Expanding the Paradigm of Telepresence to Improve Collaboration and Socialization

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Introduction

Telepresence technology, like video conferencing, has become more prevalent than ever, especially over the course of the COVID-19 pandemic. With this massive growth in use of telepresence software, we may see that its original designs may no longer be best for all different forms of interactions. Existing forms of telepresence are generally optimized for talking head scenarios, originally for business, or handheld video calls. We conducted research to explore how existing telepresence systems can be augmented to support participation in collaborative scenarios that involve the manipulation and investigation of physical objects and spaces. Specifically, we focused on collaborative scenarios that could support people aging with long-term mobility disabilities, such as remote technology troubleshooting and participating social activities (e.g., games; see table 1). We performed a series of research studies and collaborative design activities to understand the barriers faced with current telepresence systems (e.g., Zoom, Facetime) and to collect data on the impact of various novel telepresence interfaces and capabilities. Through this process, we identified key limitations in using various Telepresence platforms for remote troubleshooting and developed design recommendations to improve their accessibility and utility for older adults and particularly those with disabilities. This paper will highlight our research developing telepresence tools to support this population, the resulting design recommendations, and discuss current state of telepresence systems for these scenarios.

Motivation and Scenarios:

As mentioned before, our target users were older adults (aged 60+) with long term mobility disabilities. Many of the users we worked with also had vision loss and limited dexterity. Over the course of multiple collaborative design projects, we learned about some of the other limitations of our users, and what they would like to be able to do with various telepresence software. Users cited wanting to be able to perform activities such as ask for help with technology, scrapbook, and play games with family. Some users were simply excited to be able to have extended conversations with people during the pandemic. We have condensed these findings into a series of interactions/scenarios that would be their ideal forms of interactions over telepresence (Table 1).

Interaction	Physical Requirements	Potential interventions
Tech Support	• Multiple camera views • Mobile camera to see different parts of an object • Ability to indicate items or locations	• Access to extra cameras • annotated views • Easy view switching • Multiple methods of presenting annotation to all participants
Remote Physical/ Occupational Therapy	• Full body view of users • Ability to change view (side/back) • Ability to indicate for troublesome areas	• Access to extra cameras • annotated views • Easy view switching • Multiple methods of presenting annotation to all participants
Scrapbooking with the family	• Secondary view of the book itself • Potentially third view of the photos themselves • Methods to indicate where to place photos	• Access to extra cameras • annotated views • Easy view switching
Remotely joining an outing (picnic, beach day, etc.)	• Ability to look around the area • Ability to communicate with a whole group • Full body views • Sense of presence	• Mobile camera (360 degree) • Projecting speaker or multiple headphone output • Indicator of when remote people are active • Larger screen or projection of remote attendees
Games (Collaborative and Competitive)	• ability to have whole group hear remote persons	• 360 degree view

	• Equity between those in person and those remote • Sense of presence for remote users	• Projecting speaker or multiple headphone output • Indicator of when remote people are active • Larger screen or projection of remote attendees

Table 1: Telepresence scenarios studied in our series of experiments with older adults with mobility disabilities, along with physical requirements and potential interventions.

The following scenarios were developed based off of studies involving multiple telepresence prototypes. This includes feedback from older adults with mobility impairments, care partners, and accessibility experts in fields such as physical therapy (Thompson et al., 2024). They were designed to note common issues that these groups had with everyday life and telepresence technology, and how this technology could be leveraged to help them.

Scenario 1: Troubleshooting

Smart home technology has great potential to support older adults, and particularly those with disabilities, in the home but is difficult to maintain. One solution to this is to have a family member or paid technician help them solve an issue. This scenario will demonstrate a potential interaction between an older adult and the assistant.

Jenny is an older adult who has just purchased a new wireless router. She is very excited to be able to use internet in her home and not just on her phone. However, when she opens the box, she sees a bunch of ports on the back that all look the same. She has no idea which cable goes where, so she starts a call to her daughter Mary. With both of them on the video call, Jenny shows the back of the router to Mary, and asks where to plug in the cable that goes to her computer. Mary then uses an annotation tool to indicate the correct port with a circle, arrow, or other annotation, even adding text if necessary to further elaborate. If this used an alternative view, such as the aforementioned table space view, the object could be placed in such a way that the camera view and the first person's view would be almost identical, preventing confusion from front to back or left to right mix-ups. Jenny plugs in the right cable, then this process repeats with the other cables until the router is set up. Now Jenny's computer is connected to the internet, and she can make use of it.

