Geocaching with a Beam: Shared Outdoor Activities through a Telepresence Robot with 360 Degree Viewing

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ABSTRACT

People often enjoy sharing outdoor activities together such as walking and hiking. However, when family and friends are separated by distance it can be difficult if not impossible to share such activities. We explore this design space by investigating the benefits and challenges of using a telepresence robot to support outdoor leisure activities. In our study, participants participated in the outdoor activity of geocaching where one person geocached with the help of a remote partner via a telepresence robot. We compared a wide field of view (WFOV) camera to a 360° camera. Results show the benefits of having a physical embodiment and a sense of immersion with the 360° view. Yet challenges related to a lack of environmental awareness, safety issues, and privacy concerns resulting from bystander interactions. These findings illustrate the need to design telepresence robots with the environment and public in mind to provide an enhanced sensory experience while balancing safety and privacy issues resulting from being amongst the general public.

Author Keywords

Telepresence robots; video communication; social presence; geocaching; leisure activities

ACM Classification Keywords

H.5.3 [*Computer-supported cooperative work*]: Group and Organization Interfaces

INTRODUCTION

Friends and family members often enjoy participating in shared outdoor activities together [26,27]. This can range from doing simple activities together like walking or hiking to more complicated activities like sports. When people are separated by distance, such shared activities are often severely limited, if not impossible to do. As such, researchers have explored ways of supporting shared activities over distance through mobile video conferencing solutions [11,33]. Mobile video chat allows participants to view the respective remote location and partially experience a remote activity. Yet devices such as smartphones or tablets provide only a limited field of view and the person has no control over the view which can cause remote users to feel a lack of immersion [14]. This limits if and to what extent people feel like they are actually part of a remote activity. Moreover, an absence of embodiment or physical representation (e.g., a body) in the remote location can create awkward social interactions [32]. Privacy issues may arise for bystanders caught on camera because they may not know a video call is taking place [32,38].

To address these problems, our research explores the use of telepresence robots as part of outdoor shared activities over distance. Telepresence robots have been studied in a myriad of contexts where researchers have noted the benefits of providing a mobile video conferencing solution with a representation of a 'physical body' in the remote space (e.g., [28,35,41]). Despite this work, we have yet to see telepresence robot usage explored as part of outdoor leisure activities that are shared over distance. Outdoor activities are interesting in that they often take place in wide-open spaces, are viewable by the general public, and contain various types of terrain and environmental conditions (e.g., weather, varied lighting, smells, obstacles). In contrast, indoor environments such as museums, hospitals, or workplaces are often well laid out, have a limited set of people present, and are generally not affected by weather. Thus, outdoor environments present different challenges in terms of navigating around and seeing clearly, as well as different opportunities for interactions with the general public. Studying telepresence-robot usage in outdoor public areas allows us to understand the technology's potential to operate within a broader scope of day-to-day life thatn has been previously studied.

In our study, two users participate in the outdoor activity of geocaching where one uses a telepresence robot called a Beam+ (hereafter called a Beam). The Beam is affixed with

CHI 2018, April 21–26, 2018, Montreal, QC, Canada

ACM ISBN 978-1-4503-5620-6/18/04...$15.00
https://doi.org/10.1145/3173574.3173933

a 360° camera for half of the study and the robot's regular wide field of view (WFOV) cameras for the other half of the study as a comparison. Geocaching is an outdoor treasure hunt game where players search for hidden containers in parks or urban areas using GPS coordinates or maps [27,30]. We selected geocaching as our focal activity because it usually contains several basic actions within it including walking, conversing about the environment, navigating to specific locations, and targeted searching for objects (often found in sightseeing) [32]. This builds on prior work on shared geocaching where users geocached together over distance using head-mounted video cameras [32]. Our research was exploratory and focused on understanding on what the experience of participating in an outdoor leisure activity with a telepresence robot would be like; what the benefits and challenges of using telepresence robots for the activity would be; and, whether field of view affects social presence for an outdoor activity when using normal cameras with WFOV compared to a 360° camera.

Our results reveal challenges that arose with the use of a telepresence robot in the outdoors, including privacy concerns, environmental issues, and interactions with the general public. We conclude that telepresence robots for shared outdoor activities should be designed to provide a greater range of sensory experiences for the remote driver and more contextual awareness of the remote driver's actions to the local partner. In addition, telepresence robots need to be designed with the environment and public in mind, so that they do not convey an unwelcoming appearance or provide a disturbance to bystanders.

RELATED WORK

Shared Experiences over Distance

Over the last decade, video chat has emerged as one of the main mediums for family and friends to connect over distance given people's ability to share facial expressions, gesture, and show locations [1,4,5,16]. People even use video chat for sharing activities such as cooking together [4], watching TV [8], eating together, expressing physical intimacy[9,25], and exploring new locations [4]. Yet such usage is not always easy as people often face challenges with limited camera views and camera work by a local person [4,14].

Researchers have also studied the use of video chat for sharing outdoor experiences over distance. One focus has been on creating a hands-free experience through different technology probes affixed to users with wearable cameras or a form of physical apparatus [2,20,26]. These systems, similar to our study, focused on sharing an activity with a static remote user and using hands-free prototypes for the local explorer. In general, users found the systems to be comfortable to use [13,20]. Study results showed that having control of the camera made the remote user feel more engaged [20] though some setups created privacy challenges around what was being shared [2]. Systems also have focused on outdoor activities and sharing contexts of the location using front and back camera views [11,19]. Results of both studies showed that participants felt more a part of the activity with the additional contextual information [11,19].

