Acceptability, Acceptance and Adoption of Telepresence Robots in Museums: The Museum Professionals' Perspectives

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ABSTRACT

Telepresence robots have the potential to change our experiences in galleries and museums, allowing for a range of hybrid interactions for visitors and museum professionals, improving accessibility, offering activities or information, and providing a range of practical use cases (e.g. the robots augmenting museum exhibits). We present the results of 3 qualitative studies conducted in the UK exploring the acceptability (1 - interviews with museum professionals with no previous exposure to telepresence), acceptance (2 – focus groups for initial exposure to telepresence robots), and adoption (3 – interviews with museum professionals with long-term exposure to robots) of telepresence robots in museums. Our results identified opportunities and barriers focusing on the unique perspective of museum professionals and showed how priorities of museums shift and change according to their exposure to different technologies. We proposed a set of practical guidelines for future telepresence robots in museums, including design implications, potential applications, and integration strategies.

CCS CONCEPTS

• **General and reference** → Design; • **Human-centered computing**; • **Social and professional topics** → *User characteristics*; • **Applied computing** → **Arts and humanities**;

KEYWORDS

telepresence robotics, museums and galleries, technology acceptance lifecycle

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1 INTRODUCTION

Telepresence robots offer vast potential to provide novel ways of interacting with the world around us. They also provide new means for people to access spaces and experiences they otherwise may not be able to. Telepresence robots have been shown to be impactful tools in domains such as healthcare, education, personal assistance, and industrial applications [73]. However, their integration into public spaces has stagnated in recent years, with potential adopters remaining unconvinced, unaware of, or uninterested in their prospective value. In an effort to further innovate and utilise telepresence robots, there has been a recent surge in interest in how

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they can be used in cultural spaces such as museums and galleries [12, 16, 53, 61].

The lull in uptake of telepresence robots indicates a parallel lack of drive from public and organisations to interact with these technologies in meaningful ways. Past research on telepresence robots in particular has demonstrated the need for a more holistic understanding of where, how, and for what purposes the robots are being used. For instance, deployments at academic conferences have shown that telepresence robots are more useful at smaller events with more controlled spaces [45], and an 'unsuccessful' rollout of telepresence robots in a global technology company showed that the people who inhabit the setting need to see value in the robots in order to accept them and adopt them in the long-term [10, 11].

As such, we, as designers, practitioners, developers, and implementers, must question what is *missing*, what could be *improved*, and what prospective users such as museum professionals actually *want* these technologies to do in order to improve acceptance rates [3]. Further still, we must understand how these desires change over time in order to ensure the correct support is available when needed.

As noted, we are utilising museum spaces to investigate opportunities for improved robotic uptake with a use case example of telepresence robots. Museums offer unique insights into the application of museum robots, for instance experiencing potentially higher footfall than other environments noted previously, often being located in old buildings, and being populated with fragile, valuable, or even irreplaceable artefacts. However, museums offer a valuable site for investigation as they also showcase transferable insights that may be highly relevant to other domains - they have extremely restricted funding and resources, they are publicly accessible, and they welcome a diverse range of actors, demographics, and personalities through their doors on any given day. Indeed, we are not the first to raise the possibility of robots enhancing museum spaces [52], however, there is much still to explore in this space, particularly in light of the questions raised around current failure to adopt. As such, we turn to museum staff and museum volunteers[1] to engage their lived expertise of how telepresence robots could be designed, pitched, and integrated into museums with the ultimate goal of sustainable, long-term adoption. Drawing on the expertise of museum professionals provides insights into the 'first line' of barriers that may be faced when trying to introduce a new technology to the museum setting, as well as ensuring deeply meaningful insights that stem from the lived experiences of those who are most familiar with the environment. Future work should seek to validate our findings from a visitor perspective.

Our paper combines the work of three studies conducted in the UK that explicitly investigate the acceptability, acceptance, and adoption of telepresence robots in the museum. These studies are uniquely situated for understanding acceptance, as they each engage with museum professionals in different stages of robotic exposure. Study 1 explores *pre-use acceptability* by museum professionals who have never interacted with telepresence robots. Study 2 explores *initial use acceptance* by museum professionals directly following their first exposure to a telepresence robot. Study 3 explores *sustained use acceptance* through the lived experience of museum professionals who have worked with a telepresence robot (or equivalent technology) for an extended period of time. Analysis of these studies addresses the following research questions:

1 What are the current opportunities and barriers to telepresence robot adoption in museums?
2 What is needed to ensure progression from acceptability, to acceptance, to adoption?

As core principles of Responsible Research and Innovation [30], it is crucial to understand a setting in detail, not only looking at an isolated activity (e.g. following a guided tour, visiting an exhibit) to be undertaken or supported by a robot, but also seeking to obtain the views of different stakeholders, aiming to understand who may get affected by the introduction of the technology and in which ways, and listening to their concerns and opinions. In this paper, we present an overview of the museum ecosystem as understood through the findings of the three studies, exploring the people, activities, context, and technologies (PACT [6]) already found in museums. These initial findings present unique insights into museums as potential sites for technologies from the perspective of museum professionals with lived experiences that formulate their understanding of how the robot may integrate into their site.

We then interrogate our findings through the Technology Acceptance Lifecycle (TAL) [43] lens, drawing out opportunities and barriers and exploring how the priorities of museums may shift and change according to their exposure to the technologies. We identify which elements are key at what stages, and use these findings to generate a road-map for the future of telepresence robots in museums, including design implications, potential applications, and integration strategies. To the best of our knowledge, ours is the first in-depth study to have been conducted to obtain museum professionals' perspectives on these topics. We demonstrate that despite the current financial context and workforce pressures of the cultural and heritage sector in the UK, museum professionals are not only willing to accept telepresence robots to assist people in the completion of activities in the museum, but are keen to do so, when constraints and opportunities are taken into consideration.

2 BACKGROUND

In this section, we review past work on mobile robotic telepresence in general. We then focus on the literature around telepresence robots in the specific setting of the museum. Lastly, we give an overview of the museum space.

2.1 Mobile Robotic Telepresence

A telepresence robot, also called a Mobile Robotic telePresence (MRP) system, is a robotic system equipped with cameras, microphones, speakers, and often other sensors that provide enhanced virtual presence for remote communications between individuals in different locations. This function enables greater social presence for the telepresent or remote user [68] by allowing them to navigate around and take up physical space in a room [44]. The use of telepresence robots has been examined in office workplaces, healthcare, social care, and educational contexts [3, 16, 34]. Early applications of telepresence robots show great potential for enhancing access to

[1]From here on, collectively referred to as museum professionals. References to 'staff' or 'volunteers' from this point are referring specifically to that group

a variety of physical locations in situations where in-person attendance is impractical or inconvenient, and for improving accessibility for a range of individuals such as those with restrictive disabilities or remote workers [17, 74]. However, they also present challenges related to technical and social factors in their usage. Disruptions arising from technical limitations such as poor internet connection [29] and limited physical capabilities (typically restricted to rolling around on wheels, turning, and sometimes adjusting the height of the robot) provoke interactional issues and social ruptures between the remote user and the local people [7, 31, 35], ultimately undermining the experience of the remote person and diminishing the potential for adoption of these robots [35].

There are, therefore, open challenges and avenues for future work in the design, development, and deployment of telepresence robots. The design of these technologies has remained virtually the same since initial inception, despite growing evidence of a need for improving their affordances and functionality. Further, use case scenarios specific to said affordances continue to be under-explored [57, 67]. Common use cases in which telepresence robots have been employed (e.g. office meetings, attending a class) have shown that users do not take advantage of mobility capabilities. Whilst embodiment and "free movement" allow a user to be perceived as more present in those settings [35], the way in which these robots allow the user to move (i.e. across a large indoor space) does not entirely align with the task requirements of those cases (e.g. smaller, more communicative movements might be more relevant during a meeting) [11, 67]. This suggests a failure to understand the context of use before deployment. Whilst some activities for which telepresence robots have been used in the aforementioned settings encourage the remote user to be static (e.g. sitting at a meeting or a lecture, visiting a bed-bound person), past work has also identified situations where mobility is important, such as attending a conference (i.e. moving between rooms, moving between people during coffee break sessions) [45], moving between office rooms when working remotely [35], and moving inside the home space in long-distance relationships using a telepresence robot [71, 72]. As Boudouraki et al.(2023a), point out, robotic telepresence evokes feelings of presence and adds value specifically in scenarios where the affordances of the robots (i.e. autonomous movement in space, physical embodiment) are relevant to the activity in which they are used. We have thus chosen to explore the setting of museums, as they present a space where the key activity of users inherently requires moving across large rooms; the kind of movement current telepresence robots are designed to perform.