Scenario 2: Home Inspection

Within physical therapy for older adults with mobility disabilities, there is a subsection of use where a therapist will examine various areas in an adult's home to attempt to find tripping hazards and other areas that could be problematic in the future. Remote physical therapy has become more prevalent, but is limited in its ability to perform environment checks.

John, an older adult who uses a walker, has just moved into a new home with the assistance of a moving company, but is unsure about how safe his new furniture arrangements are. As such, he sets up a call with Larry, his physical therapist. A 360 degree camera is set up in John's living room, and the two of them begin to talk about the living space. Larry spots a few issues, such as some wires in walkways, upturned rugs, and difficult to reach areas. Larry can then circle those areas in the camera view for John to see, and John can correct them. Once Larry is satisfied with a room, they can move the camera to another room, and check out the whole house this way. John feels a sense of comfort knowing that his physical therapist has approved of his living space, and can continue to confidently live independently.

Scenario 3: Scrapbooking

Several of the participants we worked with talked about wanting to do decorative artistic activities remotely with their families, since some had family out of state. The following scenario explores how expanded telepresence could improve such an experience.

The Schulz family has an annual tradition of getting together and working on making a scrapbook of all the things they've done that year. However, in the past few years some of the grandkids have gone off to college, and some of the aunts and uncles have moved to separate states for job opportunities. Grandma and Grandpa, not wanting to let the tradition die out completely, invite the remaining family members over and set up their desktop camera system. The grandkids and absent aunts and uncles join in via a video call, able to see the entirety of the desk, as well as a view of Grandma and Grandpa. Young Allie wants to show off her new dorm room and put college memories into the scrapbook, and the view of her room is printed out and put in a spot. Aunt Bea sees some of Allie's sendoff pictures already on Grandma and Grandpa's table, and circles them on her screen. A light points at the pictures and the circle also shows up on Grandma and Grandpa's screen. With the extra direction from Aunt Bea, they make a page chronicling Allie's trip to college. The family feels close to each other despite the distance.

Scenario 4: Remotely Joining an Outing

There are many views out in the world that people say cannot be captured by a regular picture, but not all of those locations are accessible. Even normal outings are not always possible for those with mobility disabilities. The following scenario shows how an older adult with mobility disabilities may feel present in areas that may not always be accessible to them.

Rita and Jacob have gone on a hiking trip across the Appalachian Mountains. As they traverse the rugged trails, they think about how Rita's father Aaron would appreciate the natural beauty of the trails they are on. Jacob sets up the 360 degree camera on his backpack, and both him and Rita have screens in a tablet mounted in front of each of them so that both of their faces are visible, and can see Aaron's face. As Rita and Jacob continue hiking, Aaron scrolls around the 360 degree view, highlighting wildlife and plant which then show up on the tablet screens. Haptic wristbands that Rita and Jacob are wearing vibrate to let them know that Aaron wants their attention. Aaron tells them both stories of his old wildlife treks, and the three even play some I Spy as they traverse the trails.

Scenario 5: Collaborative/Competitive Play

There has been a noted disconnect between remote meeting attendees and physical meeting attendees. This disparity can also be seen in attempts to play boardgames online, without a virtual game of some sort. The following scenario depicts how expansions on telepresence technology could improve remote tabletop game experiences.

Rick, Janice, Ethel, and Mira are all older adults in assisted living communities. They are all old friends, but only Rick and Ethel are in the same community and can physically meet. All of them want to play Monopoly together like they used to when they were younger, so they set up a play time. Mira and Janice go to their own game room, where a desk with a camera and projector are set up. Rick and Ethel go to a similar game room that they can use together. As they all get onto a call together and the projector shows a monopoly board on their desks. As they all pick their pieces, Rick and Ethel argue over who gets to be the hat this time. They finally decide that Ethel gets to be the hat, and each of them sets their one piece on the board, where it gets projected onto the other boards. They draw cards from their own shuffled decks as they play, and when Janice puts a house on a property, it also is projected onto the other players screens. After a night of laughing and yelling, Mira wins and all of them think about how glad they are that they can still keep in touch.

State of Technology

Above we discussed these scenarios that our research identified as functionality that is needed by this user group. In this section, we're going to discuss where the current technology supports or does not support these types of scenarios for our target users.

There are many forms of teleconferencing software. The platforms we have investigated are Zoom, Microsoft Teams, Facetime, Google Meet, and Oneclick.chat, a teleconferencing system intended to be accessible to older adults. Each of these systems are similar in that they follow the talking heads schema designed for a work context, and have features that aid in accessibility such as meeting recording, transcription, and transcription translation. At the same time, some devices and applications have focused on expanding telepresence through routes of accessibility or different viewpoints. In the following sections, we'll discuss the specifics of the interfaces of these four different platforms, and the degree to which they provide the functionality necessary for the scenarios described above.