There are also studies that explore parallel experiences [26]. Here both users are out and about doing an activity but in different locations. For example, in shared geocaching [32] two users went geocaching in different areas while audio and video was streamed between them using a wearable camera and a smartphone attached to the user's wrist. Results showed that audio played a central role in creating a strong sense of presence and connection with the remote partner, while video was considered more secondary to the experience [32]. In shared bicycling, two users went for a bicycle ride with each other but in different locations [26]. Video and audio was streamed between bicyclists using two smartphones mounted to the bikes. For both shared geocaching and shared bicycling, because the remote user did not have a physical embodiment (e.g., a body) in the remote location, privacy challenges emerged around streaming video and audio in public settings [26]. Several studies have focused on sharing physical activities through audio alone [10,29]. In jogging over distance, users appreciated the experience and felt as if they were participating in the activity together especially when they had someone with the same pace [22-24,29].

While our work does not explore a parallel experience, we build on this research by exploring what happens when the remote user *does* have a physical embodiment in the remote location. This comes from the telepresence robot.

Telepresence Robots

Telepresence robots offer a form of mobile video communication and bring the added benefit of autonomy for the remote user who is now able to move around the environment. Telepresence robots have been found to increase one's sense of presence in remote workplaces and allow users to feel a better sense of social connection with their remote colleagues [21]. Yet telepresence robots at academic conferences have been found to create challenges around navigation and social interactions [28,34]. Telepresence robot usage in a restaurant and museum found that remote users had a richer experience compared to video chat but some interactions were awkward [36]. Studies have also highlighted features needed for telepresence robots when used indoors, such as a wider field of view, at least two cameras, and a navigation assistant system [6].

In recent years, researchers have looked at usage in home environments with distant family members and between partners in long distance relationships [41]. Results show that telepresence robots help create a sense of remote presence, similar to when a person is physically there [33,41]. This is because the robot has a physical embodiment in the remote location and, through that embodiment, they take up space, can bump into things, and can move to different places on their own [41]. These acts have been found to help create feelings that the remote person is actually present within the same environment as the local person [41]. Our work builds on this research by moving to the outdoors where additional environmental attributes (e.g., terrain, weather, a broader range of bystanders) have the potential to affect the experience. We also explore 360° camera usage coupled with a telepresence robot.

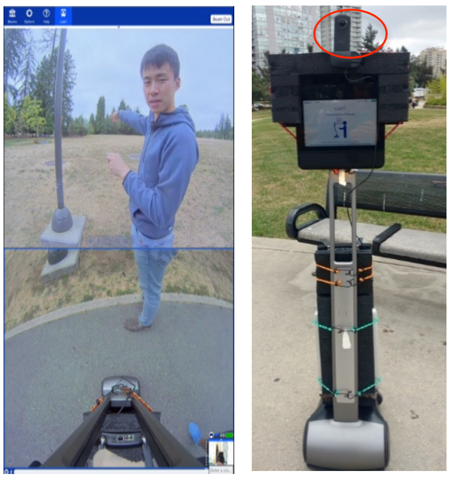

Figure 1. The Beam interface (left) and Beam robot (right).

360 Videos

360° videos offer one solution to the narrow field of view that normally comes with video communication systems. 360° videos can be viewed using head mounted displays as well as tablets. Using a head mounted display has been shown to lead to stronger feelings of immersion and emotional investment in the remote location [7]. Studies on 360° video show that using such technologies for exploring a new location can allow remote users to experience the location independent of the local explorer [16-18,40]. Using 360° video view with telepresence robots in indoor settings has also shown increases in task efficiency but it was more difficult to use for participants [12].However, it can be hard for the remote and local user to understand directions and orientation in 360° view (e.g., where they are looking) [40]. Users can also lack mechanisms to gesture and point at things in the environment [40]. In our study, we explore the role of the physical embodiment of the Beam (its monitor and body) as a possible mechanism for users to more easily interact and understand orientation and body language.

STUDY METHOD

We conducted an exploratory study to investigate shared outdoor activities over distance using a telepresence robot. Our goal was to understand what the experience of participating in an outdoor activity with a telepresence robot would be like; what benefits and challenges exist when doing so; and, whether changing the field of view from a normal camera to 360° view can affect social presence for an outdoor activity.

Participants and Recruitment

We recruited 14 pairs of participants (4 Female-Female, 8 Male-Male, 2 Female-Male) within an age range of 19 to 39 years (avg=24) through snowball sampling. All participants knew each other before the study; two were romantic couples and the rest were pairs of friends. 20 of our participants were students from university and 8 others had different jobs such as bank teller, designer, etc. 10 people had experience with geocaching and only 2 of our participants had used a telepresence robot prior to the study.

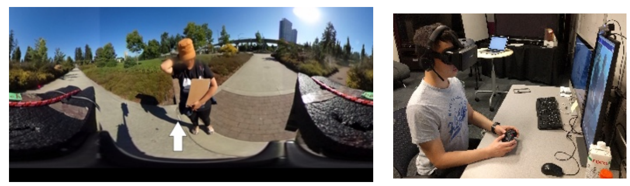

Figure 2. The VR view of the 360° live-video feed, as it was presented to the viewer through the smartphone-VR setup.

