Using Co-Design with Streamers and Viewers to Identify Values and Resolve Tensions in the Design of Interpersonal Wearable Telepresence Systems

KEVIN P. PFEIL, University of North Florida, USA
KARLA BADILLO-URQUIOLLA, University of Notre Dame, USA
JACOB BELGA, University of Central Florida, USA
JOSE-VALENTIN T. SERA-JOSEF, University of Central Florida, USA
JOSEPH J. LAVIOLA JR., University of Central Florida, USA
PAMELA J. WISNIEWSKI, Vanderbilt University, USA

We conducted a co-design study with 26 users in dyadic groups who were assigned to the opposing roles of "Streamers" and "Viewers" to design interactive, wearable telepresence prototypes for interpersonal use. The goal was to elicit values, identify value tensions, and resolve these tensions in the design of a system that allows Streamers to share their live experiences with a remote Viewer. Leveraging the lens of value-sensitive design (VSD), we found that these different stakeholders prioritized different values in design, but possibly due to our prompt to design for someone they cared about/knew, often accounted for one another's needs in their solutions to arrive at designs that were affordable, unobtrusive, and socially acceptable for the Streamer, while giving the Viewer a sense of autonomy. Our work highlights the strengths of co-design when eliciting important human values in the design of sociotechnical systems for wearable telepresence, reconciling value tensions, and conceptualizing novel hardware- and software-based solutions for enhancing the interpersonal telepresence experience of both viewers and streamers. A key insight from our study is that no single system will meet all users' needs; therefore, we should move towards building customizable toolkits to account for differing values and needs.

CCS Concepts: • **Human-centered computing** → *HCI design and evaluation methods*; **User centered design**; *Mobile computing*.

Additional Key Words and Phrases: telepresence, co-design, shared experiences

ACM Reference Format:
Kevin P. Pfeil, Karla Badillo-Urquiolla, Jacob Belga, Jose-Valentin T. Sera-Josef, Joseph J. LaViola Jr., and Pamela J. Wisniewski. 2024. Using Co-Design with Streamers and Viewers to Identify Values and Resolve Tensions in the Design of Interpersonal Wearable Telepresence Systems. *Proc. ACM Hum.-Comput. Interact.* 1, CSCW1, Article 148 (January 2024), 21 pages. https://doi.org/10.1145/3637425

Authors' addresses: Kevin P. Pfeil, kevin.pfeil@unf.edu, University of North Florida, Jacksonville, FL, USA; Karla Badillo-Urquiolla, kbadill3@nd.edu, University of Notre Dame, Notre Dame, IN, USA; Jacob Belga, jacob.belga@ucf.edu, University of Central Florida, Orlando, FL, USA; Jose-Valentin T. Sera-Josef, Jose.Valentin.serajosef@knights.ucf.edu, University of Central Florida, Orlando, FL, USA; Joseph J. LaViola Jr., jjl@cs.ucf.edu, University of Central Florida, Orlando, FL, USA; Pamela J. Wisniewski, pamela.wisniewski@vanderbilt.edu, Vanderbilt University, Nashville, TN, USA.

ACM 2573-0142/2024/1-ART148
https://doi.org/10.1145/3637425

1 INTRODUCTION

Telepresence refers to perception of and/or interaction with a remote environment [41], including remote exploration of an environment using robotic platforms [35]; research in this area typically focuses on remote work or live-streaming (one-to-many) contexts, but there is an emerging paradigm using wearable technology that focuses on one-to-one shared experiences for leisure or recreation [53] — we refer to this paradigm as "*interpersonal wearable telepresence*". For instance, a *Streamer* could capture their environment with a head-worn 360° camera (e.g. [26]), and an at-home *Viewer* could use a Virtual Reality (VR) Head-Mounted Display (HMD) to feel like they were there. This paradigm has significant value as it can help let friends and family who are separated by distance feel closer together [2, 11, 13, 20, 25, 30, 51, 60, 72, 73], and it can even allow strangers provide remote assistance [10, 21, 45, 57] or explore a remote destination together [16, 22, 39]. Such use cases are becoming prevalent with the cost of interactive technologies declining, making telepresence technologies more accessible to the general public. As such, there is now opportunity for us to create more meaningful experiences that enhance interpersonal communications. Many wearable systems presented in the SIGCHI literature have been created to facilitate interpersonal telepresence, but these tend to focus more on the features the Viewer can enjoy, with a lack of work to support the Streamer (see [53]). Further, prototypes in this domain have typically been developed and summatively assessed by end users, with little or no input from users in the design phase (see [59]).

As a result, systems-based interpersonal wearable telepresence studies have surfaced negative consequences of their designs, such as boredom and self-consciousness. Novice users feel embarrassed even when using simple devices like smartphones in public [55, 56], which indicates a specific need to focus on designing a prototype that meets their needs. We attribute this finding to value tensions between the different stakeholders, and as such, there is an outstanding need to query prospective users early in the design process to identify what would truly be desired from a potential system. One way to identify such desires is to understand the human values that are important in this context. The Value Sensitive Design (VSD) framework can be used to identify stakeholders, the potential benefits and harms to those stakeholders, and the values that envelop those benefits and harms [15]. The primary stakeholders of interpersonal wearable telepresence are the Streamers and Viewers, but there is a lack of understanding about the values that should be embedded in future prototypes to meet their needs. Thus, our work is guided by the following research questions:

RQ1: *What stakeholder (Streamers and Viewers) values should be embedded in an interpersonal telepresence system?*

RQ2: *How can we resolve the value tensions between Streamers and Viewers to realize a real-world system that enhances both users' experiences?*

To answer these research questions, we conducted a value elicitation study [15], in the form of co-design sessions [58], in which we asked dyadic groups of diverse individuals who did not know one another to collaboratively identify and justify the features that should be incorporated into a wearable telepresence prototype. The co-design technique used in this work was "Bag of Stuff" [14], with a novel application of a "Paper Dolls" protocol [19], using design materials representative of the literature (see [53]). Our participants were split into two groups — one was asked to design from a Streamer's point of view, and the other was asked to design from a Viewer's point of view, yet both were instructed to design a prototype that would let them and a friend enjoy a remote experience together. Overall, we found that our participants, though instructed to take a greedy approach, made considerable effort to ensure that the other party would still be satisfied. As such, it was not difficult to converge upon the values that matter in this context. In summary, an ideal prototype would afford the Viewer with autonomy and ample exploration capabilities, while minimizing the

Streamer's physical burden and social risk. Through this research, we make the following research contributions:

(1) We present a user-centered co-design study that allowed stakeholders to make direct design decisions for interpersonal wearable telepresence, using Value Sensitive Design and prior, proven methods in value elicitation.
(2) We present a set of design requirements / values that enable developers and researchers to balance the Viewer / Streamer power distribution.
(3) We plan the next wave of wearable telepresence research that includes empowerment of stakeholders through the creation of tangible telepresence toolkits.

In the following sections, we discuss the related work that influenced our study methods, followed by a description of our procedure and data analysis approach. We follow with the results, including a codebook that captured emergent themes from participant feedback, followed by a discussion that includes design considerations for wearable telepresence.