Zoom

As a teleconferencing application, Zoom was originally released in 2011, but gained a large amount of traction throughout the pandemic due to its base free access business model with longer meetings requiring payment, and its wide-scale adoption in schools. Zoom gained the role as a proprietary eponym for teleconferencing during this time, similar to band-aid for bandages or Kleenex for tissues. Zoom allows for users to have a limited ability to join meetings without an account, but for full use of the client's features, the user must have an account. Zoom allows for use of different cameras, though the use of multiple cameras at the same time is buried through multiple menus, and requires some effort to find. Zoom also allows for screen sharing and annotation on said screens by all participants, and even remote control of those screens. However, annotations can only be used on shared screens or a white board, and only one screen can be shared at a time. With these limitations, users are still fairly restricted in the amount of multi-camera interactions they can perform without using outside hardware or software. Zoom does have an extensive API, or Application Programming Interface, that continues to be updated to this day. It handles integration of new programs as sub-applications and can allow certain tools to be altered by an experienced programmer. However, the API still does not allow full crossover between different sections of the program, such as screenshare and camera use. Zoom also lacks a comprehensive suite like some other solutions, however this focus could just as easily be seen as a strength as it can be seen as a weakness.

Teams

Microsoft Teams is a more business-oriented telepresence suite, as it is integrated into the rest of Microsoft 365. This integration allows for advantageous linking to files in a meeting's chat, preservation of a meeting's chat logs to be referenced at a later date, and even for the same group meeting/chat to be reused for multiple meetings with old references and settings intact. The limitations of this are that an account is required in order to access Teams and Teams teleconference sessions. This lowers accessibility for outside groups, and often requires paid subscriptions for access to these features. This can also increase the security of recorded conversations and files that need to be shared. This can be important in educational, research, and medical arenas. Teams also has an API that allows for development of sub-applications for their meetings. Teams also contains screen-sharing and annotation, but once again many effects are buried behind menus.

Facetime

Initially released in 2010, Apple Facetime was created as a way to perform video calls on smartphones, in a method accessible to the public. The greatest strength of this was its ease of use as far as calls went, allowing users to simply hit a different button when calling someone's phone number and initiating a video call as opposed to an audio call. They have recently added the ability to share screens, and facetime can now be used from apple PCs as an application, and participants can be sent a link that can be opened from web browsers. However, the main initiations of said calls are still restricted to apple phones and computers, and screen sharing lacks the annotation functions of web telepresence applications. Along with this, Facetime also lacks an API for developers to use, most likely due to Apple's strict controls on their proprietary software.

Google Meet

Google Meet was more recently released in 2017 as its own replacement for Google Hangouts as a video conferencing system in desktops. Google Duo was released at a similar time as a more personal video calling system for use on mobile devices. In 2022 the two services were merged, and now both contain the same features. Google Meet allows users to share and annotate screens, as well as collaborate in various google documents. Calendar integration is there as well, and the system is free as long as the user has a google account to work from. Without a google account, a user can join a call from a link, but will not have access to all features. Google Meet also has added an API for developers to work from, and is available on all mobile and desktop platforms. There are still limitations in how much the application has been adopted, but we shall see how that changes in the future.

OneClick.Chat

OneClick.chat (OneClick), launched in 2016, has connected over 50,000 older adults. The platform makes it easier for older adults to connect with friends and family over video chat, and was integral in the lives of many older adults during the social distancing of the COVID-19 Pandemic. In addition to helping support connection between older adults and their family and friends, OneClick hosts daily events that offer social engagement opportunities and wellness classes where older adults can meet new people and form new friendships. Examples of events regularly hosted by OneClick are social mixers, chair yoga classes, trivia nights, and social game nights. During each event, rich opportunities for social interaction within the video chat conversation include voice, facial expression, and body language. Over 60% of users have been over age 65. OneClick is sold to organizations through a software-as-a-subscription model. Organizations subscribe to OneClick to provide the technology to their members. Members can use video chat meeting rooms to easily connect with friends and family through single link sharing, or they can join virtual events that promote social engagement and interaction. The entire platform is browser-based with no standalone client, and allows for meetings to be started by sending a link. The interface is fairly bare-bones, and has large visible buttons, including a "help" button to improve troubleshooting. It allows for screen-sharing, but lacks the ability to annotate even a shared screen, and has no support for multiple simultaneous camera views.