Lastly, successful usage and adoption of telepresence robots has been shown to heavily rely on infrastructural and organisational conditions that are often not taken into account when the focus is on improving usability or understanding isolated interactions [10, 11, 36, 40]. As with any computer-supported communication media, their successful adoption in any organisational space is subject to the infrastructural and social dynamics of that space [26].

More recent work has argued for re-examining the purpose of telepresence robots: instead of aiming to replicate or mimic in-person interaction, researchers have begun to argue that telepresence technologies should provide remote users with ways to meaningfully participate in local actions [9] and provide a means for *belonging* to the setting, even if this is done in 'unnatural' ways [31]. Therefore, it is important to also examine and unpack the actions for which the robot is intended to be employed, in order to provide solutions for participation [9]. These arguments motivate our research investigating the current state of the museum ecosystem, comprised by the people, activities, context and technologies within it.

2.2 Telepresence Robots in Museums

As described in the previous section, there has been substantial research investigating how telepresence robots are used or have been used in settings such as offices, classrooms, hospital rooms, conference centres, and homes. However, whether any of the findings from those contexts may also be applicable to the specific needs of museums is as yet unknown. Early work investigating user needs of seniors with a telepresence robot identified museums and theatres as desirable applications [4]. However, there is limited research following up on this by exploring their deployment in these real-world scenarios, particularly in comparison to deployments in other domains [73]. Indeed, existing research in museums mostly focuses on the technical feasibility and challenges of telepresence robots (e.g. route planning, technical assessments) [46, 48, 64]. Only a small number of user-centred studies exist; for example, assessing telepresence robot usability from the perspective of the driver [3]; reporting on the design, development, and deployment of robot tour guides [55]; and investigating the design dimensions of non-robotic telepresence in the museum [52]. Whilst limited in number, these studies highlight important potential benefits that telepresence robots could offer to the museum setting, for example as a means to give museum access to people with mobility issues or other disabilities, building international visitor audiences, saving travel costs, and enhancing convenience and comfort [3, 16, 46]. Further still, there is limited research into the common barriers to acceptability and adoption in the museum such as physical constraints in buildings, high cost, and potential accidents with the exhibits [16]. With this work, we seek to address these gaps, highlighting barriers as defined by museum professionals and investigating which potential applications are most likely to build towards long term adoption by offering realistic, meaningful opportunities that professionals are motivated to support.

Outside of research, real-world deployments of telepresence robots in museums have been primarily carried out to provide museum access to people with disabilities [16, 32, 66], and to take advantage of closed and empty spaces during COVID-19 related lockdowns [42]. However, most of these deployments have not produced publicly available reports with insights on the experience and associated learning outcomes.

Importantly, the perspectives of museum professionals have unfortunately been overlooked. When taken into account, their input has largely been framed as informing about visitor behaviour [47] and for monitoring visitor acceptance of the telepresence robot in the setting [55]. Although some positive reactions from professionals and visitors have been reported in these one-off examples, it has also been remarked that permanent or long-term deployments would require careful organisational planning and support for professionals in order to avoid negative experiences that lead to decreased acceptance and adoption over time [27, 55], a topic which must, therefore, be prioritised.

2.3 The Museum Setting: Context and Requirements

As established, in order to create optimal conditions for acceptance and adoption of telepresence robots, it is vital to form a deep understanding of the context, activities, and people within the museum space. Museology is a broad and well established discipline that provides many key insights into these topics, albeit often without the lens of novel technology to frame the discussion. Further, many of the established facets of the museum setting are drawn from quantitative data collection encouraged by funders [1, 39, 59], empirical research conducted with visitors [19, 20, 37], or critical researcher reflections [15, 56]. As such, a phenomenological understanding of the setting from the perspective of those who work in them can be challenging to obtain, despite the insightful and oft overlooked contributions these voices would make.

From the existing literature, we understand that museums are a diverse, uniform, adaptive, torpid, aloof, personal, interactive, static, provocative, and conforming paradox. Despite their apparent contradictory nature, there are many well-accepted definitions of what constitutes a museum that might focus on the collection, the interpretation, and/or the display of specimens. For clarity in this work, we rely on the definition provided by the Museums Association, wherein museums are a setting to "enable people to explore collections for inspiration, learning and enjoyment. They are institutions that collect, safeguard and make accessible artefacts and specimens, which they hold in trust for society" [2]. Using this definition, we are able to unpack some of the expectations placed on museums as organisations where people can go to interact with and learn about content they otherwise may not. As such, we see museums as primarily educational establishments, although their role in leisure and entertainment must not be undersold. This definition further grants the museum unusual characteristics when compared to other aforementioned spaces, as users attend for vague and ill-defined reasons, for undetermined lengths of time, and with variable and manifold expectations [20, 50]. Venturing further into museology, we also see uniqueness in the museum context in the vast array of motivations people disclose for attending, including self-reflection, escapism, socialising, identity affirmation, relaxation, social status, and new experiences [19, 20, 22, 25, 41, 49, 50]. As noted, research to understand the motivations and activities of museum professionals is sparser, although there is acknowledgment that professionals might work at the museum for social and cultural reasons [5, 24].

The multiple roles of museums lends well to the integration of novel technologies. Indeed, technologies in museums have long been used to enhance content, accessibility, and inclusivity [14, 49]. However, as these roles shift and advance in line with shifting societal demands, many museums are adapting from being centres for learning to being centres for experiencing memorable, out-of-the-ordinary, technologically enhanced, customisable events [69]. Although this change provides an opportunity for advanced technologies such as telepresence and robotics to take their place in museum spaces, there are barriers to acceptance that limit what is typically accepted to touchscreen devices, virtual or audio tours, or one-off exhibits. These barriers are primarily understood to be initial cost of equipment, cost of upkeep, and lack of expertise [21, 41]. As such, and given the diverse range of stakeholders needs that a museum has to consider including addressing its own ethos and priorities in relation to the role it plays within a community and society, it is necessary to adopt a formal process for defining and prioritising requirements. Requirements that emerge as part of a user-centred design process are rooted in research that seeks to gain deeper insights into social, cultural, and organisational barriers and concerns. However, conducting qualitative studies with stakeholders are likely to result in a plethora of requirements of varying significance, and these would need to be prioritised in relation to criteria such as available resources and pragmatic concerns of implementing any changes. A focus on user experience (UX) is also needed and an approach for validating UX in the requirements development stage using key UX criteria is suggest by [33]. The Analytical Hierarchy Process [63] is a rigorous method for quantifying subjective judgments in multi-criteria decision making, and this approach can be applied to requirements prioritisation [13]. The formalisation and prioritisation of requirements which emerge from the findings of the research as presented in this paper would be part of another process, conducted as part of each specific museum's organisational and contextual priorities and resources available to operationalise the ensuing changes or system.

3 THE RESEARCH CONDUCTED

The scope and methods of data collection for the three studies are described in this section. A summary of all participants, their roles, and type of museum can be seen in Table 1. Participants are assigned identifiers based on the study they participated in; A# for Study 1, B# for Study 2, C# for Study 3. An example of three museum robots are shown in 1.

Study 1 - Zero Exposure to Telepresence. Seven museum professionals, who had never been exposed to telepresence robots, participated in semi-structured interviews between February and March 2023. Interviews questioned expectations, fears, barriers, and opportunities regarding the potential adoption of telepresence robots in their museums. The study was reviewed and approved by the University of Nottingham School of Computer Science Ethics Committee (CS-2021-R53). The interviews were a mix of in person at the participant's respective museum and online through Microsoft Teams and lasted between 40 minutes and 1 hour. Interviews were recorded to .mp3 and manually transcribed and anonymised by the researcher.