2 RELATED WORK

In this section, we review the relevant literature that motivates the need to restrategize development of interpersonal wearable telepresence prototypes. We identify inherent goals of this paradigm, discuss paramount socio-technical considerations, and discuss how the inclusion of VSD assists us in directing research efforts towards what users desire.

2.1 Telepresence Goals — Spatial and Social Presence

Conceived by Minsky in 1980, telepresence traditionally refers to interaction with a remote environment through a robotic platform to complete a task, as if "actually there" [41]. Today, the term also refers to a variety of remote interaction technologies, including teleconferencing [36] and mobile robotic presence [35]. By "actually there," we refer to the user's perceived sense of *presence* [61, 70]. We note there are multiple sub-constructs of presence [49] — *spatial presence* (the sense of being in the remote or mediated environment [62]) and *social presence* (the sense of togetherness while interacting with another person through mediated communication [4]). One goal for this domain is to enhance the Viewer's spatial presence while simultaneously fostering social presence for both stakeholders, but a recent review found how studies rarely measure Streamer social presence [53]. If the Streamer uses a head-worn or 360° camera, the Viewer can essentially see the remote environment through their partner's eyes (e.g. [26, 55, 63]). Some studies show how panoramic video provides greater spatial presence [46, 75], but many researchers use body-worn mobile phones to capture an environment [2, 21, 24, 30, 67]. To potentially enhance spatial presence using mobile devices, researchers have actuated the cameras, so the Viewer could look where they desire [31, 33, 34, 64]. Others designed miniature avatars that sit on the Streamers' shoulder, such that the Viewer could further interact with the environment [29, 42, 65]. To enhance the sense of social presence, researchers have used techniques to let the users see their partner. By situating the camera away from the Streamer's body, the at-home user can see their partner [30, 63]; but, this does not let the Streamer see the Viewer. Researchers demonstrated how the Streamer could use an Augmented Reality (AR) display to show an avatar representing their partner [9, 10], or a simple graphic that depicts where they are looking [3, 27, 74]. Though more work is needed to evaluate these techniques, they are promising alternatives to *not* seeing one's partner. These previous efforts are valuable, in that they demonstrate features which could enhance the sense of spatial or social presence. However, these prototypes are typically created without stakeholder input; as we discuss in the next section, even the simplest of devices have been deemed unsatisfactory when viewed through a socio-technical lens. Our work aims to correct this problem by ensuring all stakeholders have a voice earlier in the design phase.

2.2 Outstanding Socio-Technical Gaps in the Interpersonal Wearable Telepresence Literature

A recent review of interpersonal wearable telepresence literature highlighted socio-technical considerations which must be addressed [53]. In summary, Viewers sometimes feel disinterested or disenfranchised while using various technologies [13, 48, 56], and Streamers sometimes feel self-conscious even while using common devices [30, 48, 55, 56]. While it is currently unknown if or how these problems would stop people from wanting to use a telepresence system, it is clear that certain designs are not accessible to all. Field studies identified how some people feel bored when viewing shared experiences with devices like smartphones [13, 48]. Naturally, the Viewer cannot look where they want in these cases; but in a study by Rae et al., participants negatively felt reliant on their partner for everything [56]. To counter these feelings, researchers have developed capabilities to support Viewer autonomy, with technology such as 360° cameras; but as some researchers found, these become difficult and frustrating at times, as there is a disconnect between what both users see [63]. Other works posed solutions to this problem, such as AR feedback [3, 9, 37], directional vibrations [40], and 3D spatial voice [47]. These solutions are promising as they tackle a known problem, but they generally include more equipment; however, obtrusive prototypes can negatively affect the Streamers' experience. The literature discusses Streamers' use of many non-traditional devices, including head-worn cameras [3, 9, 28, 43, 44], chest straps [21, 56], and robotic avatars [29, 33, 65]. Although these give the Viewer a stronger experience, they are noticeable. Others use simple video chat applications, but the interaction style (holding up a cellphone) makes the Streamer stand out [16, 17, 60]. Unfortunately, even simple setups and interaction styles can cause users to feel self-conscious [30, 55, 56]; if we are to ensure equitable experiences, we must reduce these negative effects.

In our work, we therefore conduct co-design sessions that specifically ask participants to make designs for two scenarios — one to enhance the Viewer's experience, and one to account for a self-conscious Streamer. We draw from previous literature and develop our co-design materials by representing devices that have been included in previous research. The work in this space is rapidly evolving, and prototypes of today will be obsolete in the future. In our work, we do not focus on identifying specific hardware, and instead present values for which *any* future designs can account.

2.3 Applying a Value-Sensitive Approach Using Co-Design Methods

While it is beneficial to develop new prototypes, the technology is rapidly evolving. At the same time, the literature presents evaluations of prototypes without asking users what they desire before design begins. As such, we find it appropriate to focus less on the technology, and more on the values that should be embedded in the technology, by gathering earlier user feedback. Co-design and value elicitation methods can help us reveal design parameters earlier in the cycle, and these methods have been conducted in computing for various domains [18, 38, 58]. For our work, in which we apply these methods to the novel domain of interpersonal telepresence, we were challenged to find a co-design approach suitable for wearable technology design. For our work, we thus apply the VSD framework, a theoretically grounded approach through which we can systematically embed values within the design process [15]. As Pommeranz et al. explain, paramount values could be out-ranked by what might otherwise be viewed as lesser values [54]. For instance, financial security may be important for many, but perhaps a parent would spend more money if it brought happiness to their child. Borning and Muller [6] discuss how identifying values can lead to the creation of new design heuristics, as future developers can reflect on their artifacts and ask if they truly capture what is valued by their end-users. Thus, it follows that we must be more mindful of values in any given context; and as there has been no work to identify values for interpersonal wearable telepresence, our work helps fill this gap. Although the literature has presented valuable feedback from users, most of this feedback has come in the *evaluative* phase of research (the point when an artifact is typically deployed with users; see [59]); there is opportunity to query users in the *pre-design* phase, before any solutions are created. Co-design is a shift in attitude from designing *for* users to designing *with* users, to develop systems around users' needs; this methodology fosters dialogue between researcher and stakeholder, enabling us to understand different perspectives and make better decisions for future design goals. Our work contributes to the interpersonal telepresence literature by using co-design to elicit values which can influence future prototypes.

3 METHODS

Previous work describes how the current trend in the wearable telepresence literature is the creation of prototypes aimed at providing new features. As illustrated by Sanders and Stappers [59], these kinds of work fall into the *Generative* and *Evaluative* phases of research, where user feedback is collected by deploying a technology probe. No work in the wearable telepresence domain (to our knowledge) has been conducted in the *Pre-design* phase [59], but such work could help resolve concerns much earlier in the design process; our goal is to fill this gap. As such, we devised a co-design study to elicit values that should be embedded in future designs, and since technology in this domain rapidly advances, our aim did not include identification of features. As Borning and Muller [6] discuss, values can be used as heuristics when creating a new artifact; i.e., we can be more mindful to ensure a future feature envelopes these values. In the following sections, we discuss the co-design sessions we held with diverse, prospective users of wearable telepresence, including the organization of these sessions and materials used, to identify these values.

