related inquiries. For example, one student said: "Students can seek remotely research assistance, ask questions, and get personalised recommendations from librarians." Another student added: "Libraries can use telepresence robots to extend their services to distance learners. Students attending remote courses or studying from other locations can virtually visit the library and participate in group study sessions through telepresence robots." Students also found the use of TPRs in libraries to be particularly useful during the pandemic.

Thus, by using TPRs, libraries can extend their reach, increase accessibility and provide services to individuals who are unable to physically visit the library due to geographical, physical or other constraints. For example, one student said: "This is very valuable for students studying abroad or individuals with mobility limitations." Another student added: "Telepresence robots allow people in remote or underserved areas to access the library's resources without having to travel to the physical location."

TPRs also provide a solution for library staff who must operate across multiple locations. By leveraging TPRs, libraries can overcome geographical constraints, providing essential support and assistance to patrons in various branches. For example, one student said: "I think that with the help of telepresence robots, one librarian can even serve several library locations, especially in such small locations where there are few library visitors." Students also found that TPRs can be a cost-effective way to extend library services to remote or underserved areas. One student also thought that the implementation of TPRs in the library would allow for cost efficiency, whereby LIS students could act as consultants through TPRs in addition to their academic duties, reducing the need for additional labour resources.

TPRs can also be used for libraries' rare or delicate collections that require special handling. TPRs can provide controlled access to these materials, allowing users to view and study unique items while minimising the risk of damage.

While TPRs can offer many advantages in libraries, they also pose limitations or challenges as discussed in Section 4.1.5. These challenges include dependency on stable internet connection and infrastructure, network disruptions affecting communication, restricted access due to poor connectivity, high costs for purchase and upkeep, adaptation time for consultants and visitors, potential resistance to technology and the hurdle of convincing users about TPRs' advantages and addressing impersonal concerns.

Thus, implementing TPRs in libraries opens up new possibilities for user engagement, accessibility and resource utilisation, making libraries more versatile and adaptive to the needs of their communities.

5 Discussions and Conclusions

This study explored the perceptions and experiences of four third-year LIS bachelor's students regarding the use of TPRs. The study examined their perceptions and TPRs' perceived usefulness, ease of use, challenges and limitations, as well as the potential of using TPRs in libraries.

5.1 Students' Perceptions of Telepresence Robots

The students' general perception of TPRs was positive, finding them to be exciting, innovative and engaging tools offering new opportunities for communication and interaction. This positive response reflects the novelty and unique nature of TPR-mediated interactions, which can create a sense of excitement and interest. Students used terms like "remarkable," "enriching" and "uncommon" to describe their interactions with TPRs, which suggests that TPRs have the potential to provide new perspectives and insights, allowing users to interact with others in ways they previously did not know. Students appreciated the flexibility and convenience offered by TPRs as well as the ability to remotely control the TPRs and interact with their surroundings and other participants. The ability to move around different locations was highlighted as a key advantage over traditional video conferencing platforms, which suggests that TPRs can provide a higher level of spatial interaction and presence, enhancing the sense of immersion and engagement. Despite some technical limitations, the students perceived TPRs as unique and practical tools.

However, students noted that TPR-mediated communication lacks certain human physical cues and nonverbal communication present during in-person interactions, such as body language and gestures, while technical glitches, delays or malfunctions were also mentioned as potential disruptors of communication. These observations emphasise the challenges that TPRs might face in fully replicating the richness of face-to-face communication, however, while the medium of interaction differed, students still found psychological similarities between human interaction and TPR-mediated interactions. This suggests that fundamental principles of human psychology continue to shape the nature of these interactions, regardless of the technological medium.

The students recognised the numerous benefits and opportunities that TPRs offer in various contexts, particularly in the GLAM sector. They identified applications for consulting services, remote meetings, conferences and workshops, with TPRs seen as enhancing communication and personalisation, particularly in scenarios where visual presence and mobility are crucial. Students also highlighted the potential benefits for remote working, learning and socialising, as well as improving accessibility for individuals with mobility impairments, and appreciated TPRs for their flexibility, independence and ability to offer a sense of immersion and connection beyond traditional video calls. The students' recognition of TPRs' benefits and opportunities in various professional, educational and social contexts, particularly in the GLAM sector, underscores the transformative potential of this technology, with the findings indicating that TPRs can address challenges related to communication, accessibility and engagement in remote settings, offering a range of capabilities that extend beyond traditional video communication methods.

The students highlighted a range of positive attributes of TPRs: user-friendliness, manageable learning curve, adaptability and remote navigation. These factors collectively contribute to a positive user experience, with this positive feedback speaking to the effectiveness of the TPR's design and interface. It is obvious that the TPR's controls were well thought out and intuitive and were likely crafted with user-friendliness in mind. The feedback suggests that the TPR's learning curve is manageable and that users can quickly adapt to its features.