Telepresence-Robot Setup

We used a Beam+ commercial telepresence robot as part of the study. The robot was 134.4 cm tall and consisted of three wheels, a gray body, and a 25.4 cm monitor displaying the face of the remote user (Figure 1). A forward-facing camera and microphone are embedded in the monitor for streaming video and audio. A downward-facing camera below the display faces the ground to help navigate in the remote environment. For safety and to prevent damage, we affixed Styrofoam around the Beam's screen. We attached a Ricoh Theta S 360° camera to the top of the Styrofoam protecting the Beam (Figure 1, right, circled in red at the top) and connected it to a MacBook Pro laptop attached to the Beam's base. The laptop streamed the live 360° video from the camera to a remote viewer via WebRTC. The resolution of the streamed video (which included the entire 360° view) was 1280x640 pixels. The Beam and laptop were connected to a mobile hot spot with a 4G/LTE cellular signal and data rates of ~100 Mbps.

Desktop Setup

Users drove the Beam using a PlayStation-3 controller within a desktop application on an iMac computer with a Dell P2417H 60-cm-wide 16:9 monitor in portrait orientation; thus, the screen was 60-cm tall and 33.8-cm wide. The monitor was in portrait orientation to allow for the videos from the two camera sources of the Beam (which were each of 4:3 aspect ratio) to be adjusted to equal size and stacked one on top of the other. The 360° video was displayed on a Nexus 5X smartphone set to a Google-Cardboard VR configuration and placed inside a Xiaozhai I plastic case that was worn by the user. A white semi-transparent arrow was overlaid onto the 360° view in the VR configuration, to indicate which direction was forward in relation to the Beam (Figure 2, left).

Procedure

The study lasted 90 minutes on average for each pair (15 min pre/post questionnaires, 45 min activity, 30 min interviews).

1. Pre-Study Questionnaire: Participants completed a questionnaire focused on demographics and their experience with outdoor activities and playing first-person-shooter games. We wanted to understand their experience in navigating remote spaces with a first-person view. We then assigned one participant to be the *Local Explorer* (or just *Explorer*) and one to be the *Beam Driver* (or just *Beamer*) based on each participant's experience with VR and susceptibility to motion sickness. Those who had more experience and comfort with VR and/or less susceptibility to motion sickness were chosen to be the *Beamer*.

2. Tutorial: The *Local Explorer* and one of the researchers walked to a park near our university campus. The *Beam Driver (Beamer)* stayed at an office on campus. After reaching the destination, the Beam driver was instructed on how to drive a Beam and practiced driving in a small area.

3. Shared Geocaching Activity: Both participants were given a paper map of the park with flags indicating the location of four geocaches. Participants were asked to complete the task together as a team. We chose to give both partner the same paper map as opposed to searching with GPS coordinates in a geocaching app in order to simplify the activity slightly and provide a common reference artifact for both participants. If we had used a geocaching app, only the Local Explorer would have had access to seeing the map and the continual updating of their location.

The geocaches were hidden in an urban park consisting of asphalt walkways, trees, benches, tables and fountains. Geocaches were placed in locations where it was easy for both the Beam and the Local Explorer to reach (e.g., within a foot of the walking path). The radius of the area where the activity took place was less than 1km. The distance between each geocache was between 50 and 200 meters. Two of the geocache containers were 'micro' in size (about 2 to 3 inches) and two were 'regular' in size (a small Tupperware container). The micro geocaches were both magnetic key holder boxes, commonly used as geocache containers [27]. The regular-sized geocaches were both small Tupperware containers that were camouflaged to blend into a bush background. The geocaches varied in difficulty with two that would be considered 'easy' in the geocaching community (placed at the edge of a bush) and two that would be considered harder (placed under a park lamp stand and attached to sign) [27].

The pair's mission was to find all the geocaches in 45 minutes. The Beamer used the 360° camera setup for two geocaches, and the regular WFOV Beam camera for the remaining two. We counterbalanced which geocaches each pair found within the two different camera setups. We also counterbalanced the ordering of the two camera setups so that half of the pairs used the 360° camera first and half used the regular Beam cameras first. Thus, while our study was meant to be exploratory such that we could observe emergent behaviors, we included elements of quasi-control such that we could explore different design factors.

4: Interview: After the geocache hunting, we interviewed each participant separately to understand each person's experience. We asked about their general thoughts, what worked well for them, and what did not work well about the technology setup and activity. We asked how they communicated during the activity, how they navigated through the park, and how they felt about using a head mounted display for navigating in a 360° view. Interviews were semi-structured. We used an initial set of questions and probed for more details during responses. If something appeared interesting such as interactions with bystanders or styles of collaboration, we asked more questions to gain an in-depth perspective.

We used portions of the validated Networked Minds Measure of Social Presence questionnaire [3] to measure social presence based on co-presence, psychological involvement and behavioral engagement in each of our camera setups. This involved using 28 of the 38 seven-point Likert scale questions in the questionnaire. Some of the paired questions were dropped from the questionnaire because redundancy for our setup and context. Modifying this questionnaire is a common practice [31,35]. When answering the questionnaire, Beamers rated the degree to which they felt socially present in the remote location in the 360° camera condition and separately for the normal WFOV Beam cameras. Ratings were done after using both setups.

Table 1. The 19 main questions used from the Networked Minds Measure of Social Presence. Each question is asked from a first person perspective and their friend's perspective.