3.1 Co-Design Session Overview

We conducted 5 co-design sessions with 26 participants to identify values that should be embedded in future interpersonal telepresence prototypes. This study was conducted during the COVID-19 pandemic, and we did not want to exclude anyone from our study by conducting the sessions in-person; we held our sessions online to eliminate health risk by using a private Zoom call. We received IRB approval to conduct our study, and consent was obtained electronically prior to

Table 1. Design prompts issued to our participants. The scenario was constant, but each group was asked to approach the prompt from a specific perspective (Streamer or Viewer).

Viewers	Streamers
You and a friend wanted to go to Disney Springs together. Disney Springs is a Disney-themed entertainment, dining, and shopping area in Orlando, Florida. However, due to a health concern, you need to stay at home. So, your friend is putting together a new live-streaming prototype that will let you feel like you are actually there. **They want to design it in a way that will let you have the best possible viewing experience. Our job is to design this prototype.**	You and a friend wanted to go to Disney Springs together. Disney Springs is a Disney-themed entertainment, dining, and shopping area in Orlando, Florida. However, due to a health concern, you need to stay at home. So, your friend is putting together a new live-streaming prototype that will let you feel like you are actually there. **However, they tend to feel self-conscious in public. They want to design the prototype in a way that will let them feel most comfortable when using it. Our job is to design this prototype.**

the study sessions. Each session followed the same agenda: first, researchers and participants introduced themselves and their microphone functionality. Sharing video was not required, but was encouraged. Then, co-design activities were conducted in the following order: 1.) Icebreaker and Scenario Brainstorming, 2.) Designing an Initial Prototype, 3.) Presenting Big Ideas and Design Critiques, and 4.) Designing a Balanced Prototype. At each session conclusion, participants were instructed to complete a final survey in which participants could provide further insight into their design decisions or any additional feedback; this enabled participants to state anything they were not comfortable sharing with the group. The approximate length of each session was 90 minutes, and participants were compensated with a $20 USD Amazon gift card. All activities were audio- and video- recorded for analysis, and the recordings were manually transcribed. In the following sections, we describe each of the activities in detail.

3.1.1 Activity 1: Icebreaker and Scenario Brainstorming. First, the lead researcher described the purpose of the study and introduced the concept of interpersonal wearable telepresence. Then each participant was asked to share a recent live-streaming experience in an ice-breaker activity. They were given two prompts:

- *Think about the last time you watched an "in-real-life" mobile live-stream. What was the scenario?*
- *Think about an activity you would like to watch in an "in-real life" mobile live-stream. What is it?*

Participants were encouraged to verbally share as much information as they wanted, and the lead researcher followed up with various questions as necessary, to dig deeper into the participants' disposition to their experiences. This activity was performed to help participants feel more comfortable sharing their thoughts in the sessions, and to set the stage for the remainder of the session; however, data was not extracted from this activity.

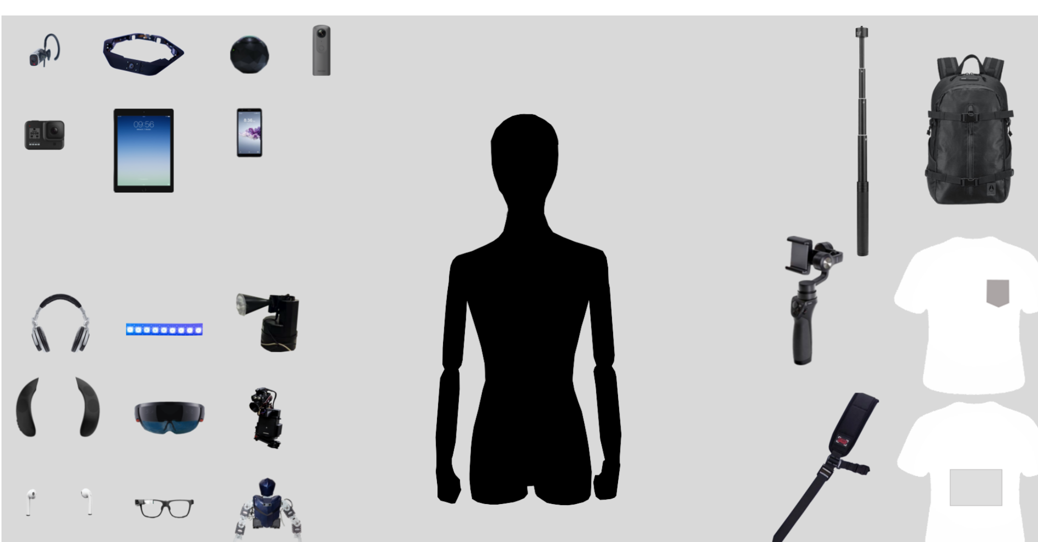

Fig. 1. The "Bag of Stuff" materials presented to participants. We provided a blank mannequin, akin to a "Paper Doll", and participants could dress it with various materials. The materials were presented on their own slides, with the mannequin alone to start.

3.1.2 Activity 2: Designing an Initial Prototype. Participants were split into two pseudo-random groups; these groups were balanced by gender and experience level with live-streaming technology (see Table 2). Each was given a private breakout room and asked to design a prototype for a given scenario. The scenario asked both groups to design a prototype for a friend who would be giving an interpersonal telepresence experience; the participant would be receiving that experience. The Streamer groups' caveat was that the friend is self-conscious in public, and the Viewer groups' caveat was that the prototype should provide the best viewing experience possible. See Table 1 for exact design prompt verbiage. We used this language as we wanted our participants to envision using the system in an interpersonal context instead of thinking about the Streamer as a service provider, and we wanted to understand how participants would tackle Streamer self-consciousness and Viewer boredom, by teasing out and rectifying value tensions (c.f., [13, 30, 48, 53, 55, 56]). As the study sessions were conducted online, and due to the wearable nature of interpersonal telepresence technology, we decided to implement the "Bag of Stuff" co-design technique [14], allowing participants to design on a mannequin like a "paper doll" [19]. The study materials were accessed by participants through Google Drive, and they could synchronously work on the design. Each group had access to a unique file containing the same 4 slides. The first had the blank mannequin on which participants could design; the 3 subsequent slides comprised the "Bag of Stuff" and depicted various live-streaming technologies, based on a collection of prior literature. Each technology had a picture representing it, a caption that described it, and a link to an example picture. We selected these items as they represent academic works or as they are commonly used in live-streaming setups — our goal was to provide as comprehensive of a list of technologies as possible. Figure 1 illustrates the collection of digital materials[1]. Participants were informed they could use images from the internet, draw with primitive shapes, or write text. Prior work [1, 12] suggests these co-design techniques can be effective when used with adults and that low fidelity prototyping tools (e.g., paper prototyping) are appropriate for the ideation phase of a given HCI problem. Each group had 25 minutes to build their prototype, discuss their ideas, and describe why they selected or rejected items.