Telepresence Add-Ons and Hardware Accessories

While we have discussed existing platforms and their strengths and weaknesses, there are other forms of technology already on the market that could assist in expanding what we can do with telepresence technology.

Many new forms of technology have challenged the traditional views on teleconferencing. In 2020 at the start of the COVID-19 pandemic, the IEEE-VR conference was able to rapidly move their entire conference venue to a virtual one, hosted on Mozilla Hubs, a Virtual Reality application focused on hosting virtual locations and interactions within those virtual environments (https://ieeevr.org/2020/). VR Chat has also shown a large amount of growth as a platform for socializing through virtual avatars that can be controlled through a keyboard or VR headsets and controllers that allow for full limb movement representation and deictic gestures.

New hardware has also come out over time to expand upon traditional webcam viewpoints. Cameras such as Logitech's MX Brio 705 both automatically focus on movement or sound, and can be flipped to readily view a desktop surface (Logitech brio site). Many mounting arms have come out on other cameras, but these still have issues of requiring more extensive setup. Owl labs has made a conference room speaker and camera combo that covers a larger area of a room, and focuses in on whoever is speaking at the time (Owl Labs site).

Related Work

People have been researching novel telepresence interfaces for over 50 years. The following is a sampling of relevant studies that informed our experimental questions and research design.

Current telepresence technologies follow a variety of philosophies regarding immersion and user experience, defining and measuring immersion in different ways. One taxonomy describes shared spaces according to three criteria: transportation, artificiality, and spatiality (Benford 1998). Some teleconferencing solutions take a “natural presence” approach, attempting to mimic the presence of others within the context (ex. Sitting at the same table) at appropriate scale. In addition, the camera system is situated such that the user can look at their conversation partner in the eye, akin to natural in-person behavior (Kauff & Schreer, 2002).

Other studies have examined the advantages of heavily adjusting the spatial side of telepresence. Room2Room was an examination of a room-scale telepresence interaction where users would interact with a 3d representation of another user to complete various tasks. They found that the Room2Room system allowed for faster task completion than using Skype (Pejsa, 2016). However, lower visual fidelity meant that verbal information became more important for these task completions. An important part of the additions in this study was the improved ability to use deictic gestures (indicating position through pointing, etc.) over traditional systems.

The concept of resonance embodies the phenomenon in which the sensory input perceived from the environment highly correlates with possible reactions to such input, especially as they pertain to physical space. High resonance is a component of presence, where a person feels “in touch” with where they are and has a sense of agency within that context. Systems that do not facilitate the tangible aspects of perceptive input-output do not facilitate resonance and therefore provide less support for presence and immersion for user (Reiner 2004).

The placement of the camera to facilitate direct eye contact is an important factor in eliciting a sense of presence for conversation participants (Ishii 1992). The user’s method of control and means of interacting with the hybrid space also contributes to the user's sense of immersion and agency of actions. In one study, most users did not care to use a remote control means of sharing visual viewpoints in a given scenario. A handful of users claimed that this feature enhanced their telepresence experience, but this was in cases where one-way, linear communication occurred (such as in lectures). A tablet-sized display allows for users to perform selection tasks more quickly, and that a user-perspective lens has benefits over a device-perspective lens for such tasks. In our study, partners shared writings and drawings on physical artifacts (such as paper and various sizes of dry erase boards) by holding the artifact up to their partner on the screen or otherwise moving the artifact or their body so their partner could see (Baricevic 2013).

Agency may promote immersion more than graphical fidelity, especially for instances where a system's visuals are abstract or of lower quality. Even if a system has lower visual fidelity, users of the system may experience a greater sense of presence with another user and/or objects if other immersion factors perform well (for instance, a deformable screen that provides more agency at the cost of visual quality) (Kushida 2016).

We started with an understanding of these studies as a base to develop our own series of development projects to facilitate older adults aging in place with mobility disabilities in utilizing various forms of home technology.

Research Projects

Over the past 5 years, we did a series of projects focusing on the same goals, to support those scenarios in an accessible way. The first project was three phases of design research studies funded through TechSAge (NIDILRR grant number 90REGE0006-01-00). Our first two projects focused on Augmented Reality as an aid for older adults with mobility disabilities in understanding various connected home technologies, but gave us valuable insights that led to our later understandings of the importance of telepresence for our participants. This led to the third project: examining telepresence through the lens of an expanded space and annotated video feeds.