However, the participants did identify several challenges concerning TPRs, which include various factors influencing TPR usability, safety, adoption and the overall user experience. Students noted limitations in pointing accuracy, connectivity, battery life, spatial requirements, cost, safety and security risks and limitations in social interaction compared to in-person communication, challenges which indicate areas where improvements can be made to enhance the user experience with TPRs. The suggestion of incorporating a laser or other means for object indication is a solution that could enhance user experience, while safety also emerged as a significant concern, encompassing both physical accidents and intentional misuse of TPRs. The instability of TPRs and the potential for them to fall or malfunction highlight the need for robust engineering solutions to ensure their reliable operation. Implementing automatic safety measures, as suggested by participants, can mitigate these risks and enhance user confidence in using TPRs.

TPRs need a favourable spatial environment for efficient movement to be enable to navigate in a narrow space, climb stairs and use an elevator, which are currently challenging for TPRs. The study showed that in order to use effectively TPRs, it is important to design environments that facilitate their movement in modern architecture, while it also suggested that addressing the cost factor could be crucial in expanding TPR accessibility and usability, making them more attainable for a wider range of users. Security emerged as a potential barrier to TPR adoption, with participants expressing concerns about the potential for hacking and unauthorized access; ensuring robust security measures are crucial to prevent privacy breaches and unauthorized control of TPRs, thereby fostering user trust. The participants highlighted that TPR-mediated communication may not fully replace face-to-face interactions, which suggests that TPRs should be positioned as tools to complement rather than replace in-person interactions.

In sum, the study suggests that TPRs have the potential to offer unique benefits, such as enhanced remote communication and personalisation, increased accessibility and improved engagement in professional settings. However, there are challenges that need to be addressed to optimise TPR functionality and user experience.

5.2 Potential of Telepresence Robots for Libraries

This study highlighted several valuable applications of TPRs in libraries that can enhance user experiences, accessibility, flexibility and efficiency of library services. TPRs were seen as extensions of librarians' roles, enabling them to provide remote assistance, virtual tours, author talks, virtual events and more, with these applications extending beyond physical limitations, offering virtual access to library resources, special collections and reference assistance. TPRs can support distance learners, assist in database searches, provide research help and enable group study sessions, which is especially relevant during the pandemic; by bridging geographical gaps, offering virtual experiences and personalised assistance, TPRs can bring remote users closer to library resources and reach to a broader audience. They can make services more accessible to those who cannot physically visit the library due to various constraints.

The use of TPRs in libraries provides multiple benefits. TPRs can allow virtual exploration of library spaces, enhancing engagement and accessibility, as well as facilitate interaction with librarians and experts regardless of physical location. TPRs provide a cost-effective solution for extending library services to underserved or remote areas, while also enabling librarians to serve multiple locations, leveraging their expertise across various branches. The study also suggests that TPRs can provide controlled access to rare or delicate collections, minimising the risk of damage while offering users the opportunity to study unique materials.

TPRs present distinct advantages in library settings compared to traditional online and videoconferencing tools. They offer heightened spatial awareness in a real-time, immersive perspective of the environment, thereby enabling users to navigate physical spaces with increased efficiency. The unique capabilities of TPRs facilitate the visualisation and interaction with objects, individuals and surroundings in a manner not achievable through traditional tools, which is particularly beneficial for site visits, facility inspections or social events in libraries. TPRs excel in facilitating direct interaction with the physical environment and individuals, offering a more immersive, interactive and accessible experience, making them valuable in scenarios where physical presence is crucial but challenging or costly.

The study also acknowledges the challenges associated with implementing TPRs in libraries, which include connectivity issues, cost considerations, technical limitations and user adaptation. TPRs require stable internet connections, which might limit their accessibility in areas with poor connectivity, while the financial investment required for purchasing and maintaining TPRs can be a barrier for libraries with limited budgets. Library staff and users may need time to adapt to using TPRs effectively, and there could also be resistance from some users who prefer traditional human interaction. However, despite such challenges, this technology contributes significantly to redefining the way users interact with library spaces, opening up new possibilities for remote engagement and exploration.

To conclude, the study underscores the beneficial influence of TPRs on library services. It posits that TPRs provide libraries with diverse advantages, encompassing expanded accessibility, enhanced user experiences and streamlined remote interactions. However, the study also acknowledges the challenges associated with implementation and underscores the imperative of surmounting these obstacles to fully realise the potential of TPRs in the library context.

However, this study offers insights into the perceptions of a small group of students about TPRs and the results are not generalisable. Nevertheless, the study sheds light on various aspects that may guide the further development and refinement of TPR technologies to better meet user needs and expectations. Suggestions for future research could include:

- Expanding study with a larger, diverse student population to gather varied perspectives on TPR use
- Broadening research to include library staff perspectives on integrating TPRs into library services
- Comparing the user satisfaction of TPRs with other remote communication technologies used in library settings
- Conducting security and privacy assessments of TPRs in libraries, addressing concerns about hacking, unauthorized access and privacy breaches raised by participants in the current study
- Conducting a cost-benefit analysis to assess the economic viability of TPR implementation in libraries
- Investigating the potential of TPRs to improve accessibility for the elderly and individuals with disabilities

These recommendations can guide future research, contributing to a more comprehensive understanding of the integration of TPRs in library settings.

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