3.1.3 Activity 3: Big Ideas and Design Critiques. After Activity 2, both groups merged to present their designs. The first group to present was randomized. Each presented their ideas along with justification of why items were chosen. The lead researcher asked clarifying questions related to the planned capabilities exhibited in the design. After a group finished presenting, the other was asked to identify its strengths and weaknesses. Then, the two groups swapped roles. Using this method, groups were able to exchange ideas and receive feedback regarding what may not necessarily work for their stakeholder counterparts, preparing groups for the final activity. This activity lasted approximately 25 minutes.

3.1.4 Activity 4: Designing a Balanced Prototype. Finally, participants were asked to consider the strengths and weaknesses identified in Activity 3 to design a prototype that could meet the needs of both stakeholders. This activity resembled the "Mixing Ideas" technique in which participants share in large groups their respective inputs [69]. The lead researcher assembled the design in a new document according to the input from all session members. Participants were encouraged to discuss rationale for selected items and reach a consensus in the event of conflict, particularly to work together to find appropriate compromises. The lead researcher ensured that both stakeholder groups had representation by moderating the conversation and calling on both groups. This activity lasted approximately 25 minutes.

[1]The raw study materials are available upon request — please contact the corresponding author (kevin.pfeil@unf.edu)

Table 2. Participant Demographics. We had five unique sessions; participants were pseudo-randomly assigned groups for break-out activities. "Expertise" was an index of self-reported experience with relevant live-streaming or technologies.

Session ID	Participant ID	Group	Age	Gender	Expertise (of 5)
S1	P1	Streamer	28	F	3.6
S1	P2	Streamer	21	M	1.1
S1	P3	Viewer	20	F	3.6
S1	P4	Viewer	19	M	2.1
S1	P5	Streamer	20	M	3.6
S1	P6	Viewer	22	F	2.1
S2	P7	Viewer	18	M	2.3
S2	P8	Viewer	24	M	3.6
S2	P9	Streamer	26	F	1.1
S2	P10	Streamer	20	F	2.6
S3	P11	Viewer	20	M	2.0
S3	P12	Viewer	20	F	1.1
S3	P13	Streamer	23	F	2.9
S3	P14	Streamer	27	F	2.9
S3	P15	Viewer	31	M	3.3
S4	P16	Streamer	30	M	3.0
S4	P17	Streamer	29	F	1.9
S4	P18	Viewer	19	F	1.4
S4	P19	Viewer	28	M	4.3
S4	P20	Viewer	24	F	2.4
S4	P21	Streamer	19	M	1.0
S5	P23	Streamer	19	F	2.9
S5	P24	Streamer	20	M	2.3
S5	P25	Viewer	18	M	2.7
S5	P26	Viewer	20	M	3.1
S5	P27	Viewer	18	F	1.7

3.2 Participant Selection and Demographics

We distributed recruitment information through the University of Central Florida and online message boards in Orlando, Florida to invite a diverse group of people to our study. For instance, we posted our call in channels for women in STEM and national societies for Black, Hispanic, and Asian engineers. Interested individuals were asked to fill an online form to ensure eligibility and indicate which sessions they could join. Participants were required to be 18 years old or older, speak English, and have access to a computer with Zoom and a stable internet connection. Most respondents were young adults, primarily college-aged students, which is consistent with the demographic of users who are most likely to produce and consume live streaming content [5, 71]. We had a total of 26 individuals participate in our study (P5, P20, and P27 left the session early but participated fully in

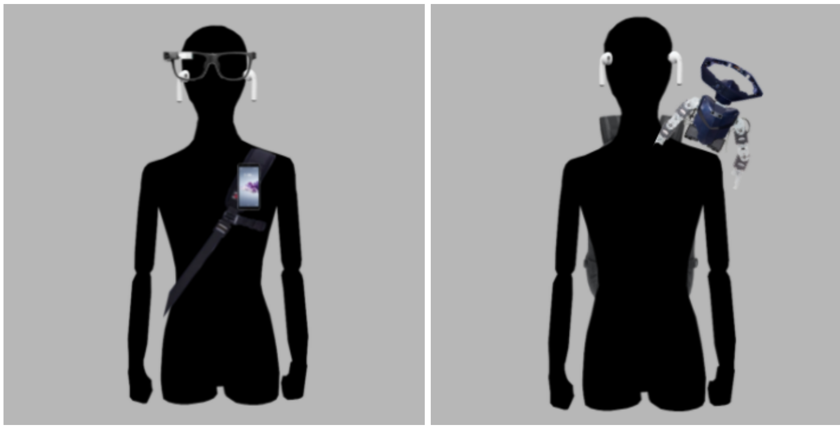

Fig. 2. Example design artifacts from Session S1, Streamer group (left) and Session S2, Viewer group (right). Streamer groups generally envisioned simplistic designs that would not burden the user, whereas Viewer groups tended to include more advanced technologies.

Activity 2). We had 13 females and 13 males, and their ages were between 18 to 32 (M = 22.4, SD = 4.11). We asked participants to provide their age, gender, and to self-report — using a 5-point Likert scale (1 = No Experience and 5 = Very Experienced) — their level of experience with various live streaming technologies and activities. The average ratings for each item are as follows: VR (M = 3.04, SD = 1.25), Videography (M = 2.81, SD = 1.13), AR (M = 2.73, SD = 1.48), Filmmaking (M = 2.53, SD = 1.10), Live Vlogging (M = 2.31, SD = 1.19), DSLR Cameras (M = 2.08, SD = 1.16), and 360° cameras (M = 1.88, SD = 1.11). We averaged these to form an index, which helped us assign a diverse group of participants for a given session. Anecdotally, about half mentioned having live-streamed in some capacity in the past. Table 2 provides a demographics summary.

3.3 Data Analysis Approach

All sessions were recorded and manually transcribed by the first author. Using the transcripts from Activities 2 and 3, the first author conducted a thematic analysis; coding for the human *values* that were important to our participants. The first author started by reading through the session transcripts several times and used open coding to create initial codes that captured the values exhibited by participants' utterances. Throughout this process, they consulted with co-authors to form a consensus around the codes, as well as resolve any ambiguous codes. Axial coding was used to conceptually group the codes and form major themes. The final codebook summarizing our themes and codes is shown in Table 3 and presented in more detail within our results below.

4 RESULTS

In this section, we present the results of our thematic analysis. We conceptually grouped codes into three main themes — Support Social Needs of the Streamer, Reduce Burden on the Streamer, and Allow the Viewer Freedom to Explore — highlighting value tensions and resolutions.

4.1 Identifying Values Regarding the Streamer's Experience

We first describe the codes related to the Streamer's experience (N = 24). In general, participants wanted to promote a better user experience by reducing the social, physical, and economical

Table 3. Final Codebook for our thematic analysis of eliciting Human Values.