Initial Work: AR and Telepresence within the Home

The first project we will discuss involved understanding older adults and how they engaged with various forms of technology in the home, and how to visualize their interactions in situ. Our findings in this study informed us that in order to help older adults make decisions about various forms of technology, and moved us to examining how users would gain understanding from augmentations on videos. While these videos were not interactive, they would contain additional information in relation to the user's home. These augmentations, and the studies that utilized them, informed us that their understandings of technology could be further expanded through the use of augmentations within a telepresence experience.

The first project led to the construction of various Augmented Reality tools to aid older adults with mobility disabilities in understanding smarthome technology, and whether or not it could be useful to them specificially. It achieved this by allowing them to see information and representations of these technologies within their own home (Thompson et al., 2024). From these studies, we found that older adults learned more with augmentations, but still preferred instructional videos for learning.

From our findings in the first project, we decided that the best use of our findings would be to start developing canned videos (which the users preferred more), with the addition of being in the context of their own homes and including augmentations (which seemed to better inform the users). Initially we developed a generic form of this video to work from as a framework. This used footage shot at the Aware Home, as well as augmentations for additional information using printable image targets from the last study (Thompson et al., 2024).

Once we had these videos, we modified our generic video to use footage from the home of the participant that would view it. The participants would then be asked to get on a video call with a researcher, explain what they remembered from the generic video, then watch the new video and answer questions about the Alexa, as well as how they felt about the personalized aspects of the video. All users who participated in the second part of the study preferred the personalized video to their original video (Thompson et al., 2024).

Primary Work: Using Telepresence for Supporting Collaborative Activities in the Home

At the end of our initial studies, we received positive feedback on the personalized videos, but realized through these and other telepresence studies conducted during the time, that telepresence was lacking in solutions for troubleshooting CHT as well as other devices, such as smartphones.

Because of our results in Phase 2 of this project, as well as our findings in the second project (more on it further below), we realized that a helper being able to assist our users would be vital in the troubleshooting process of many technological issues. At the same time, we recognized that the physical presence of this person would not always be possible, so we pivoted to a live collaboration with remote helpers.

Live Collaboration with a Remote Helper

Phase 2 took place in 2020, meaning that it was during the beginning of the COVID-19 pandemic. We therefore decided to look at a multitude of our studies at that time, and parse out what from our data may be indicating the utility of the method we deployed and what were artifacts from life during COVID. For example, we found in our virtual studies that participants used the time to socialize with researchers far more than usual. We adapted our method to accommodate this conversation, even when it was at the expense of conducting the actual research methods. We found it apparent that participants needed this time to have this conversation, as many had been isolated from others due to COVID for months. This was the inspiration for the third phase turning towards interventions that would facilitate socialization over telepresence. We began exploring other kinds of smart home technologies with video screens (e.g. Facebook Portal) that could help older adults with disabilities age in place both through control of the Internet of Things, but also to reduce feelings of isolation and loneliness.

We created and piloted new research designs with the Facebook Portal meant to leverage its fish-eye following video tracking, but also explore the ways it either helps or fails remote participants collaborating on an activity (e.g. solving a puzzle). We identified different games and puzzles that researchers and participants could play together over the technology that represented different physical and virtual elements of play. This method also served as a proxy to understand how a remote helper may be able to aid an older adult in troubleshooting some technology in their home.

From these we generated a series of design concepts on how to expand upon traditional telepresence and make it more viable both for technical troubleshooting, as well as for socialization. This was covered on two main fronts: camera perspective, and deictic indicators. The camera perspective side of these design concepts was covered in 2 forms: table space and room space. The table space design was made to allow the user to simply place objects on the table to be viewed, like a phone or scrapbook, and then have the table space camera see it. The room space design utilizes a rotating camera that both sides of a call can control, and has a laser pointer to indicate various spots visible by the rotating camera of the person on the other end of the call wants to point something out.