Study 2 – Initial Exposure to Telepresence Robots. Two focus group sessions were undertaken in June 2023 that introduced museum professionals to telepresence robots for the first time. Two participants attended the first session, and six participants attended the second session. Focus groups gathered initial reactions to robot exposure and discussion on opportunities and barriers around the potential adoption of the robots. The study was reviewed and approved by the University of Nottingham's School of Computer Science Ethics Committee. Focus groups were conducted at the Cobot Maker Space located at the University of Nottingham. Three participants were researchers investigating the museum setting.

Figure 1: Three examples of museum robots, Lindsey the interactive tour guide (left), Ohmni telepresence (middle), and Double3 telepresence (right). Photographs taken by authors.

We include their perspectives as experts in the museum who have empirically observed visitors' behaviours and their interactions with the content, surrounding people, and technologies in-situ, and possess an in-depth understanding of the museum ecosystem. Both focus groups followed the same protocol. A Double 3[2] telepresence robot was introduced and demonstrated. Each participant was invited to use the robot to move around different areas of the building. Whilst one participant piloted the robot, the others were encouraged to accompany the robot and interact with it whilst it was in motion. After, participants discussed their experience of using the robot for the first time and whether and how they could see it fitting in their museum. They were then prompted to discuss what additional features they would find useful in the museum. Focus group sessions were video and audio recorded. Audio was transcribed using an automated transcription service, and manually cleaned and anonymised by the researcher.

Study 3 - Long-term Exposure to Robots. Eleven semi-structured interviews were conducted with museum professionals in June 2023. Interviews were in-person at the site of the participants' respective museums, except for one online interview conducted through Microsoft Teams. Each lasted between 30 minutes and 1 hour. All participants had long-term experience working with a robot and/or telepresence robot in one of two museums; a local history museum, and a contemporary art gallery. The contemporary art gallery uses an Ohmni[3] telepresence robot to offer remote guided tours. A staff-member controls the robot and shares their screen with remote visitors through a video conferencing platform. Visitors may be offered training to pilot the robot under supervision. A second staff member is present in the physical museum to facilitate the robot route and lead the tour. The local history museum has a custom-built, autonomous mobile robot that provides physical tours and information about specific exhibits. Visitors directly interact with it through a built-in touchscreen.

Interview questions focused on the lived experience of working with a robot and looked to explore attitudes toward new technologies, potential benefits, barriers, concerns, and proposed solutions. The study was reviewed and approved by the University of Nottingham's School of Computer Science Ethics Committee (CS-2021-R53). Interviews were recorded to .mp3 and transcribed and anonymised by the researcher.

Participants for all studies were recruited through a combination of professional networks, web searches, and snowballing techniques and represented museum organisations from around the United Kingdom (UK). Participants were all required to work in or alongside the museum industry, and have relevant levels of exposure to telepresence robots.

3.1 Data Analysis

To make sense of the interview data from all three studies, transcripts of interviews were analysed through the same thematic framework focused on drawing out information about "people [using] technologies to undertake activities in contexts" [6, p. 29]. This

[2]https://www.doublerobotics.com/
[3]https://ohmnilabs.com/products/ohmni-telepresence-robot/

Table 1: Participant roles and IDs

Participant ID	Role	Museum Type
A1	Operations Manager	Independent technology museum
A2	Volunteer	Local history museum
A3	Collections Officer	National Trust
A4	Programme and Partnerships Officer	National Trust
A5	Volunteer	National Trust
A6	Freelance Engagement Officer	Multiple museums
A7	Membership Database Officer	Large history museum
B1	Sole employee	Local historic house and museum
B2	Chief Executive	University museum
B3	Volunteer	Local history museum
B4	PhD Researcher	Multiple museums
B5	Professor	Multiple museums
B6	PhD Researcher	Multiple museums
B7	Volunteer	Local history museum
B8	Senior Collections and House Officer	National Trust
C1	Director of Programmes	Contemporary art gallery
C2	Learning Coordinator	Contemporary art gallery
C3	Visitor Services Manager	Contemporary art gallery
C4	IT and Health and Security manager	Local history museum
C5	Visitor Experience	Local history museum
C6	Visitor Experience	Local history museum
C7	Exhibition Collections	Local history museum
C8	Exhibition Collections	Local history museum
C9	Learning Experience	Local history museum
C10	Learning Experience	Local history museum
C11	Learning Experience	Local history museum

method of analysis comes from the PACT framework, which utilises prospective user voices to determine user-oriented conditions required for the development and implementation of a technology; in this case, telepresence robots in the museum [6]. PACT is well suited for the analysis of our data as each of the elements of the framework; People, Activities, Contexts and Technologies, ensure a systematic review of user-oriented and contextually relevant aspects, where people's underlying motivation and characteristics are considered through the lens of what they do and where the activities are take place. It enables a holistic understanding that is bound by the interplay between each of the themes.

Researchers using this method begin with four primary themes:

- P The characteristics of *people* involved in the museum including their skills, needs, and motivations.
- A *Activities* conducted in the museum including what, how, and why
- C The social, physical, and cultural *context* of the museum
- T Existing and potential *technologies* in the museum including capability of technology, and attitudes or expectations of users

To populate the themes, we utilised a combination of deductive coding (based on the original framework from [6]) and inductive coding, mutually developed and agreed by [R1, R2, and R3] to ensure validity and rigour of application. Results from this analysis provided us with an overview of the museum as a potential site for telepresence robots, generated from the situated perspectives of the museum professionals. However, this understanding alone is not sufficient to understand why telepresence robots have not been adopted by museums, nor to explain what the needs of the museum are that are not being met. Therefore, to fully contextualise these findings and generate meaningful insights and recommendations, it became necessary to apply a second lens through which we could understand how these themes actually impact the potential and actual uptake of telepresence robots.

After having completed the thematic analysis using the PACT framework, we applied the TAL to investigate the opportunities and barriers to acceptability, acceptance and adoption of telepresence robots in the museum setting. We adopt the trifecta approach of the TAL to understand what makes a technology acceptable (pre-use acceptability), how a technology becomes accepted (initial use acceptance), and ultimately how we can ensure a technology is adopted and used over time (sustained use adoption). Drawing on the definitions provided within the TAL, acceptability is a determined *quality* of an object, service, practice, technology etc., that notes its potential to be approved of prior to use. Acceptance is a *process* that stems from interaction with the object, service, practice, technology etc., that shows that it has been given approval. Finally, adoption comes from sustained use of or commitment to the object, service, practice, technology etc., once it has been accepted. There are a number of established technology acceptance models and variants such as TAM2, TAM3, HITAM, STAM and UTAUT2 [18, 65]. The variants build upon each other to address aspects not previously considered, either as an upgrade to the model or for a focused purpose. We advocate for technology acceptance to be considered as a process, rather than a discrete measure, that takes the temporal dimension and possible evolution of acceptance into account [43]. For this reason, we utilise the TAL, as it recognises the evolving nature of technology acceptability, acceptance, and adoption across the different stages of the user journey, allowing findings to be articulated with regard to the entire process [43].

From the themes identified in the previous step, we re-interrogated our data temporally, drawing out what opportunities, barriers, and design implications for telepresence robots are present in each stage of the acceptance life-cycle. We present these findings study-by-study in section 5, highlighting key concepts and quotes from each stage.

4 UNDERSTANDING THE MUSEUM ECOSYSTEM

We believe that obtaining a broad overview of the museum setting is a fruitful and needed endeavour when the ultimate goal is to deploy or embed robots within it. Firstly, we present an overview of the museum context drawn from the unique perspectives of museum professionals that can be utilised as a primer for researchers, roboticists, and museum organisations wishing to design and deploy mobile robots in museums. Our findings highlight the complexities particular to this setting; namely, that no museum is the same but overarching commonalities or attributes can be outlined. Herein, we paint a broad picture of the museum ecosystem, detailing the elements that comprise it including People and Activities in table 2 and Context and Technology in table 3). Note that any information detailed about visitors is provided by museum professionals from their own observations and experiences.