Theme	Codes	Exemplar Quote
Streamer Experience		
Support Social Needs of Streamer (N=19, 73%)	**Social Acceptance** (N=16, 62%)	"*I think it's just one of those things where like, if you're in Disney Springs, you're gonna be out in public, right? So you don't want to look ridiculous with all the stuff...*" - P25, Viewer, Activity 2
	Privacy (N=4, 15%)	"*I don't know if the wearable speakers are going to be too much, but if they work, he could listen to you pretty clearly, but people around you will also listen to you clearly; so I don't know if you want to keep that privacy aspect just for your friend, or you want to share that to basically everyone.*" - P8, Viewer, Activity 2
	Safety (N=3, 12%)	"*If you're walking at Disney... there's a little kid that runs in front of you, just for safety reasons, for the streamer and their environment, they should still be mostly tapped-in with where they are physically.*" - P26, Viewer, Activity 2
Reduce Burden on Streamer (N=24, 92%)	**Physical Comfort** (N=18, 68%)	"*One thing we did also talk about was to keep in mind the experience for the friend as well... if it does become a burden, then the experience at home won't be the same... they might not feel going on and doing the stream.*" - P7, Viewer, Activity 3
	Easy Set-up/Removal (N=17, 65%)	"*It would be nice if at lunch, when you take everything off and just rest, they can put everything in the backpack... or if they're using the restroom, they can just put everything away quickly, and then put it back on once they come out.*" - P13, Streamer, Activity 2
	Affordability (N=13, 50%)	"*You also have to consider price, and that most people, when they do a live-streaming thing, they would want to use it with a device they already have...*" - P21, Streamer, Activity 2
	Minimalist Design (N=12, 46%)	"*In our design, we don't want to put so much hassle for my streamer. I want him to experience Disney springs as well, I want him to enjoy as well, so I don't want him to control too many devices.*" - P19, Viewer, Activity 3
	Personal-ization (N=7, 27%)	"*If the viewer wants, it's just a preference... [They] should have both options. Like you have that option, if you are using the VR, or you can just control like hand, and move it any other place.*" - P16, Streamer, Activity 2
Viewer Experience		
Allow Viewer Freedom to Explore (N=19, 73%)	**Natural Sight** (N=13, 50%)	"*We don't want it too low, because then, the person seeing it... we need a good placement for the camera for them to see.*" - P9, Streamer, Activity 2
	Autonomy (N=10, 38%)	"*I don't have to rely on my friend to move... if I wanted to see what is on the left or on the right, or on my backside, I don't [want] to ask my friend to make a turn or look in that direction.*" - P19, Viewer, Activity 2
	Embodied Interaction (N=9, 35%)	"*I was maybe thinking, if there's any way to merge the backpack with some sort of system in which you could have a robot next to you... because I was thinking of an extension to the person who was not physically there.*" - P8, Viewer, Activity 2

burdens on the Streamer. As an example, Figure 2 (left) shows a design artifact from one group that meets these needs, by using low-cost, low-profile technology.

4.1.1 Support the Social Needs of the Streamer. The prompt for Activity 2 used specific language to prime our Streamer participants towards a prototype that would meet the social needs of that stakeholder. Expectedly, the majority of that group expressed consideration for that value. However, the majority of the Viewer participants expressed this as well, for a total of 19 participants (10 Streamer, 9 Viewer). At least 50% from each group (N = 16; 9 Streamer, 7 Viewer) expressed that the ideal telepresence prototype would be ***socially accepted*** by others in proximity with the Streamer. Overall, participants felt that the Streamer would not want others to know a live-streaming interaction was taking place, and some devices were more deemed socially acceptable than others due to their obtrusiveness:

> *"The [head-mounted] 360-degree camera... that one might be best, since you'd be able to look around wherever; but then it might look a little ridiculous when the person is walking around."* - P11, Viewer, Activity 2

Therefore, they felt that the ideal prototype would be one that is hidden from the view of the public. Yet, participants recognized that this is not always feasible; so, they suggested that any visible technology should be ones that are socially acceptable and used by the majority of the public (e.g., a smartphone). An alternative solution offered by some participants is to design these devices in a way that is visually attractive (i.e., fashionable). Four participants (3 Streamer, 1 Viewer) expressed an interest in ***privacy***, and three (1 Streamer, 2 Viewer) valued ***safety***. As our prompt involved an outing at a public, Disney-themed location, the scenario is implied to be safe with reasonable privacy akin to a call.

4.1.2 Reducing the Burden on the Streamer. The Activity 2 prompt verbiage was not specifically designed to prime either group towards supporting the physical or economic needs of the Streamer, although the scenario for both groups included a shared experience between friends. Most of the participants (N = 23; 11 Streamer, 12 Viewer) responded with some desire to reduce the burden on the Streamer. More than half (N = 18; 10 Streamer, 8 Viewer) were concerned for the ***physical comfort*** of the Streamer. They wanted the wearable devices to be lightweight so that the Streamer could have an easier time handling the equipment. Some suggested including a harness or some sort of back support to help the Streamer with the weight of the equipment; see Figure 2 (left) for illustration. Some participants even considered the heat emitted from electronics, feeling that devices should not be secured directly on the body.

Seventeen participants (9 Streamer, 8 Viewer) valued ***easy set-up/removal***. Use cases include both planned and unplanned incidents that would require the attention of the Streamer; these include situations where a pause is necessary (e.g., a lunch or bathroom break), or where a disruption of service may occur. Thus, an ideal system would require little effort to use. Half of the participants (N = 13; 9 Streamer, 4 Viewer) discussed inclusion of devices which users already have; they valued ***affordability***. Many participants specifically mentioned how use of their own personal smartphone is more preferable to spending money on new equipment. Yet, this sentiment mostly came from Streamers. Viewers tended to choose the new and exciting devices, thinking these would give the best viewing experience. Next, almost half (N = 12; 5 Streamer, 7 Viewer) valued a ***minimalist design***; in this case, this meant reducing the quantity of devices to those that were *absolutely necessary*. If the Streamer had to juggle too much equipment, it would interfere with their experience. Lastly, there were a number of participants who felt the prototype should allow for ***personalization*** (N = 7; 4 Streamer, 3 Viewer). These participants were against a "one size fits all" approach. Some Streamer participants felt the on-site individual could bring an array of cameras and swap between them as needed. For instance, a head-mounted camera could be used when the hands need to be free, and a handheld camera could be used when more precision is needed. In this way, the Streamer would have more input and would not simply serve as a mobile tripod.

4.2 Identifying Values Regarding the Viewer's Experience

Next, we describe the codes related to the Viewer's experience. Although the activity prompt used language to prime the Viewer groups towards such design decisions, we note the majority of participants responded with this value in mind (N = 19). Participants wanted to ensure the video provided an adequate view, and they wanted the Viewer to have autonomy. In addition, some wanted the Viewer to have a physical representation in the environment. As an example, Figure 2 (right) shows one group's design artifact that meets these criteria, by allowing the Viewer to explore on their own will, from a natural angle, and with a remote-control avatar that gives a sense of agency.