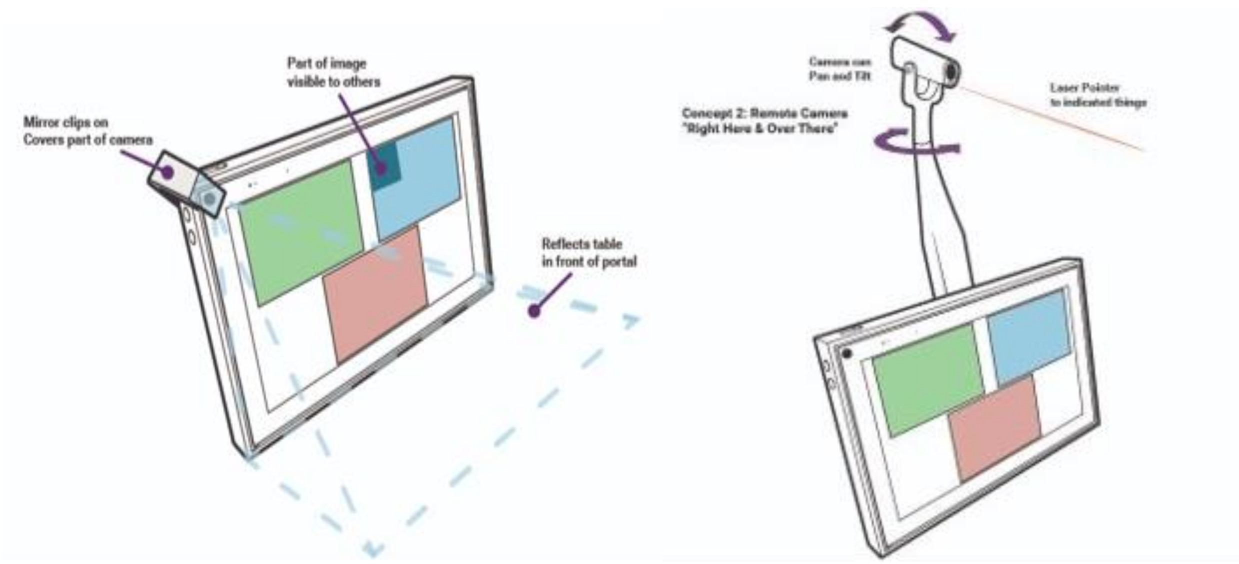

Figure 1: Initial Desk Space (Left) and Room Space(right) designs for telepresence prototypes

While these had benefits on their own, we wanted to make sure that both sides of a video call would be able to indicate specific parts of the camera view. As such, we decided that the second part of this effect would come in the form of screen space annotations. We have already seen such annotations as useful in the screenshare abilities of systems such as zoom and teams, but these had not been applied to these systems' camera views.

Prototypes

We ended up using Zoom as the software base for the video calls we would use to test these prototypes, as they had an existing screenshare annotation and remote desktop system.

In order to allow Zoom's built in annotation to work with the camera, we had to find a way to get a camera view as a shared screen. In order to perform this, we used Open Broadcasting Software (https://obsproject.com/) to set up multiple camera views in a window, so that that window could be shared and annotated. The limitation of this method is that it is a complicated setup, which meant that it was limiting to small-scale studies where researchers could set up a call, and then set up the participant in front of a computer.

The hardware varied for the desk space camera and the room space camera. Our tablespace solution was originally intended to be a mirror on the camera of a laptop, which would reflect the table in front of the laptop, however, we decided that a camera mounted on an arm would be more viable for initial testing, so that we could further adjust the view space of the table itself. Once the view was set up, the table view camera as well as the face cam from the laptop would be loaded into OBS, and the screen would be shared for annotations from the other side of the call.