Co-Presence	
Isolation	- I often felt as if I was all alone - I think my friend often felt alone
Mutual Awareness	- I was often aware of others in the environment - Others were often aware of me in the room
Attention Allocation	- My friend paid close attention to me - I was easily distracted when other things were going on around me - I tended to ignore my friend
Psychological Involvement	
Empathy	- I could easily understand what my partner was doing when using the interface. - I was influenced by my friend's moods - My mood did NOT affect the other's mood
Mutual Understanding	- My thoughts were clear to my friend - My friend understood what I meant - I understood what the other meant
Behavioral Engagement	
Behavioral interdependence	- My behavior was dependent on my friend's behavior - What I did affected what my friend did
Mutual Assistance	- I worked with my friend to complete the task - I did not help the other very much
Dependent Action	- I could not act with my friend - My friend could not act without me

Data Collection and Analysis

Interviews were audio and video recorded and transcribed. We recorded the Beam's video feed and the participant driving the Beam in the private office so we could record actions that the participant might do. Two researchers accompanied the local Explorer in the park, one recorded video of the Beam and Explorer and the other took notes. We used open coding to label our findings within the interview transcripts. While performing this coding, we watched (and re-watched) videos of each of the groups to understand what happened during their session. Axial coding was used to group our findings into categories, which included the physicality of the embodiment, mobility and control, physical limitations, sensations, roads and unreachable areas, and a lack of environmental awareness. Lastly, selective coding was used to identify main themes through a refinement and selection process. Main themes included embodiment and social presence, the outdoor environment, and privacy and the general public. We conducted inferential statistical testing for responses to the Networked Minds Measure questionnaire [3] to compare the feelings of social presence across our two camera conditions, WFOV and 360°. Next we present our findings where we focus on our main themes. Quotes from participants are listed with a P# followed by a B for Beamer and E for Local Explorer, depending on the person's role.

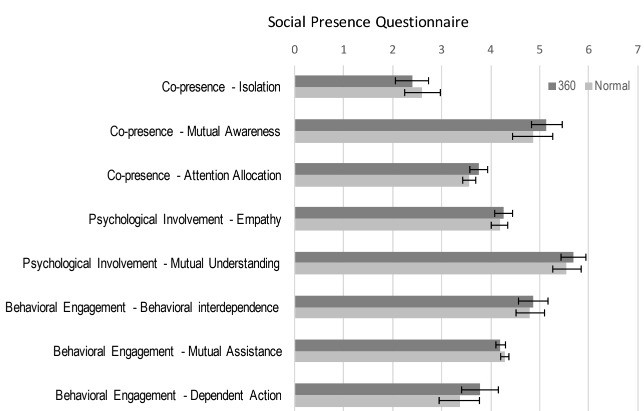

Figure 3. Mean ratings for the 360° versus normal (WFOV) camera condition for each of the eight scales of the Networked Minds social presence questionnaire [3]. Error bars depict ±1 standard error

EMBODIMENT AND SOCIAL PRESENCE

All participants said they enjoyed the activity of geocaching over distance. Five pairs found all four of the geocaches, six pairs found three of the geocaches, two found only one geocache, and one pair found none of the geocaches. Within these experiences, what stood out during our analysis was the ways in which the physical embodiment of the robot was used and affected the experience. Pairwise repeated-measures t-tests showed that the type of camera (360° versus normal WFOV) did not have any significant effect on any of the social presence measures depicted in Figure 3 (all p's > .13).

While our quantitative findings did not show statistically significant differences in most cases between the two views, our observations and interviews revealed interesting nuances around why participants chose these scores and how they experienced geocaching with a telepresence robot, described next.

The Physicality of the Embodiment

First, the physical embodiment of the telepresence robot led to all of the Explorers and Beamers in our study to have feelings of connection and presence with their partner. During our interviews, Explorers talked about extending their mental representation of their remote partner on to the telepresence robot. Here they visualized their partner as the robot and imagined that parts of the robot's frame were actual body parts of their remote partner. For example, P1E placed his paper map in-between the poles of the Beam's base and told his friend, "*please hold this for me!*" as if the gap between the Beam's pole was an imaginary hand for his friend. When the papers fell down, his Beamer friend told him "*oh sorry I dropped your paper, they were too heavy for me*" as if he envisioned his body in the robot. In another case, the participant repeatedly placed her hand on the Beam's pole to make sure the robot was staying with her and had the correct orientation. She talked about this as though she was holding the hand of her remote friend. In some cases, Explorers patted the Beam monitor as a form of endearment and affection. The Beamers talked about these experiences and, similarly, felt that the Beam was an extension of themselves. Thus, they noticed when the Explorer interacted with the Beam's physical form and said it, at least partially, created sensations of physically being in the remote location.

"It was interesting to be sitting in one location and be able to still be able to transfer somewhere else remotely. It was interesting to be able to just go down the park, down some of the roadways there and just casually chatting as I walked by people or whatnot. And then the one time that this other passerby stopped by, and he asked questions and whatnot." –P11B

Mobility and Control

Second, Beamer participants felt that their ability to control and change their own view led to strong feelings of connection with the Explorer. This mobility helped create feelings of immersion in the remote environment as seen in indoor settings [33]. This was especially the case when using the 360° video and the headset. As they collaborated to find the geocaches, the mobility allowed them to smoothly move into and out of close collaborative work where, at times, they were looking at the same area, and other times were exploring different areas within several meters of one another. Thus, they could both think about and explore independently while still enjoying each other's company. This was seen as beneficial when compared to a more typical Skype call on a phone or tablet, since, in that case, the video call would need to stay with the explorer.