4.2.1 Allow the Viewer the Freedom to Explore. Most participants (N = 19; 9 Streamer, 10 Viewer) directly expressed a desire to ensure the Viewer could explore the environment in a natural way. The most prominent consideration (N = 13; 8 Streamer, 5 Viewer) was ensuring the camera angle captured a viewpoint that could give ***natural sight***. While designing the prototype, Viewer participants generally believed 360° views are necessary, in order to maximize the exploration ability, i.e. to look at what *they* would want to look at. As such, all 5 Viewer groups chose some sort of omni-directional camera. However, some Streamer participants felt 360° views would be a detriment; since the Streamer would be unable to control where their partner looked, they might miss out on what they are trying to show. Thus, equipping a camera near the Streamer's eyes would provide an aligned view. Ten participants (4 Streamer, 6 Viewer) opined that the Viewer should have ***autonomy***. Similar to the above, these participants expressed that the Viewer should be able to manipulate the view; Streamer participants noted this would reduce the number of times the Viewer would need to ask their partner to make adjustments. In essence, giving control to the Viewer offloads work that the Streamer needs to perform, while simultaneously making the viewing experience more robust. Lastly, nine participants (2 Streamer, 7 Viewer) indicated they would want the Viewer to have an ***embodied interaction***, such that that they could feel like they were *actually there* in the remote environment. As one group indicated, remote control robots could allow the Viewer to point in various directions. Another group opted to use a simple quadrotor drone, granting a physical entity in addition to viewing autonomy. Our Streamer participants succeeded at designing prototypes that would let a user *see* the environment, but the Viewer participants designed prototypes to let them *interact* inside it.

4.3 Identifying Values and Tensions for Viewer & Streamer Interaction (RQ2)

Although our participants were primed to design for their particular role, over 80% made some consideration for the opposite role. During Activity 2, in which Streamers and Viewers were separated, participants would encounter and resolve value tensions within their own processes. We did not anticipate this to occur; since the identification of these tensions occurred naturally, the groups generally agreed with each other during Activity 3. Further, the Activity 4 did not require much dialogue, as the tension resolution was completed before that step. In this section, we report tensions using counts of *groups* (N = 5 sessions x 2 roles = 10) from Activity 2, illustrating independent tension resolution. In whole, 9 of these groups encountered a value tension (the only exception was from the Streamers). Of these nine, only 1 group resolved the tension in favor of their own role (again from the Streamers).

The first major tension encountered by 6 groups (3 Streamer, 3 Viewer) was *Social Acceptability* against *Natural Sight*. The more capable technologies found within our Bag of Stuff were found to be rather obtrusive, and providing a decent view generally means sacrificing one's social acceptability. Yet, the three Streamer groups concluded how today's common setups (e.g. smartphones or action cameras) simply do not provide the best viewing experience; these groups chose to sacrifice some social acceptability in order to let their partner have a more positive viewing experience. On the other hand, the 3 Viewer groups all weighed the advantages of more advanced devices and opted to not make the Streamer stand out from the crowd. In the final design activity, the merged designs tended to use a 360° camera *only* if it could be hidden in some way, i.e. inside of a hat.

The next major tension encountered by 4 groups (all Viewer) was *Physical Comfort* against *Natural Sight*. Here, all of these groups were designing towards a positive viewing experience, but they all recognized how the addition of more equipment meant the Streamer would have to carry or juggle too many devices, which is not what they wanted:

> *"I didn't want to make it too heavy so that it would becomes uncomfortable. I think that taking into consideration the friend's comfort while they go to [Disney] would be pretty cool."* - P7, Viewer, Activity 2

Therefore, these groups opted to use as few devices as possible in their designs, while prioritizing the more important features which would provide a positive viewing experience. The final value tension encountered by 2 groups (both Streamer) was *Social Acceptance* against *Autonomy*. These groups recognized how there is opportunity to let their partner explore the remote environment on their own accord, but it would generally require the Streamer to use atypical devices or wear them on their body. One group decided that some sacrifice to enhance the viewing experience was necessary, by allowing the remote user to control a miniature, actuated camera. The other group instead weighed the pros and cons of robotic platforms, ultimately deciding against devices that would bring unwanted attention.

5 DISCUSSION

We make a contribution to the interpersonal wearable telepresence research by leveraging co-design techniques that were well-suited for the wearable nature of this novel domain. We used the "Bag of Stuff" technique with a "paper dolls" approach (see [19, 32]), which are typically performed more within social computing/HCI research and with software-based systems. Further, we used value elicitation to identify values that should be embedded in a future prototype, which (to our knowledge) has not yet been applied to this domain. We also serendipitously found how stakeholders desire a balanced system and made consideration for their partner.

5.1 Identification of Wearable Telepresence Design Heuristics from A Value-Sensitive Approach (RQ1)

Our work identifies values that should be embedded in future interpersonal wearable telepresence prototypes (Table 3). As described by Borning and Muller [6], instead of including a list of *features*, we can use a set of *values* for which future designers can account. The first major dimension we expected to find was ***support for the Streamer's social well-being***. The participants in to that role naturally designed for that criteria, but the Viewer groups also significantly valued social acceptability, which was not expected. Field studies in this area have identified, in the evaluative phase of research, negative disposition to simple technology probes due to their obtrusive or noticeable nature (e.g. [13, 30, 48, 55, 56]). This finding, which we also uncover in the pre-design stage of research (see [59]), complements these prior works that found social acceptability to be a concern. We further highlight how our Viewer participants valued their friends' ***physical***

well-being, through a design that would be physically comfortable and easy to use. Although these groups tended to select more expensive features, they still envision the technology being rather simple. These values — social acceptability, physical comfort, and ease of use — must be embedded in future designs.

In addition to supporting the Streamer, we must also ***allow the Viewer to explore the remote environment freely***. This parallels the original purpose of telepresence (allowing a user to experience a remote environment as if "actually there" [41]), and it is no surprise that this was found, since we explained this to our participants prior to sessions starting. The codes appearing in this dimension describe the values which can be used for future designs. Our participants expressed a desire to provide video in a "natural way" to the Viewer. "Natural" implies it would be intuitive to the *Viewer* and perhaps from a point of view that they would expect, but since telepresence can be used for a variety of contexts, it might be detrimental to have the camera fixed at a user's "natural" location (e.g. in a crowded environment, perhaps raising up the camera over the heads of bystanders will help to see visual stimuli better). It seems more appropriate to allow the Viewer to see the environment in a way that facilitates maximal exploration opposed to measuring the camera's exact location. In previous works, some of the most Viewer-satisfying prototypes included 360° cameras that were mounted to a pole or were worn on the head of the Streamer (e.g. [9–11, 26, 63]), such that the user could look around on their own volition. Although panoramic cameras do offer *autonomy*, it is also possible to mechanically actuate cameras with narrower fields of view (e.g. [31, 33, 34, 64]). We find giving some sort of power to the Viewer to explore the surroundings (panoramic video or actuated cameras) is a minimum, as it will allow them to seek out interesting stimuli opposed to waiting for their partner to highlight what they think is the most important.