Three key actors were identified by participants; staff, volunteers, and visitors. Small mention was also made to researchers and funders, although these references were sparse. Most participants noted that their museums primarily saw people fitting the demographics detailed in table 2, however, some museums noted that they had deliberately taken steps to ensure that other types of visitors frequented their museums such as LGBTQ+, ethnic minority, and visually impaired visitors.

Most of the participants noted that their museums, or museums that they visited, were established in old, listed buildings that require special permissions to make adjustments to. However, other museums were seen to be established in newer, or even custom built buildings that were subsequently less likely to face some of the barriers listed. Physicality was extremely important to professionals, but particularly to volunteers who often made a point of explaining that they volunteered in part because they wanted a reason to leave the house and socialise with other people. They also made clear that they believed the ambiance and environment of the physical museum was an important part of the visitor experience, particularly in historic buildings. Volunteers were also most vocal about, and noted by staff to be more resistant to, the introduction of more complex technologies into the museum space. Typically this was attributed to the fact that many volunteers are older and therefore have less technological literacy. However, even volunteers who described not liking technology acknowledged that museums must introduce new technologies in order to survive in the modern world.

5 THE TECHNOLOGY ACCEPTANCE LIFECYCLE OF TELEPRESENCE AND ROBOTIC TECHNOLOGIES IN THE MUSEUM

Now that we have presented an overview of the museum context from the perspective of museum professionals as a path to understanding the museum ecology, we turn our focus specifically to telepresence robots in museums. Applying the TAL model as a lens to understand what opportunities, barriers, and design implications are present in each stage of the acceptance model provides deeper insight into how the museum ecology may work against, or in favour of, the acceptability, acceptance, and adoption of telepresence robots. We present this section of findings according to the TAL, beginning with pre-use acceptability and progressing to sustained use adoption.

5.1 Pre-use Acceptability

Professionals interviewed in Study 1 had never interacted with a telepresence robot prior to their interviews. Key findings from Study 1 are that telepresence robots should prioritise use by professionals (and not visitors), the robots should improve accessibility for professionals, and that training and support is vital.

5.1.1 Use by professionals. Generally, Study 1 professionals were optimistic about the use of telepresence robots in museums and demonstrated willingness to accept them. Study 1 professionals also showed a high level of interest in exploring potential applications of the technology within their sites, however, there was a strong preference that the telepresence robots be piloted by professionals and not visitors. This preference was highlighted through fears that use by visitors would introduce new risks around, for example, hacking, inappropriate behaviour, interruption (when other curious visitors try to interact with the robot), and damage to museum content by untrained pilots.

Instead, Study 1 professionals prioritised discussing how the telepresence robot could be used to make *their* roles easier and more efficient. Professionals highlighted that the ways in which most museums currently function requires extensive flexibility and fluidity in regards to activities completed. Further, several professionals also discussed being frequently understaffed, a fact which they say subsequently negatively impacts visitor experiences. It was anticipated that a telepresence robot would be able to assist in the completion of a number of different professional activities, increasing efficiency and thereby increasing the capacity of professionals to keep up with the demands of the site. Examples given included conducting environmental monitoring (e.g. temperature, humidity, pest counts), accessing dangerous or hazardous areas (e.g. mouldy store rooms), personalising who is available to answer questions or interact with different visitors, and providing security and health and safety across the site. As a direct result of this, professionals anticipated that visitor experiences would be improved by the introduction of a telepresence robot.

People	**Typical Demographics**	**Notes**
Staff (paid professionals)	Young to middle aged; Female; Well-educated; Middle class	Larger museums had a higher staff:volunteer ratio
Volunteers (unpaid professionals)	Students or retired; Female; Well-educated; Middle class	Smaller museums had a higher volunteer:staff ratio
Visitors	Families; School groups; Social groups; Individuals; White; Middle class; Middle aged; Straight; Able bodied; Very few teenagers; Highly dependent on museum	Limited by physical and cognitive limits e.g. language barriers, disability; physical and financial accessibility
Activities	**Motivation / Perceived Motivation**	**Notes**
Museum professionals: Preservation; Conservation; Curation; Education; Marketing; Sales; Security; Hosting parties; Team meetings; Writing exhibit text; Auditing; Data entry; Tours; Knowledge exchange; Administration; Ticket sales and admissions; Directing visitors and answering questions; Queue management; Socialisation	Ensuring integrity of content; Enhancing visitor experiences; Socialising; Educating; Starting difficult conversations; Encouraging communication; Encouraging social change; Flexible working patterns	Activities are ill-defined and highly responsive to the needs of the museum Professionals are therefore extremely fluid and flexible in their roles
Visitors: Learning; Socialising; Playing; Having fun; Relaxing; Doing unusual activities (e.g. archery); Entertaining and educating children	'In line' with professionals; Education; Socialisation; Fun; Relaxation	Noted to sometimes be negative e.g. vandalism, theft, inappropriate engagement with exhibits

Table 2: Overview of people and activities in the museum ecosystem, as perceived and experienced by museum professionals

5.1.2 Improving accessibility. Above and beyond its use to improve efficiency, many of the professionals were interested in the possibility of using the telepresence robot to improve accessibility. As noted previously, museum professionals, particularly volunteers, skew older. As such, museums are increasingly facing challenges to ensure their volunteers are able to physically and mentally access their sites. The anticipation of increased accessibility and capacity of professionals due to the telepresence robots was expected to improve visitor experiences *as well as* professional experience, through being able to support visitor interaction and even enable museums to put on additional activities and events. Moreover, the museum professional demographics could expand to include people with disabilities (e.g. people with limited mobility, people who experience chronic illnesses or flare-ups); where the telepresence robot could support them in conducting some of the museum tasks remotely. One participant even suggested the potential offered by these robots to allow prisoners to volunteer as a professional as part of reintegration programs.

Indeed, accessibility was a key consideration for the acceptability of the telepresence robots, and was the main avenue for achieving acceptability due to its anticipated use by both professionals and visitors:

> *Yeah, it'd be a massive help for people that can't afford to travel to get to museums. So that would be massive. ... And then also people that would struggle to get out of the house, whether that is because they've got mobility issues —and mobility aids are just like hard to come by sometimes— or whether it's to do with sort of like agoraphobia and stuff like that. I suppose it could be quite useful for therapy in terms of sort of like grading yourself in and sort of like, you know what this space looks like, you've seen this object, you really want to go and look so you need to build yourself up to go there in person.* (A2)

In both cases, it should be noted that accessibility was discussed not only in terms of physical access needs, but also neurological needs such as controlling noise and light levels. The only other reason that emerged at this stage to allow visitors to use the telepresence robot was to utilise it as an additional source of income for the museum.

5.1.3 Training requirements. Despite the high levels of interest and engagement with the idea of introducing a telepresence robot to the museum, Study 1 professionals also showcased nervousness and uncertainty about how the telepresence robot would be received by both professionals and visitors:

> *That would be a risk. Yeah. So I think some volunteers would think, 'Oh my goodness, you're bringing robots*

Context	**Opportunities**	**Barriers**
Historic, old, sometimes listed buildings	Sense of 'presence' and historical importance	Damp; Mold; Pests; Uneven flooring; Poor WiFi coverage; Inaccessible areas; Ghosts; Preservation concerns
Being a physical location	Capturing and preserving lived experiences; Forging, promoting, and enhancing community links; Meaningful and mutual exchange between visitors and professionals; Providing 'safe spaces', Creating unique experiences, Offering activities targeted at specific communities	Extreme variation in size, staffing levels, visitor numbers, and exhibit content; Crowding; Getting lost
The nature of museums	Defined by their capacity to educate, curate, preserve artefacts and knowledge, and inspire people; Driven by passionate people interested in museums	Funding cuts mean struggling to remain open, improve exhibits, offer interactive content, or participate in 'risky' behaviours
Technology	**Opportunities**	**Barriers**
Audio guides and touch screen displays	Simple to use; Can offer accessibility features	Not very interesting for visitors
Vitual reality or video games	Enhance accessibility and interest, particularly for non-typical visitor demographics	Require dedicated engineers and/or workshop spaces
Social media	Accessible	Usage was mixed
Virtual tours	Increase accessibility for people who cannot visit in person, or who may struggle to navigate the physical space	Often out of date, not well advertised and may only be available on site or by request
General	Good for engagement and therefore funding	Limited by cost of purchase, cost of upkeep, and lack of on-site technical skills; Concerns around distracting visitors; Volunteers are often elderly and don't have technical skills or interest in learning technical skills. They also don't have confidence in supporting visitors to use technologies.