“I felt like we still connected on a more emotional and even a physical level because I had free roam.” -P11B

“I could enjoy the environment on view…I could change my direction, go to the environment, go back, forwards, see the environment from different angles. And it could help me to come up with some new ideas...in Skype then probably I could not change the input to my eyes, so I could not come up with new ideas on how to geocache.” –P1B

Some close friends used the Beam robot to do tricks such as circling around or doing a “Moonwalk” for their friend to see. Another Beamer participant became bored during the study while the Explorer was looking in some bushes. As a way to still use his robot-self in the environment, he started chasing the researchers. He thought that in real life it would not be appropriate to bump into people or chase them, but in the robot, it was more socially acceptable.

“So if you are there you can't touch people, it's a little awkward. But then you are in robot, that's okay? You know, maybe. So, yeah, I maybe just by my instinct I tried to explore other possibilities there” –P1B

Since the robot was not always easy for the Beamer to drive, they occasionally accidentally hit their partner with it. Explorers tended to be annoyed by such instances, though such acts helped to further emphasize the presence of the remote user. Sometimes romantic pairs in our study purposely bumped into their partner as a method of presenting affection and gaining their partner’s attention.

Participants found driving with the 360° view to be harder to control than with the WFOV cameras. Yet, despite this, all of the participants said that they enjoyed the 360° view experience more as it made them feel more immersed in the remote environment. They were able to look around while driving and change their viewpoint by just moving their head. This was seen as being very natural to them. Sometime participants said they became so immersed in the remote space that they forgot about the location they were *actually* in and the fact that they were behind a desk.

“Looking around was just cool to see what's around me because I have control of what I want to see so in a way it felt more real because in real life you can always look around and keep walking forward.” –P5B

Like the past literature [40], it was sometimes hard for the Explorers to know what the Beamers were pointing at despite the inclusion of the physical embodiment. The Beamers wanted additional features to support a greater range of body language than what they were able to do by turning and reorienting the Beam. The Explorers wanted to be able to know exactly where their friend was looking in order to understand what they were pointing at more easily. This was more often the case when the Beamer wore the 360° view because their viewpoint did not always match the direction that the Beam was pointing, since they could easily look around the environment by moving their head.

“If I could somehow also see what P10B was seeing, P10B's point of view, on the screen. So I could see that maybe ... This didn't feel a problem because we both are in the proximity of each other.” –P10E

Two of our Explorer participants wanted to be able to share their own perspective with the Beamer so that they could see where they were looking at.

Physical Limitations

Our geocaches were all placed in locations at a height of a half meter or less. Beamers had difficulties looking at lower areas and wanted to be able to easily adjust the height of the Beam or have better options for a pan-tilt-zoom camera. This came up in both camera conditions. The speed of the robot was a problem for all of our participants. The speed of the Beam was set to 80% of its fastest pace to make sure participants would not run into obstacles or have motion sickness while using the 360° view. Some Beamer participants made jokes about the Beam’s speed when they could not go as fast as the ‘excited’ Explorer. Some told the Explorers to go faster and that they would reach the location at their own pace. This was a problem especially with pairs where the Explorer was impatient and could easily find the geocaches by themselves. This took away from the experience of doing the activity ‘together’ and made participants feel less connected with each other.

“Mostly I was just walking ahead because I was impatient and then when he gets there I could start looking for it but he can't really help me. So he's kind of just watching. And then, it's cool and I find it. When I found the [container] that I can show him what's inside, yes, that's nice.” –P5E

OUTDOOR ENVIRONMENT

The fact that the telepresence robot usage took place in the outdoors greatly affected participants’ experiences.

Sensations

First, outdoor environments often come with a range of sensations not common to the indoors. In our study location, this included the smells of flowers and greenery, warmth from the sun, the occasional wind breeze, and ambient noises from cars on the adjacent street and people walking through the park. Participants talked about how outdoor activities usually encompass seeing, smelling, hearing, and touching nature. Yet these sensations were lost or severely impacted for the Beamers. These feelings were independent of the camera view being used.

“The outdoor experiment is not just part of doing something together. It's just being outside, being in front of this, and being beneath the sun, enjoy the lights, smelling flowers, interacting with the environment, touch the grasses, talk to your friends. So, it changes your mood, because of all these natural things you can see there. But, when you are not there, just your Beamer is there, so you

will lose all these parts, so you cannot do some sort of physical activity which gives your brain some more endorphins…So it was less enjoyable." – P1B

In contrast, one participant was jealous of his friend driving the Beam from an indoor office with air conditioning while he was in the outdoors in hot weather. This shows the discrepancies in the environments of the two users, which, at times, affected their experience and made it feel less than shared.

Roads, Paths and Unreachable Areas

Second, an outdoor environment meant that the Beam had to move across different surfaces, including pavement that was not always level and would switch between cobble stones and smooth asphalt. Sometimes Explorers would leave the pathway to search for the geocaches on grassy areas, even though all geocaches were hid next to the sidewalk. This restriction led to different reactions from our Beamers. Some started to look at the clues on the map, while others would simply 'give up' or feel useless because of such limitations.

The surface of the pavement and the edges being unlevel caused the robot to lose balance sometimes and almost fall on the ground. This caused the Beamer to be more cautious around places with bumpy pavement or near the edges of the walkway. This detracted from participants' ability to focus on their partner and do an activity with them. This distraction was more prevalent in the 360° view because the default WFOV showed directional lines on the Beam's interface to show where the robot was heading. This feature was not available on the 360° view.