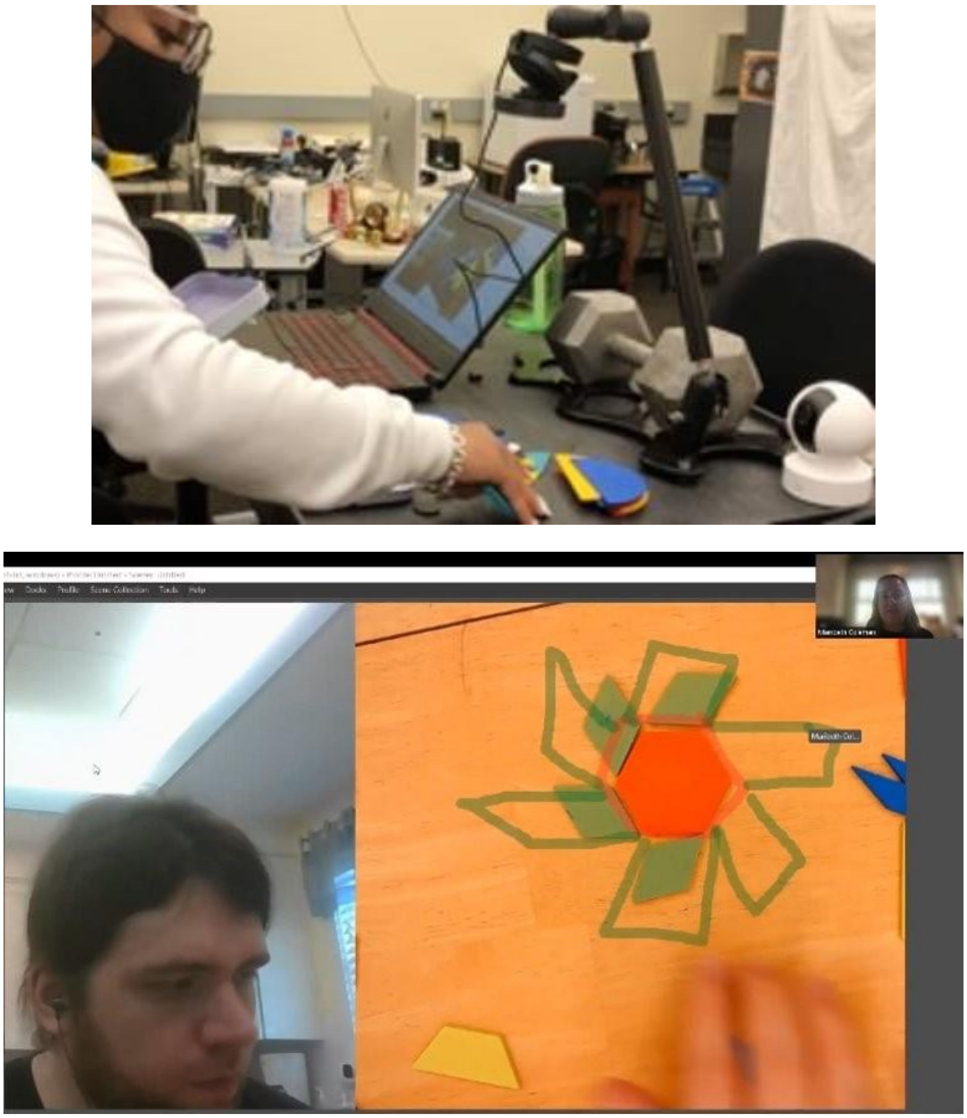

Figure 2: Views of first Desk space prototype. The physical system (top) and the software view with annotations (bottom)

The room space solution utilized a Kasa pan/tilt/zoom camera, with its own built in mobile application for viewing and controlling. By using an android emulator, we were able to connect to the app on the computer, and control the camera through clicking. We were able to then allow for remote control via screensharing the emulator, where both sides could use their mice to click on the screen.

Figure 3: Views of the room space prototype. The Pan Tilt Zoom camera used (top) and the view of the room with annotations (bottom)

Codesign Charettes

In order to evaluate this prototype, we conducted a series of codesign charettes with both the target users, and accessibility experts. We had three participants for this study, two females and one male, all aged over 60 with mobility disabilities for at least 10 years. Two of them used powered wheelchairs, while one was able to walk short distances. All of the participants had used telepresence software before, and had smartphones.

Our two accessibility experts both worked with older adults, and have conducted several accessibility studies. Their fields of work focused around home safety and rehabilitative exercise. They received a light primer on the technology before the design sessions.

Three participants were taken through a series of activities spanning 90 minutes utilizing our telepresence prototypes, then asked a series of exit questions . They were put on a Zoom call with a researcher (who was in a separate room of the home), who would instruct them on how to perform these tasks. Another researcher was in the room with the participant, to take notes or make adjustments to the prototype as necessary. The researcher on the call would instruct the participant in how to make various pictures with a series of shapes called tangrams. Only the researcher would be able to see what the completed image would be, until the participant had managed to make the image.

The researcher would then take the participant through a picture search, where there would be hidden objects in a drawn image that the participant would need to find. The researcher would see if the participant could find the image on their own, and then draw to indicate a smaller region for the participant to search for the object. The third game used to test our annotated telepresence system involved using a Where's Waldo search, where the researcher would indicate a starting point, then guide the participant along a series of directions to different objects in order to find waldo. In a second version of this test, the researcher would draw smaller and smaller regions to search within until the participant could find waldo.

After this, the researcher would have the user navigate an iPhone's settings in order to turn on various accessibility features. The researcher would draw on the camera image of the phone to indicate which menus to navigate next. Finally, the user would be moved to a more open area for the call, with a drawing board and a 360-degree camera, where they would play a game of I Spy with the researcher, as well as draw part of an object on the drawing board, for the researcher to finish with annotations. After all of these activities, the participant would be asked a series of questions.

Our older adult participants reacted positively to our system, saying that it would be useful for navigating in tech support, as well as for playing games and showing photo albums to their family. Minimal concern was expressed about cameras in the home, and participants appreciated the ability to adjust the table-space camera. We did notice, however, that users would generally look at the phone itself during the phone guided activity, and forget to look at the screen to see any further instructions being mentioned to them. For this problem we concluded that a sound after an annotation was made could prompt the user to look back at the computer screen. We also noticed that the glare on the phone screen, as well as the glare on the computer screen could cause issues, and so allowing the user to adjust contrast settings on the camera view would be important.