Table 3: Overview of the context and technologies in the museum ecosystem, as perceived and experienced by museum professionals

> *in, you're trying to replace us. We're not wanted anymore.' And so obviously we would have to do change management in that respect, so you'd have to be very, you know, gentle and you'd kind of present the benefits and you'd say like it's very much not, it's to help you, it's not to replace you.* (A3)

As noted earlier, reticence to introduce new technologies is common in the museum sector, and is often considered as a 'risk' that many museums believe they cannot afford to take. Further still, other context-dependent barriers were seen to raise concerns, including uncertainty about infrastructural capacity such as access to reliable Wi-Fi and a good enough computer both on-site and at pilot locations, uneven flooring, lack of lift access, need to navigate outdoor spaces, and so forth. Other barriers to acceptability demonstrated by the Study 1 participants included concerns around the privacy of other visitors, the physical safety of visitors and content, the robot's ability to move through crowds, the robot's ability to see everyone around it (particularly children, wheelchairs, and little people), and the ability of visitors to see the robot (especially partially sighted or blind visitors).

There was some consideration of what kind of training could be offered in order to overcome these barriers and ensure acceptance, safety, and usability of the telepresence robot. This training was considered to be not just in terms of practical information, but also to slowly introduce the robot to reduce volunteers' anticipated fears around technology going wrong and jobs being replaced by technology.

Overall, we see that professionals who have not yet interacted with a telepresence robot prioritise opportunities around potential impact on people and their activities, but are deeply concerned about barriers stemming from the museum context and technology uncertainty.

5.2 Initial Use Acceptance

Those who participated in the Study 2 focus groups were given a chance to interact with telepresence robots for the first time during the session. Key insights from this study include potential applications for the telepresence robots, their usability in the museum context, and the affordances and limitations of the robots in the physical museum space.

5.2.1 Potential applications for different actors. Overwhelmingly, Study 2 professionals noted the potential of these robots to improve or enable accessibility to visitors or professionals who cannot be in the museum in person (e.g. due to disabilities or inability to travel). In addition, participants expressed that having an expert or curator give a remote tour or talk could add value to their exhibitions whilst supporting their financial capacity:

> *The idea that the person who knows most about this particular picture on the wall, is actually in the gallery in Los Angeles. There's no way we're going to be able to— we might bring that person over once in a blue moon, but we're not gonna bring them over often, and being able to access that is quite interesting.* (B2)

Participants also mentioned after-hours access with the robots, opening-up the possibility to connect with international audiences and offering themed experiences such as ghost tours. Other suggested uses included social visits, where a visitor could be in-person and have a companion (e.g. family member or friend) joining remotely, and allowing professionals to monitor areas that are not busy at all times, such as the reception. Participants expressed that replacing real people with robots was a sensitive topic but also noted that museums are struggling to get new professionals after the COVID-19 pandemic, highlighting telepresence robots as a potential solution.

Other suggested uses for the telepresence robots were more creative, including being able to visit multiple museums in succession, having the robot providing guided tour by historical characters (e.g. played by actors or using deep fake), and integrating the robots as part of an exhibition in and of itself.

5.2.2 Robot usability. Being exposed to a telepresence robot gave deeper insight to professionals about what is needed for the robot to be accepted into the museum. Naturally, some participants felt more at ease while using it, while others expressed the need for getting familiar with the system and the importance of knowing the space where the robot is navigating. Participants identified that different audiences would react differently to the robot. Whilst children were expected to find it novel and fun, older visitors were expected to be more likely to become impatient and frustrated. Some noted that easier ways of interacting with the system would be needed to encourage user acceptance.

Throughout the sessions, but particularly directly after exposure, participants discussed the issue of driving the telepresence robot (i.e. Double 3) under its two standard modalities: manually by using the keyboard or mousepad, and autonomously by clicking on a point in the visual display of the software. Participants noted that controlling the robot (i.e. navigating, turning around, zooming in and out) could distract users from their main activities at the museum, thus suggesting the need for reducing complexity:

> *If you have a map of the site, and just click the exhibit and then the robot goes automatically there, rather than being all the time busy with navigating around corners. On the other hand, if you just have a website with pictures of the exhibits, it's almost similar, isn't it? So what's the point of having something like that? But I think some of the advantage of this is to experience the space. So seeing how you're moving through the space is important, but having to navigate yourself to it might, the preoccupation [would be] with the technology.* (B5)

Participants were also interested in testing the collision avoidance features of the robot, as they considered this an important feature to protect exhibits and spaces. An incident occurred in the second workshop when the telepresence robot started banging against a wall while trying to automatically navigate through a glass corner, which was seen to hinder the acceptance of telepresence robots in museums:

> *The only main concern from it was observing it when it tried to crash down the wall from across. Being the historic space, that's a bit like 'Oh!'. But otherwise it was, apart from that part, it was quite good, it did seem quite trustworthy. It avoided everything, wasn't it?* (B8)

5.2.3 Physical affordances and limitations. There were also reflections on the physical museum context and the opportunities or limitations of using telepresence robots in there. Where some could seem naturally fitting ("*Most of ours [exhibition spaces] are flat, the doors are very open, it's all accessible*", B2), others would require multiple robots ("*It's complicated because of the stairwell*", B1), or extremely restricted movement ("*I would prefer to have a tracker so that people could see where it is going because we're in a very small space*", B7). It was noted that telepresence robots can also offer access to these constrained spaces where, for instance, wheelchairs cannot get through. This, however, needs to be considered with care, as "*disabled people already get discriminated against when they're out and about and treated differently. Is that just gonna be an extension of that, or will it actually offer some freedom?*" (B8).

Overall, we again see opportunities for people and activities to be a driving factor towards acceptance. However, as well as the aforementioned barriers around technology, more barriers were identified around people including negatively affecting visitor experiences and perpetuating prejudices that are already barriers to engagement.

5.3 Sustained Use Acceptance

Study 3 participants had all worked with robots in museums for an extended period of time and focused on garnering reflections on sustained use. Key findings from this study were that the robots: improve accessibility by attracting people not typically represented in visitor demographics; require additional, appropriate resources; and raise concerns around safety and security.

5.3.1 Improving accessibility. As with the other findings, accessibility was noted to be the key factor that influenced acceptance of the robotic technologies. Museum 2 noted that their robot successfully attracted repeat visits from people that were typically underrepresented in their museum before; children and families.

This was understood to generate a mutually beneficial relationship for both the museum and the visitor and was anticipated to represent long-term acceptance as "*there is a relationship building and I hope that it brings in the toddlers, and they come back as they grow, go through their lives*" (C5). This was understood as in part being due to the robots acting as attractions themselves for a broad number of potential visitors including families, schools, and teenagers. Visitor acceptance of the robots was understood to be mostly positive, with occasional exceptions such as in Museum 2 where "*some of them [visitors] like the robot, some of them hate the robot or are scared of the robot and don't want to come to the museum because of the robot*" (C7). In Museum 2, positive attitudes were especially common among demographics such as children with special needs who were noted to particularly like the robot, and "*come because they find [the robot] quite interesting and that they can interact*" (C6). Oftentimes and in both museums, concerns of visitors were understood to be related to the robot acting as a distraction from the content, although this was broadly dismissed by professionals as unrealistic based on their experiences.

In addition to increased interest and attendance, professionals also made note of how telepresence technologies specifically could be used to improve accessibility, for example providing access to the museum for children, people who live far away, and people with disabilities. In Museum 1, telepresence robots were indeed used during the COVID-19 pandemic both by general audiences and people with disabilities to access the site. The telepresence robots were subsequently adopted long-term by the museum, and are still used there by schools, and people with mobility issues and/or chronic conditions at time of data collection.