"I was careful not to get too close to edges. Edges of the sidewalk, so the robot wasn't in the grass, even though that did happen two times. I tried not to get too close to anything cementy, because I didn't want the robot to fall over, and I tried not to bump into people." –P3B

Sometimes when the Beam was stuck on unlevel pavement, the Explorers would pick up and move the Beam for the remote Beamers. Explorers asked for the Beam to be lighter so that they more easily perform such movements. Yet these types of movements were problematic because quick view changes in the 360° view created feelings of motion sickness for the Beamer.

"I tried to not go there because when I go to the grasses, then somebody need to take the robot and put that in the street. And then you do that ... and if your view changes fast you will be shocked with the slight motion sickness, because you don't move but the view changes fast." –P1B

Lack of Environmental Awareness

For several reasons, our participants were not always completely aware of the environment and people around them. They could see the paths and could, most of the time, comprehend where they were in relation to the paper map given to them. Sometimes they even helped lead the Explorer to the right geocache locations. However, there were times when their comprehension of their location became very limited and some participants were noticeably confused. One reason for this was that controlling and driving the Beam required a lot of mental effort. They needed to look at their surroundings, drive, and follow their partner at the same time. This took away from one's ability to feel like they were doing an activity with their partner.

"Honestly, I not really paid attention around them, because I was just being with my friend, so I didn't look around for them, the people outside. And for the view, I just look forward. I couldn't see anything on the left, on the side (Normal view). Yeah. " –P9B

Sometimes a lack of environmental content awareness caused the Beamer to be in situations or locations that created problems. This occurred for both camera views. For example, in one instance, a Beamer was unaware of the surroundings and the location of a group of people. Individuals in the group had previously asked the Explorer and Beamer to stay away, but the Beamer did not realize that they were heading back to the same area. When the Explorer asked the Beamer to use another path, the Beamer kept insisting on using the first path, not realizing the awkward social situation that he would be heading into.

PRIVACY AND THE GENERAL PUBLIC

We asked our participants whether they had any privacy concerns about using the Beam in a public setting around others in the park. First, there were challenges around undesirable interactions with members of the public, as just described in the previous section. In these situations, Beamers sometimes invaded the privacy of those in the general public through their interactions with them.

Second, participants wanted a greater sense of privacy for some of the conversations that they had with their partner. We observed some participants trying to talk privately to each other about people that they saw in the park. For example, P14 talked about a homeless person that they saw who began cursing at them when they were nearby. Other participants talked about people they thought 'looked funny.' In these cases, participants told us that they wanted to be able to whisper to their partner, but it was hard to judge the volume of one's voice.

Third, many participants (both Explorers and Beamers) expressed concerns over the additional attention that they received because of the novelty of the technology in the public park. Instead of it being a somewhat private activity that they were doing with their partner, geocaching with the Beam drew attention and it sometimes felt like the activity was 'too public.' This tended to be more the case for Explorers in the park, rather than Beamers in the remote office, and it took away from the Explorers' experience.

"I think that people look at her, because she's talking with a robot. Not me, because I'm standing alone in my room, so I don't care about that. It's just normal video call. But for

her, it's different. She's outside with a robot, and then people look at her, and they look at me and the robot, and curious." –P8B

One of the Beamers said he felt self-conscious since his face was being shown on a monitor in the public. This was different than being physically present because people were attracted to the technology, making him more noticeable.

A fourth major concern for our participants related to the privacy of people in the park. They felt that bystanders in the general public may not like that they were streaming video, or they might think that video was being recorded of them. In fact, this even happened twice during the study where participants were asked by bystanders if they were recording what they were doing. For example, one of the bystanders who was sitting with a group of friends at first thought the Beam was a camera that could be controlled and was capturing everything that was going on in the park for security reasons. The bystander started shouting to turn off the camera otherwise he would break the "expensive" camera. This confrontation caused our participant to ask for a robot that did not look like an autonomous camera.

One Beamer found that because he was not physically present in the park, it was easier for him to accidentally stare at people in the park through the Beam. The Beamer felt it was wrong of him to look at others while they were not really considering him as a person in the environment.

"Once I notice myself like kind of looking at people when I realize they didn't know. I try not to do that like intentionally ... I felt like I was invading others privacy at that point because I was there but not really." –P5B

Other participants tried to ease the potential concerns that they felt the general public might have about being streamed over video by directly interacting with them and introducing themselves. They felt that by being friendly, people might have less of a concern.

"I said hello to some of the passersby as I went by, and then [my partner] was like hey, it looks like you made a friend ... I would want to be said hello to as I walked by one of these things." –P11B

In another case, an Explorer tried to make the robot presence seem like more of a human presence than a machine, especially when she felt they might be invading people's privacy. On one of the study days, the park was hosting an event for dogs with several kiosks near one of the geocaches. An animal photographer had set up her photo shoot station next to where the Explorer needed to be. The Explorer told her Beamer friend to say hi to everyone there to make them feel more comfortable with the presence of the Beam. This caused the photographer and the couple with their dog to be very friendly and comfortable with the presence of the robot.