The accessibility experts were given more freedom in their use of the prototypes, being shown how they worked, and then allowing them to give feedback on the prototypes themselves. Our accessibility experts expressed interest in using our prototype in future studies, saying that they would be useful for performing future studies with participants in different states, or in areas that were difficult to reach. They mentioned that in existing telepresence systems, the limitation of the camera view to the user's face and shoulders meant that it was more difficult to evaluate room spaces for safety, and to confirm that users were performing their exercises properly. They also commented on the contrast issues, mentioning that annotation colors should be limited to colorblind-friendly colors, and should be changed based off of the brightness of the camera view.

Findings from Phase 3

There was one other issue with our prototype in its current state: it required many different software and hardware tools working together, and any one of these parts failing meant that the user could not use it well. With the additional requirements of OBS broadcasting, and a phone emulator having to be screenshared, the aforementioned users could not be expected to reliably set this up, and having to troubleshoot a troubleshooting application ruins the point. From here, we explored hardware and software options to reduce the cognitive load on our users. We found a 360-degree camera that we could code to zoom in on different areas on the software side, though it was somewhat costly. Future instances of this may need to facilitate several forms of 360-degree camera in order to be more cost accessible to users.

Discussion

The findings from our research are useful in understanding areas in which telepresence still has room to expand and grow. As technology continues to progress, a future where telepresence systems could fulfill all of our earlier mentioned scenarios is becoming more viable. However, while the pieces may all be there, they are not connected. Multiple camera views are supported currently in some telepresence systems, but are often heavily buried behind menus. This makes them much less likely to be accessed by anyone with limited technological understanding. Camera annotations exist as standalone applications, but within the telepresence systems, they seem almost intentionally excluded. While the APIs exist on these telepresence tools, we are still limited to what functions we can add within them.

The work mentioned in this paper has also informed a series of research studies now being conducted by Potluck LLC under an SBIR grant. This grant involves using and improving the company's telepresence platform (Oneclick.chat) to enable collaborative play between older adults with Mild Cognitive Impairment and their Care Partners.

Alongside this formal result of our efforts, we have used the findings from our series of projects to generate a series of design recommendations for companies looking to improve their telepresence programs to improve accessibility and accommodate new modes of communication within their systems.

Design Recommendation	Examples	Useful Scenarios
Allow for easy access to the client	• Instant access link • No login.	• Accessibility • Aging
Allow For multiple viewpoints	• Desktop Camera • Controllable 360 degree camera • Face cam • Easy access to second and third camera views • Switchable between multiple views (picture in picture, side by side) • Full Body View	• inspecting a room • Live virtual apartment tours • Desktop work • Tech Support
Allow for Deictic Indicators for video screens, and not just share-screen annotations	• Virtual Drawings on physical technology • Indicating where scrapbook pieces should go with arrows or circling • Projected light pointer • Projected screen overlay with annotations	• Physical Therapy • Social Play • Tech Support • Remote Judging in a contest • Constructive Criticism of sculptures/ drawings/diagrams.
Have a "tutorial" or "Wizard" setup for users	• Microphone, Speaker, and Camera adjustment tutorial • Permissions for screen-sharing • Setting up 2 cameras	• Troubleshooting for the camera, microphone, or speaker not working • First time setup
Subtle View Manipulations can add to sense of presence during a call	• Facial Tracking for shifting a zoomed camera FOV • Gesture tracking and recognition • Pointing as a way of generating an annotation	• Social Play • Collaborative Exercise • Seeing a new area
3D representations in a virtual/camera-based environment can add a sense of collaborative control	• 3d pieces on a physical board • Augmented Reality representations of objects	• Collaborative Decoration • Scrapbooking
Scalable User Interface Allows for Increased accessibility	• Resize buttons • Hide/show UI (button for this always visible, distinct).	• Accessibility

Table 2: Design suggestions for future telepresence systems

With these design suggestions, you are both increasing the usability of your system for a group of users who are often underserved, but also broadening the arenas in which your system can be used in everyday life, further expanding its ubiquity. Users with limited mobility are some of the ones who can benefit most from an increased use of telepresence, allowing them to feel more seen and letting them experience more facets of the world more easily. Older adults will have an easier time getting into and fixing issues in their usage of the systems, and may even get to communicate with other populations more often, building a better sense of community and improving mental health.

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