5.2 Through Co-Design, Stakeholders Resolved Value Tensions Together (RQ2)

As our participants were primed to create solutions to support their own role, the expressed values were initially prioritized for their respective groups. However, our participants organically identified and resolved value tensions through the co-design process, and surprisingly made significant considerations for each other. Although previous work has shown how telepresence researchers tend to design a system to primarily benefit the Viewer [53], end users of such systems actually desire a prototype that supports the Streamer as well. After all, if an experience is being shared by a loved one, it is natural to make sure that the physical and social well-being of one's partner is guaranteed. This unanticipated finding is likely the result of having participants co-design for someone they cared about through our prompt, which is a novel and useful approach; but we acknowledge how these findings may not generalize to *all* wearable telepresence scenarios; our prompt was specific to the context of the two users knowing each other. We cannot speak to cases where (for instance) a guide is giving a tour to a stranger (e.g. [22, 39]); but, even in cases where the two users are strangers, we need to make explicit consideration for the Streamers as we ask them to use a system that strongly benefits someone else. Although the participants' set of values (in this context) were mostly aligned, we did notice the groups selecting different features to foster these values. This illustrates how the combination of co-design and value elicitation helps focus on what matters most to the participants, instead of putting the technology in the foreground. Instead of iterating upon a given prototype (in the *evaluative* phase of research; see [59]), we included stakeholders earlier in the design process to create design heuristics that any future designer can reference. Given the two distinct stakeholders with their own desires, co-design and value elicitation were well-suited for our study; we were able to identify compromises between these stakeholders without making it a zero-sum game. We expect future efforts to continue using the value-sensitive design framework and design towards more than just the typical dependent variables of spatial and social presence; as our work complements field studies of the past to triangulate Streamer social acceptability and Viewer autonomy as primary goals, we now envision the development of new tools (i.e. questionnaires) to directly measure these outcomes.

5.3 Design Implications for Wearable Telepresence Systems

While our two stakeholders groups held similar values, their final design solutions, in some cases, diverged. This implies how a "one-size-fits-all" solution is not sufficient for this domain. However, in this section, we highlight certain designs presented in the literature which envelop the values identified through our work.

5.3.1 Communication is Key: Supporting Voice Chat and More, in a Natural Way. Supporting a conversation between stakeholders is necessary to allow both users to have a sense of social presence. Using ubiquitous devices, voice chat is easily supported in any telepresence prototype. However, as noted by previous work, other forms of natural communication (e.g. pointing, head nods, gestures, etc.) are often lost when the two users are not physically together [30, 63]. Previous work uses AR devices to let the Streamer see exactly where their partner looks [3, 27, 37], but current models such as Microsoft Hololens and Apple Vision Pro have obtrusive forms which may prevent everyday users from using them in public. Previous iterations such as the discrete Google Glass are not as powerful, but they may be more usable in this context. Manabe et al. [39] used a circular strip of LED lights to convey Viewer's gaze, and our participants envisioned these as a bracelet to gently indicate gaze direction without looking out of place. These examples illustrate it is possible to design new communication modalities and still foster social acceptability and affordability.

5.3.2 Making Streaming Life Easier by Reducing the Workload. Most of our participants wanted to reduce the Streamer's physical burden, and there were multiple strategies to manage this need. In a framework developed by Rae et al., **Initiation** was one of the major dimensions, comprised of themes such as "amount of planning" and "setup costs" [56]. Our participants identified that reducing the workload for the Streamer would not just entail low setup costs, but also low *tear-down* costs — for instance, if they need to take a break, the setup needs to be quickly collapsible, or minimal enough to be turned on/off with a simple switch or button press. Pan and Neustaedter discussed a mobile phone application with which users could set conditions that, when true, turns off cameras [50]. This idea might possibly be extended to the automatic detection of private/intrusive situations, so the streaming equipment would moderate itself. Other works in this space applied a shoulder strap to the user's body, on which a smartphone could clip on and off [21, 30]. The Streamer could thus simply lift the device to focus the camera as needed, and then store it on the strap when finished. We find this technique to be strong, but it, too, violates the social acceptance value. Drawing from our participants' ideas, the easiest way to setup/teardown cameras would be to use devices that *do not need to be removed*; i.e., ones that are comfortable, hidden from the public eye, and easily controlled (e.g. from a smartphone). For instance, though a panoramic camera might offer an all-in-one solution that allows a Viewer to look around on their own, it is difficult to situate it in a way that the Streamer's body does not prevent natural sight [52], without the user wearing a post (e.g. [63]) or holding a handle (e.g. [75]). An alternative solution is the inclusion of multiple, small webcams which can be used to provide a similar effect. These examples illustrate that it is possible to design prototypes that are physically comfortable, do not have an initiation / termination cost, and still provide the Viewer with autonomy.

5.4 Limitations and Future Work

We recognize our study is not without its limitations and discuss future work to help to reconcile possible shortcomings. Since our goal was to receive input from novices and prospective users of interpersonal telepresence (everyday people), we did not explicitly capture data from those who would be considered professional Streamers, but we expect to collect data from such people to help understand their perspective on this topic. Similarly, we acknowledge that many sociotechnical systems are designed to support various, underprivileged classes (e.g. the disabled community); yet, our work did not directly engage with these communities. We urge future work to address inclusion in this space, to ensure we can amplify the voices of marginalized and stigmatized users, who are often early adopters and could most benefit from these technologies. We also acknowledge that our results do not generalize to all interaction scenarios, focusing on a one-to-one leisure context where both parties know each other. Future work will apply value elicitation and co-design to understand if and how the stakeholder responses would change in other domains such as cooperative work, where telepresence is emerging (e.g. [37]). Next, though much previous work has been performed to generate Streamer devices to enhance the Viewer's experience, our work ultimately makes a call to be more sensitive to the Streamer; and, our co-design prompts — though presented through the eyes of the Viewer — did not ask participants to design Viewer hardware complementary to the Streamer setup. While we believe our work is necessary to swing the pendulum back towards the center, we must remind ourselves that our goal is to identify ways to support *all* major stakeholders. In the same vein, our study is not sensitive to the third stakeholder — the bystanders who are collocated with the Streamer. We acknowledge that our design strategies involve live-streaming cameras that are hidden from the public eye. We must ask ourselves if this solution, though practical, is *ethical*. Previous work has shown that even simple technology probes with private voice chat can be confusing or even offensive to those collocated with the Streamer [55, 56], and, to our knowledge, no work has been performed to directly identify how to balance their expectations within this context. Future work should directly query third-party members for the growth of this interaction paradigm.

5.4.1 Towards Toolkits to Support User-Created Wearable Telepresence. As we reflect on *how* wearable telepresence devices are typically generated — the designers (typically researchers) create an artifact and deploy it with everyday people — we find that this "classical" method of design (see [58]) creates a severe disconnect between what is developed and what is desired. As researchers, we need to begin empowering the users by providing *them* with the means to create their own artifacts. Although everyday users may not have the technical skills to create an advanced prototype, we could begin with the creation of a framework that will allow them to choose and swiftly incorporate features, or develop new skills such that they can conceptualize and realize their own features. For instance, there have been a number of works that discussed the creation of toolkits to bring specific populations into the maker culture fold. Buechley et al. created the LilyPad Arduino to help non-experts create wearable devices or to learn skills applicable to such creation [7, 8], and Jelen et al. [23] presented work to engage with elderly and help them apply electronics for new crafts. Ververidis et al. [68] describe work towards helping non-experts develop VR experiences, and Vargas González et al. [66] discuss techniques to help non-experts author AR programs. There is opportunity to extend these works such that anyone could create their own wearable telepresence artifacts, including novel hardware and software applications. Traditionally, wearable telepresence devices have been created to benefit one stakeholder (the Viewer) [53] — but we, as researchers, need to do a better job creating artifacts *for everyone*. We do not have to present specific technology solutions when we design to support values. By eliciting values and identifying tensions — instead of building one static system to try to meet all user needs — we pave the way toward inclusive design that can lead to customization. Such an approach is less vulnerable to trends in technology and more flexible to the needs of diverse users.