SAFETY

Our study revealed very different reactions to safety by the Explorers and Beamers in our study. The park where our study took place contained a range of different people using the space. This included parents and children, joggers, bicyclists, children and their friends, teenagers, and homeless people. At times, participants felt safety risks, particularly in relation to homeless people who would sometimes approach the Beam and Explorer and wonder what they were doing. Explorer participants felt that having the remote partner present in the Beam made them safer. Some participants even extended this feeling to other contexts beyond just our study park.

"Maybe if I was lost in the wild or I have to go to some places for some reason but my friends can't go with me. I can bring one of these. Since it's seen in some way. Yeah I'm certain that it works." –P7E

While our Explorers in the park sometimes worried about people around them or that the location of the geocache was crowded, the Beamers had a much different sense of the social situation and tended to feel safer, even to the point of feeling 'immortal,' in some cases. Here we found a general lack of concern from the Beamers about the safety of the technology itself and the potential for it to be stolen or damaged in the park. Instead, the onus on such safety and security was placed in the hands of the Explorer, or, not really considered at all.

For example, P5E was worried about a couple of people near his geocache and told his Beamer friend about his concerns. His Beamer partner told him that he should not worry since the Beamer could scare the people away with his robot self, as if he had an advantage of not being there physically and being embodied as a machine. In another case, an Explorer was surprised to discover that his Beamer partner had struck up a conversation with a homeless person in the park. In response, the Beamer told him that he was immortal while being embodied within the robot.

"*What are they going to do to me? Pull out my cables!? I'm immortal!" –P11B*

In some cases, the 'immortality' that came with being in a telepresence robot dissipated as a result of deeper interactions with the general public. For example, during an evening study session, a group of teenagers were gathered, smoking near one of the geocaches. The Explorer felt uncomfortable about reaching the location and asked the Beamer to finish searching for the geocache. When the Beamer approached the group, they were amazed by the robot and became excited. They began talking to the Beamer and invited him over. This was not the case for the Explorer. Instead, the participants said that the group appeared to be more comfortable with the Beamer than himself. When the Beamer drove over to the group, however, they began blowing smoke at his camera and pulled at his poles, threatening to take him away. In that moment, the Beamer felt uncomfortable and started to feel as if he was bullied. The Beamer participant further felt scared about the situation because his face was shown on the Beam display and the group of teenagers now might know who he actually was.

"I felt a little bit nervous, actually, because I realized, I'm pretty sure my face was being shown on the screen, on the laptop attached to the robot, so they could see that there's somebody there. And I was a little bit worried that some people might just interrupt the process a bit too much, like what happened, like people interested in what the heck's going on here and maybe disrupting it or something like that, like what happened." –P8B

In the related literature, we have already seen that people in telepresence robots at academic conferences have felt bullied [34]. These results build on this idea and show the effect of having different demographics and types of people within the environment occupied by the telepresence robot.

DISCUSSION

We now discuss the main implications of our results for the design and use of telepresence robots for shared outdoor activities, and we propose a set of design solutions meant to improve the experience of participating in shared outdoor activities through telepresence robots.

Perceptions from Explorers and Beamers

While telepresence robots can provide a rich experience for the Beamer, and 360° views have the potential to enrich those experiences, the Explorers' sense that the Beamer is present in the space and participating in the activity is still limited. Participants generally felt like they were 'with' their partner, but, to many pairs, it felt less like a shared activity in the sense of completing a physical task together. Beamers said that this lack of involvement and the fact that they were dependent on the Explorer made them value the experience less and in some cases feel like an observer only. Because of the Beamer's ability to move autonomously, the Explorer felt free and independent of the Beamer, which meant he or she could complete the activity alone, if desired. This contrasts past research, which found that users felt a strong sense of having a shared experience in situations where remote users had to rely on local people [11,36].

Providing additional awareness to the Explorer of what the Beamer is doing in his/her own space could give the Explorer greater assurance that his/her partner is interested in the shared activity and that he/she is making active attempts to participate in it. As it is now, the screen on the robot still mimics a 'talking-heads' experience, and it does not do much to communicate that the Beamer is actively participating in the activity. Many Beamers moved the robot around the park a bit while their partners were in an area inaccessible to the robot, because they felt that this conveyed more than just sitting still. Previous work has shown that providing additional contextual information can enhance the experience of sharing activities over video calls [19]. This could potentially enhance shared experiences via telepresence robots. A simple solution could involve increasing the FOV of the Explorer's view into the Beamer's space, or showing what the Beamer is looking at (e.g., on the computer screen, or through the 360° view).

The Explorer has a vested desire to see the Beamer's face, and this was one of the reasons why Explorers in our study kept in front of the robot. They could only see the Beamer if they could see the front of the robot. When conversing, Explorers also often kept close to the front of the robot because the sun's glare would make it difficult to see the Beamer's face on the screen. In addition, with the 360° view setup, even though the Beamer's head gaze was visible on the screen of the robot, it was not always obvious to the Explorer which way the Beamer was looking. Adding more natural representations of the Beamer's head gaze on the robot would be beneficial. A simple solution could involve the use of LED lights on the robot.

Interactions with Bystanders

Previous work studying telepresence robot usage in indoor environments such as conferences has shown that telepresence robots often draw unwanted attention from bystanders [6,36]. The Beamer, being displayed front and centre on the screen of the robot, easily becomes the centre of this attention. This is also the case for usage in public outdoor environments; however, the implications of this are potentially more severe in outdoor public spaces, where the demographics of those present vary more as well as their expectations around technology usage, privacy, and video streaming. Bystanders might neglect to treat the Beamer with the same respect he/she would receive if physically present. Bystanders may bully, intimidate, or hinder the Beamer (as was also found by [34]), and these actions can affect the shared experience. Bystanders could also interrupt the activity or conversation without invitation. Unwanted attention and bystanders' reactions to the robot can easily break the illusion that the Beamer is present in the space as a person.