The acceptance of telepresence robots comes on the heels of a growing awareness of the need to make museum spaces more accessible for people with disabilities, despite limited time and resources:

> *Certainly for disabled access, for people who can't get to certain areas, they are a brilliant thing. There are a lot of buildings which can't afford to put in huge amounts of accessibility platforms, lifts and change the structure of the building because of the complexities of planning* (C4).

Other future uses for the telepresence robots that were suggested by professionals in this study included the artists remotely visiting the museum during curation or attending the exhibition while abroad, providing pre-recorded multilayer interpretations and narratives, and even having a robot cleaning whilst conducting other activities such as a remote tour.

5.3.2 Resource concerns. One further key insight generated by professionals was that pre-use acceptability and initial use acceptance would have been smoother with the involvement of different departments in initial discussions prior to the introduction of the robots. In these discussions, professionals wanted to be given space to express their concerns and propose ways that the robots could facilitate specific purposes as educational projects and in general ameliorate visitors' experiences, so as to feel involved and invested in the changes to come. Deployment would be easier if professionals were given more support, appropriate information and time to plan.

Moreover, lack of time and resources also impacted the acceptance of the robots. This was sometimes related to the physical needs of the robot, such as a lack of reliable WiFi or lighting, but more often related to technical and functional maintenance. As highlighted in the previous section, most museums — including the two represented here — do not have access to on-site expertise that could help with the robots in the event of a breakdown or maintenance concern. This was seen to lead to delays in fixing the robot, and therefore disappointment for visitors who wanted to engage with them but could not.

Overall, acceptance by museum professionals of the existing robots was seen to be high. In contradiction to the concerns expressed above, professionals did not express concerns about the robots trying to replace them, instead showing increased confidence that the unique insights of the professionals could not be replicated by the robotic technologies, given that, for example, "*some of my colleagues who are like super experts would have a job for years and years and years trying to tell the robot everything that they knew*" (C8). Further dissuading any fear of human replacement, it was explained by professionals that the robots, particularly the telepresence robots in Museum 1, required regular guidance, input, maintenance, and assistance from the professionals to be successfully utilised in the museum. As such, while some of the professionals found that their roles had adapted, none felt that they had been replaced.

Despite generally high acceptance amongst professionals, there were some concerns raised that professionals wished to be addressed. One example given related to the user interface being designed for a single user, despite the social nature of museum visits (e.g. schools):

> *I feel it's very much designed for one person to log in to operate it and see using the camera. So when you want to have a tool say with a group of people, then you have to share your screen, connect it with teams or some or kind of you can't necessarily have* (C3).

5.3.3 Safety concerns. Validating the concerns of professionals in Studies 1 and 2, there were also a number of concerns raised by almost all Study 3 professionals about the safety and security of exhibits, professionals, and visitors. Most of the participants referred at some point to the risk of the robot colliding with and damaging the exhibit. Most also expressed concern at the risk of the robot harming people or the robot falling and breaking, be that through deliberate misuse, or accidental collision:

> *The pole area is vulnerable. Visitors are not necessarily going to see that, but that's. You might get more visitors colliding with telepresence rather than the other way around*. (C5)

Moreover, participants explained that museum visitors, especially children, tended to experiment with the robots, often as a prank. As such, security features such as a remote kill switch were considered an essential element for a robot's acceptance.

Overall, the robots were seen to bring typically positive experiences and opportunities to the museums for both professionals and visitors, with most opportunities being seen to come from the context and technology — in direct opposition to the pre-use and initial use findings. Further still, the sustained use interviews highlighted an even broader range of barriers than the previous studies, most commonly relating to people, activities, and context but notably not to the technology.

6 DISCUSSION

Telepresence robotics offer a developing area of study that has potential to improve accessibility and interactivity in remote spaces. To date, there has been limited in-depth research into the ways that these technologies could be applied in the unique setting of the museum, not only from the perspective of the robot users, but also from the perspective of the organisation seeking to adopt them.

In this paper, we have brought together the findings of three studies with museum professionals that explore the current museum ecosystem in the UK and the acceptability, acceptance, and adoption [43] of telepresence robots. In the following, we first discuss the considerations and potential applications of telepresence robots in museums. Then, we elaborate on opportunities and barriers for acceptability, acceptance, and adoption. Lastly, we present design implications and limitations arising from this work.

6.1 Museums as Sites for Deployment of Telepresence Robots: Opportunities, Barriers, and Potential Applications

Table 4 shows the opportunities, barriers, and potential uses of telepresence robots, as identified at the pre-use (P), initial use (I), and sustained use (S) stages by our participants. The table also showcases how these priorities could be seen to change between the different studies at different phases in the TAL, fluctuating as the familiarity of the professionals with the robot evolved. In this section, we will unpack these priorities, drawing attention to how and when the shifting priorities ought be addressed.

6.1.1 Opportunities. A number of opportunities were highlighted across the three studies that show how acceptability and acceptance evolve with increased familiarity and experience of use. Accessibility was an influential opportunity showcased across all groups. It has long been the purview of museums to consider accessibility as both a key feature and a key concern to maintain in the face of an evolving social, cultural, political, and economic landscape [16, 46]. As such, it comes as no surprise to note that accessibility accounts for roughly two thirds of opportunities prevailing across all three studies, shown to increase acceptability and acceptance of telepresence robots in museums regardless of position in the TAL.

Priorities of the *pre-use* group were broadly related to the improvement of conditions for professionals, with the express intention that this would then have a knock-on effect of improving the experience of visitors by proxy. This prioritisation is attributable to the chronic under-resourcing of museums and the decreasing volunteer pool putting excessive pressures on professionals to be able to complete multiple roles with minimal time, resources, and funding with which to do so [39]. As such, it can be seen that pre-use acceptability of telepresence robots in museums must ensure clarity and transparency as to how the technology can benefit the professionals.

The *initial use* group were also interested in how the telepresence robot could benefit museum professionals to increase capacity and improve accessibility, however, there was also more explicit interest in ensuring that visitors received direct benefit from the technology. Novelty and surprise are a powerful part of new experiences [60], and this was shown to be true in Study 2 where participants were responding to a demonstration of a telepresence robot and found it easier than the *pre-use* group to visualise how the robot would be used in their specific museums. This change in priorities can be seen as a shift away from understanding what the technology needs to do to be acceptable, and towards understanding how the robot would be accepted and therefore used.

Finally, the *sustained use* group were more closely aligned in terms of prioritisation with the *pre-use* group than the *initial use* group, favouring opportunities that directly benefited the professionals, with the intention that this would improve visitor experience by proxy. However, where the *pre-use* group were concerned with what would be needed to make the robot acceptable, the *sustained use* group were able to draw on existing experiences to understand what made the robot accepted. This paradigm highlighted the benefit the robot had for the museum itself, in terms of offering a unique selling point and adding value (such as enhanced information provision) to the museum content and therefore experience.

6.1.2 Barriers. Table 4 also shows the barriers that were identified and at which points in the TAL they were seen. In terms of *pre-use* acceptability, the findings show that there is a great amount of fear related to the telepresence robots and ways in which the robots could negatively effect professional and visitor experiences. As seen above, there was a bias in terms of professionals from the pre-use group focusing on the potential negative impact the robot might have on themselves, at the expense of consideration of negative impact on visitors. These findings are in line with workers' perceptions of the integration of robots in other sectors such as manufacturing [38], healthcare [62] and professional cleaning [23]. Further, we can see that the pre-use group identified the most barriers relating to the technological element of the telepresence robot, with fears surrounding physical, emotional, and social impacts of technology.

Whilst remarkably similar to the pre-use group, the *initial use* group were slightly less likely to focus on technological barriers, rather exploring barriers across a broader range of elements. It can also be inferred that the novelty and excitement of experiencing the telepresence robot for the first time had some impact on the barriers towards acceptance, as there was less discussion of the potential negative responses and experiences of professionals. Instead, the initial use group were able to transfer their initial experiences to the museum setting to highlight barriers around safety, novelty, and training.