The biggest aspect that draws attention to the robot is the fact that the robot is unfamiliar to most people, which we have also seen from bystanders in indoor public areas [36]. Many people, out of curiosity, will approach the robot to inspect it and learn more about it. In our study, some bystanders were concerned that the robot was a moving camera deployed to record illegal activities, and these bystanders had privacy concerns. Given time, as the novelty of these robots wears off, bystanders may be less inclined to approach and interrupt them [37]. Past research has shown that the appearance of telepresence robots can affect how people interact with them [21,35 ,36]. Our results build on this idea and suggest that designers need to design telepresence robots such that they convey more that they are a means of bringing a person into the space, and less that they are (for example) just a moving-camera machine.

Taking steps like these might help reduce unwanted attention and make bystanders more comfortable with the presence of the robot. A simple solution could involve giving the robot features that make it look more human (e.g., clothing, arms), while avoiding uncanny appearances.

Another aspect that draws attention to the robot, as was also found by in past research [28], is the fact that Beamers are generally not aware of how loud their voices are being transmitted in the remote environment. In the outdoors, a loud speaker volume is sometimes necessary in order for the Explorer to hear the Beamer over ambient noises. However, not all areas in the outdoors are loud, which exacerbates the problem of knowing how loud one is. Our participants also wanted to be able to whisper at times to each other in order to have a private conversation where they talked about others in the environment. To our knowledge, this is the first time that a study of telepresence robots has found the need for pairs to talk directly about those around them, in somewhat of a gossiping fashion.

Simple solutions to these audio problems could involve providing the Beamer with better feedback of the robot's volume, or having the volume automatically adjust to appropriate levels, based on the surrounding noises. Similar ideas are suggested in the related research [28,34]; we show their applicability in outdoor settings for leisure activities. Other solutions might involve streaming audio directly to the Explorer through an earpiece, though this raises questions around whether or not this might take away from the feeling of being truly embodied in the remote space since only the one user would be able to hear the remote person. It would, however, permit users to privately whisper with one another. Hybrid solutions that allow users to smoothly transition between earpieces and more public speakers within the Beam would likely be most appropriate.

Senses

Sensory experiences of the activity environment are still limited for the Beamer, in comparison to physical presence. These sensory limitations create consequences that affect a pair's shared experience. To begin, the senses of smell and touch are completely missing for the Beamer. Some participants mentioned that they thought the smell of nature is one of the most enjoyable aspects of being outside. Others mentioned that the feeling of the sun's rays, the wind blowing, or rain or snow falling were also enjoyable aspects. In addition, people who share a close relationship with each other often interact through touch. While we did see instances of the Explorer touching or tapping the robot, and other instances of the Beamer driving the robot into the Explorer intentionally to give a playful tap, the natural sensation of touching another human is missing.

While the sensations of smell, physical touch, and feelings from environmental conditions like wind cannot be completely recreated in a telepresence environment, attempts at recreating them may add some benefit. Smells could be reproduced by, for example, using incense candles. Wind and temperature conditions could be mimicked through, for example, the use of fans, heaters, and air conditioners placed throughout the room. The sensation of touch could be recreated by, for example, placing touch sensors on the robot, and having the Beamer wear actuators that vibrate when the robot is touched. Similar prototype systems for communicating via touch across distances have been explored in video-communication contexts (e.g., [39]). Incorporating similar designs in a telepresence robot context might add to the feeling of presence and to the value of shared experiences.

Physical Abilities, Control, and Reach

Telepresence robots are designed to give users more control. As opposed to traditional video-communication tools like Skype and FaceTime, telepresence robots allow users to move around the space and control their own view of the environment. This increased control gives the user more freedom to act the way he/she wants as it has been reported [6,33], and increased ability to not only contribute to the activity, but also influence the direction it takes.

CONCLUSION

Our work builds on the related literature by exploring the use of telepresence robots for supporting outdoor leisure activities over distance. Here we focused on geocaching as an exemplar activity given that it contains a variety of basic activities within it including, walking or hiking, conversing, and looking for specific objects (similar to sightseeing). We found that by having a physical embodiment in the form of a telepresence robot, remote participants felt a strong sense of presence in the remote space. The mobility of the robot aided these feelings. The experience was limited, however, as remote users did not always have a strong understanding of the environment and they missed out on sensations typical of outdoor spaces, e.g., smells, wind, warmth from the sun. We also found challenges as a result of being in a public space with a variety of people with the potential for different perspectives and safety and privacy issues.

These findings show that if telepresence robots are to be used to support outdoor leisure activities, similar to those we studied, that designs can be improved through the incorporation of additional environmental sensations as well as features to balance safety and privacy issues resulting from being amongst the general public. Of course, outdoor leisure activities can be more complex than the basic activities we studied. They might, for example, involve sports or activities with greater movement (e.g., throwing a Frisbee). It is likely that our findings about safety, privacy, and environmental concerns with telepresence robots extend to other settings, yet different types of telepresence robots would certainly be required with additional capabilities (e.g., faster movement, arms) for other more complex types of leisure activities.

ACKNOWLEDGMENTS

This research was funded by NSERC of Canada.

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