Finally, the *sustained use* group were able to draw on their pre-existing experiences to reflect on what barriers they had experienced or had learned to overcome in order for the technology to be accepted. A number of the barriers were consistent across the entire TAL, particularly barriers regarding people and structural concerns. However, some new barriers to acceptance also emerged such as the creation of additional work for professionals, loss of overall faith in robotic capabilities, and a better understanding of how visitors might want to utilise the telepresence robots. Finally, a number of

Table 4: Opportunities, barriers, and potential applications of telepresence robots in museums

	***P**: Pre-use, **I**: Initial use, **S**: Sustained use*	**P**	**I**	**S**
Opportunities	Could be used by professionals	✓	✓	✓
	Could be used by visitors	-	✓	✓
	Could increase accessibility for professionals	✓	✓	-
	Could increase accessibility for visitors	✓	✓	✓
	Could improve professional's capacity to do variable roles	✓	✓	-
	Could improve visitor experiences	✓	✓	-
	Could increase numbers of professionals available	✓	-	✓
	Could attract new, younger professionals	-	-	✓
	Could add value to the museum experience	-	-	✓
	Provides a unique selling point for the museum	-	-	✓
	Robot could be an attraction in and of itself	✓	-	✓
Barriers	May elicit negative reactions from professionals	✓	✓	✓
	May elicit negative reactions from visitors	✓	✓	✓
	Increases risk to people	✓	✓	✓
	Increases risk to content	✓	✓	✓
	Increases risk to the organisation	✓	✓	✓
	Increases risk to privacy	✓	-	✓
	May not align with preferences of professionals	✓	-	✓
	May not align with preferences of visitors	-	-	✓
	May provide an unwelcome distraction	-	✓	✓
	May not meet expectations and become a source of disappointment	✓	✓	✓
	Will require additional training for professionals	✓	✓	✓
Potential uses	Environmental monitoring (e.g. temperature, humidity, pest counts)	✓	✓	✓
	Cleaning whilst conducting other activities (e.g. remote tour)	-	-	✓
	Robot acting as an exhibit in and of itself	✓	✓	✓
	Accessing otherwise inaccessible spaces (e.g. floors with limited access)	✓	✓	✓
	Accessing dangerous or hazardous areas (e.g. mouldy store rooms)	✓	-	-
	Remotely assessing sites after inclement weather	✓	-	-
	Providing security and health and safety	✓	-	-
	Providing more consistent and efficient tours for visitors	✓	-	✓
	Enabling disabled professionals to attend the museum	✓	✓	✓
	Allowing prisoners to volunteer as part of reintegration	✓	-	-
	Hybrid social visit (remote and in-person people)	-	✓	✓
	Facilitating after hours, special events and unique uses (e.g. ghost tours)	-	✓	✓
	Facilitating tours by historical characters (e.g. by actors or deep fake)	-	✓	-
	Providing pre-recorded, multilayer interpretations and narratives	-	-	✓
	Managing queues and sharing information	✓	✓	-
	Enabling access to multiple museum in quick succession	-	✓	-
	Settings for people with additional access needs e.g. large print	✓	-	✓
	Interpretation services (e.g. other languages)	✓	-	✓
	Personalising who is available to answer questions or interact with visitors	✓	-	-
	Bringing guest experts into exhibits	-	✓	✓
	Allowing artists to attend their exhibits or exhibitions from abroad	-	-	✓

barriers highlighted earlier in the TAL were seen to be mitigated or adapted around including barriers regarding physical hazards and expected capabilities [16]. The findings offer proof that over time, some barriers to acceptance can be overcome and designed around, whether that be by the robot or designer, or whether that be by the users being supported to adapt. Further, the findings show that generally, professionals are happy to accept telepresence robots *despite* the difficulties that come with it, due to the overall benefits they perceive [38].

From the users' perspective, through our three studies we were able to confirm findings from previous research on telepresence robots in other public settings such as shopping malls [70], workplaces [35], and outdoor spaces [28]. For example, worries about how the robot could be perceived in public spaces and that bystanders could have concerns about privacy and being recorded [28, 35, 70], perhaps not surprisingly, also apply to the museum setting. Moreover, the concern that controlling the robot can distract users from their main activities at the museum aligns with previous findings that mobile telepresence users' performance on certain tasks decreases due to the effort required for controlling the system, taking away the focus from the main activity [51]. Lastly, the suggestion to have a designated pilot different to the main user (e.g. visitor) has also been found in previous work proposing multiple users having control over the robot [45]. Despite these concerns, our findings also show that museums are a relevant site with untapped potential for further exploring the key features and future design of telepresence robots.

6.1.3 Potential applications. In Table 4, we provide a list of potential use cases drawn from our findings, either as explicit suggestions made by professionals, or as implicit suggestions designed to address needs and desires identified within our analysis. These use cases do not offer a comprehensive list of ways the telepresence could be used, but rather offer a reflection of the necessary fluidity, adaptability, and usability that could ensure acceptability, acceptance, and adoption of these technologies. We are aware that many of these activities can be performed by other means and even other types of robots (e.g. cleaning or social robots); however, we offer this list of use cases as an outcome from our engagement with museum professionals through which they were prompted to foresee the potential value of telepresence robots in their spaces. Given the financial constraints currently experienced in the cultural and heritage sector and the fact that robots are still very expensive technological devices, finding multiple uses for single robots are a potential way forward in the process of acceptance and adoption. These use cases can also provide some directions for the design and development of new and expanded features of telepresence robots [31, 54]. Priorities for use cases were museum management, education, novel engagement, and accessibility. Indeed, museums are a unique context offering opportunities to defy existing findings in industry and research about who uses telepresence robots and how [9], therefore being a site with an untapped potential to diversify the user base of Human-Robot Interaction research in Western contexts [58].

6.2 Design Implications for Acceptability, Acceptance, and Adoption

Overall, as summarised in figure 2, we see that opportunities to improve acceptance at different stages are typically related to how the telepresence robot could improve experiences for *people* and their *activities* within the museum site. In particular, pre-use acceptability and initial use acceptance were heavily tied to these two elements, highlighting that professionals are well equipped to envision how the technology may be used within their sites, reducing burden on designers and people introducing the technologies to museums to reassure prospective users of their utility. Instead, we see that pre-use and initial use barriers to acceptance are most often related to uncertainty around the technological elements of the robot. Therefore, designers and people introducing robots into museums should focus on reassuring museum professionals that the technologies are safe [23] and providing support to integrate and use the technologies effectively. Further, to support the transition to sustained use adoption, it becomes imperative that the telepresence robots are shown to be as reliable and consistent as possible in order to continue to be seen as affording opportunities for people and activities.

It is also a notable trend that once the robot enters *sustained use*, the technological challenges that are seen as barriers early on are not only mitigated, but further, are replaced by technological opportunities that actually contribute to the robot being accepted long term. It became apparent from the Study 3 that the professionals adapted to using the robots in ways that were both intentionally designed for, and unintentionally enabled. Professionals evolved how they used the technologies to integrate into their specific museums by changing, for example, who could pilot the robot, what areas it was allowed to access, and how they marketed the robot to prospective visitors. Many of these changes were made by professionals without input from designers or experts, but rather were the result of trial and error, communication, or responsiveness on the part of the professionals. Indeed, instead of being impacted by issues that arose along the way, professionals sought to make the technology work for them because of the opportunities they saw in the technology for their museum. As such, sustained use adoption of the technologies was heavily influenced by the opportunities that were identified in the earlier TAL stages, motivating the professionals to continue using the robots. Consequently, the professionals in the sustained use study described seeing many of those opportunities realised in terms of increased visitor numbers, unique experiences for visitors, and improved accessibility, but also noted that the main barriers they faced came from trying to realise those goals. In response, we identify a necessity around maintaining efforts to reassure professionals of the safety and usability of the robots in both formal (organisational level) and informal (peer supported) ways.

As such, whilst technical support must still be available, long-term support for museum robots should pivot to realizing the opportunities identified in pre- and initial use phases, focusing on the capacity the robots offer to improve the experiences of people within the museum site, particularly the museum professionals and not, as seen in the literature, exclusively on visitors. One example may be ensuring that future iterations of telepresence robots improve accessibility for an aging demographic of volunteers, and providing more variable utilities that are flexible to the fluid and myriad nature of activities undertaken on-site. This is in relative contradiction to current approaches that focus on 'selling' the robot based on its people and activities utility, and then switching to providing more technological support and reassurance long term.

As such, we advocate for designers and people introducing robots to museums to adapt their approach to supporting museum professionals with the ultimate goal of sustained use adoption in mind. Based on the findings from our research, there will be a series of complex decisions that will need to be made, stemming from the opportunities, barriers and potential uses for a telepresence robot. These will need to be articulated as formal requirements and will underpin decisions relating to the type of telepresence robot, how many might be needed, and how they will be operationalised and

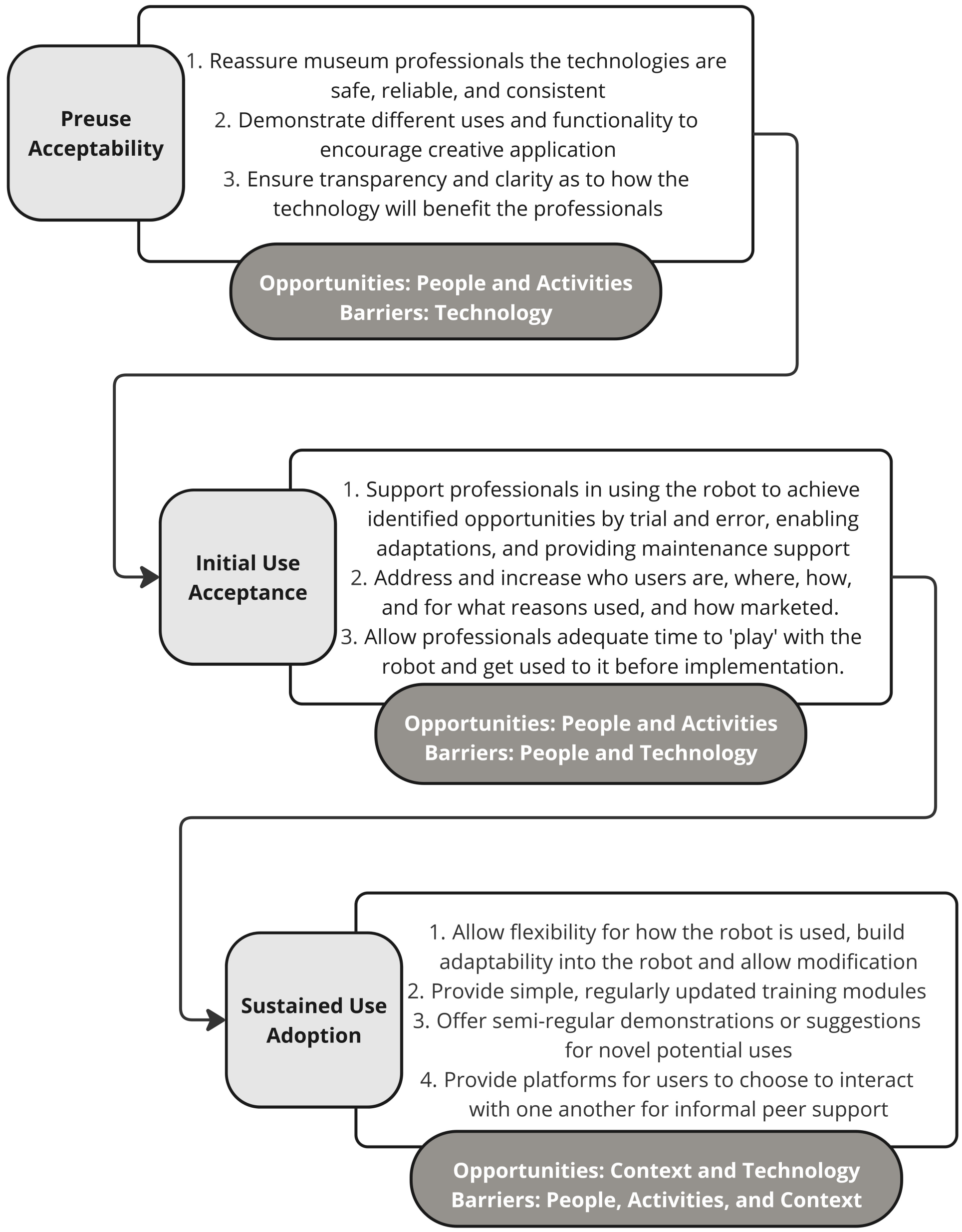

Figure 2: Recommendations for practitioners and designers to support progression from acceptability, to acceptance, to adoption

deployed. This will require a formal process of requirements management, where certain considerations will need to be prioritised over others based on organisational needs. Priority should initially be given to reassuring professionals that the technology can be safely and functionally introduced to their sites. Once introduced, focus should shift to ensuring that all key actors who the museum want to interact with the robot are able to, be that through modified design, training, or adapting the robot's usage. Finally, once accepted, the priority should become making sure that the museum is able to realise the previously identified opportunities, modifying and supporting more functionality and utility for people and their activities according to the specific needs of the museum. This may be achieved by modifying the robot or by supporting professionals in adapting to their own way of co-existing with the technology.

6.3 Future Work

Results from these three studies are limited to the UK context, therefore, future work should investigate the applicability of these findings in other countries and cultural contexts.

We also recognise that although we strived for a diverse representation of museums and roles of participants in the three studies, no museum is the same, and thus some views from other types of museums and galleries may be underrepresented in our analysis. Nonetheless, comparing our findings with the works of scholars from other applications grants us confidence that our analysis offers a realistic overview of the contemporary museum ecosystem and the technologies within it. Further, our use of the TAL framework ensured that we focused on drawing out differences and commonalities based on level of exposure and expertise with robots. This lens ensured that our findings rely less on specific museum features and more on prospective applications, somewhat mitigating the impact of our limited data sample and reducing fear of overgeneralisation. Future work into robots in museum, or telepresence robots in general, can use the findings presented here as guidelines - providing both a grounded point of reference and further validating and expanding on the results.

Further, this paper has only presented findings from interview and focus groups with museum professionals. Future work should investigate, compare and contrast views from visitors and actual deployments and interactions with the robots in a real museum setting.

Trust is an important concept in HRI and HCI literature and creates a provocative and interpersonal lens through which to examine peoples' interactions with robotics. Although trust was rarely explicitly mentioned in the studies, we propose that investigating how trust evolves throughout the TAL process is a valuable next step to develop the findings presented in this paper. More specifically, this research has demonstrated the differing needs across people, activities, context, and technology at different points in the adoption lifecycle. Building on these findings, applying a lens of trust will deepen insights into the evolving needs and perspectives of museum professionals, thereby contributing to and strengthening design implications for acceptability in culture and heritage use cases.

Finally, we advocate for continued investigation into the potential uses identified by professionals, both as development opportunities for telepresence robots, but also as provocation for other technologies potentially introduced into the museum space.

7 CONCLUSIONS

In the museum sector, telepresence robots have the potential to offer a number of unique experiences, as well as to address some of the existing limitations and barriers that museums face.

In this paper, we present results from three different interview and focus group studies with museum professionals (i.e. staff and volunteers) from the UK about the potential and current use of telepresence robots in museums. Our contributions are threefold; first, providing an overview of the museum ecosystem from a Human-Computer Interaction perspective, aiming to contribute to the body of work on museums as a potential site for novel technologies. Second, we offer an overview of potential applications of robots in the museum as both context for robotic adoption and as provocation for future work. Third, we provide a comprehensive overview of the Technology Acceptance Lifecycle (TAL) as applied to telepresence robots within the museum context. Through this, we show that the acceptance of telepresence technologies develops alongside exposure to the technology. We show that in different stages of the TAL, professionals are more focused on opportunities and barriers relating to different, specific elements of the museum context. We use this to suggest what opportunities and barriers should be tackled at different points in time, in order to ensure acceptability, acceptance, and adoption of telepresence robots by museum professionals.

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Consent was not gained from participants for this dataset to be made available to other researchers.

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