6 CONCLUSION

In this paper, we elicit and present values that should be embedded in future interpersonal wearable telepresence prototypes which satisfy the needs of two major stakeholders — Streamers and Viewers. Through co-design sessions, we were able to draw out values users share. Although we purposefully primed our participants to create designs that would benefit their own stakeholder role, we surprisingly found that they made major considerations for their counterparts in the other role. Whereas previous work has shown that telepresence designers tend to create new capabilities that are ultimately noticeable and perhaps socially unacceptable, our participants strongly desired a prototype that would allow the Streamer to mask the interaction, while still allowing the Viewer to have autonomy in exploring the remote environment. By reflecting on previous work, we present design strategies that balance these values and can be used for future designs. Through this work, we are moving towards the vision of making this form of telepresence mainstream, with capabilities to foster a sense of togetherness in a time where "being there" is difficult.

ACKNOWLEDGMENTS

This work is supported in part by NSF Award IIS-1917728.

REFERENCES

[1] Cristina Azevedo Gomes, Sónia Ferreira, and Bárbara Sousa. 2020. Older Adults' Participation in VIAS'Mobile App Design. In *International Conference on Human-Computer Interaction*. Springer, 3–17.

[2] Uddipana Baishya and Carman Neustaedter. 2017. In Your Eyes: Anytime, Anywhere Video and Audio Streaming for Couples. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing - CSCW '17*. ACM Press, Portland, Oregon, USA, 84–97. https://doi.org/10.1145/2998181.2998200

[3] Mark Billinghurst, Alaeddin Nassani, and Carolin Reichherzer. 2014. Social panoramas: using wearable computers to share experiences. In *SIGGRAPH Asia 2014 Mobile Graphics and Interactive Applications on - SA '14*. ACM Press, Shenzhen, China, 1–1. https://doi.org/10.1145/2669062.2669084

[4] Frank Biocca, Chad Harms, and Jenn Gregg. 2001. The networked minds measure of social presence: Pilot test of the factor structure and concurrent validity. In *4th annual international workshop on presence, Philadelphia, PA*. 1–9.

[5] Nicola Bleu. 2022. *47 Latest Live Streaming Statistics For 2022: The Definitive List*. https://bloggingwizard.com/live-streaming-statistics/

[6] Alan Borning and Michael Muller. 2012. Next Steps for Value Sensitive Design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Austin, Texas, USA) *(CHI '12)*. Association for Computing Machinery, New York, NY, USA, 1125–1134. https://doi.org/10.1145/2207676.2208560

[7] Leah Buechley and Michael Eisenberg. 2008. The LilyPad Arduino: Toward Wearable Engineering for Everyone. *IEEE Pervasive Computing* 7, 2 (2008), 12–15. https://doi.org/10.1109/MPRV.2008.38

[8] Leah Buechley, Mike Eisenberg, Jaime Catchen, and Ali Crockett. 2008. The LilyPad Arduino: Using Computational Textiles to Investigate Engagement, Aesthetics, and Diversity in Computer Science Education. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Florence, Italy) *(CHI '08)*. Association for Computing Machinery, New York, NY, USA, 423–432. https://doi.org/10.1145/1357054.1357123

[9] Minghao Cai, Soh Masuko, and Jiro Tanaka. 2018. Gesture-based Mobile Communication System Providing Side-by-side Shopping Feeling. In *Proceedings of the 23rd International Conference on Intelligent User Interfaces Companion - IUI 18*. ACM Press, Tokyo, Japan, 1–2. https://doi.org/10.1145/3180308.3180310

[10] Minghao Cai, Soh Masuko, and Jiro Tanaka. 2018. Shopping Together: A Remote Co-shopping System Utilizing Spatial Gesture Interaction. In *Human-Computer Interaction. Interaction Technologies*, Masaaki Kurosu (Ed.). Vol. 10903. Springer International Publishing, Cham, 219–232. https://doi.org/10.1007/978-3-319-91250-9_17

[11] Minghao Cai and Jiro Tanaka. 2017. Trip Together: A Remote Pair Sightseeing System Supporting Gestural Communication. In *Proceedings of the 5th International Conference on Human Agent Interaction - HAI '17*. ACM Press, Bielefeld, Germany, 317–324. https://doi.org/10.1145/3125739.3125762

[12] Chhaya Chouhan, Christy M LaPerriere, Zaina Aljallad, Jess Kropczynski, Heather Lipford, and Pamela J Wisniewski. 2019. Co-designing for community oversight: Helping people make privacy and security decisions together. *Proceedings of the ACM on Human-Computer Interaction* 3, CSCW (2019), 1–31.

[13] Anezka Chua, Azadeh Forghani, and Carman Neustaedter. 2017. Shared Bicycling Over Distance. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA '17*. ACM Press, Denver,

Colorado, USA, 455–455. https://doi.org/10.1145/3027063.3049776

[14] Jerry Alan Fails, Mona Leigh Guha, and Allison Druin. 2013. Methods and Techniques for Involving Children in the Design of New Technology for Children. *Found. Trends Hum.-Comput. Interact.* 6, 2 (Dec. 2013), 85–166. https://doi.org/10.1561/1100000018

[15] Batya Friedman, Peter H. Kahn, Alan Borning, and Alina Huldtgren. 2013. *Value Sensitive Design and Information Systems.* Springer Netherlands, Dordrecht, 55–95. https://doi.org/10.1007/978-94-007-7844-3_4

[16] Lilian de Greef, Meredith E. Morris, and Kori Inkpen. 2016. TeleTourist: Immersive Telepresence Tourism for Mobility-Restricted Participants. In *Proceedings of the 19th ACM Conference on Computer Supported Cooperative Work and Social Computing Companion - CSCW '16 Companion*. ACM Press, San Francisco, California, USA, 273–276. https://doi.org/10.1145/2818052.2869082

[17] Jiajing Guo, Yoyo Tsung-Yu Hou, Harley Mueller, Katherine Tang, and Susan R. Fussell. 2019. As If I Am There: A New Video Chat Interface Design for Richer Contextual Awareness. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems - CHI EA '19*. ACM Press, Glasgow, Scotland Uk, 1–6. https://doi.org/10.1145/3290607.3312759

[18] John Halloran, Eva Hornecker, Mark Stringer, Eric Harris, and Geraldine Fitzpatrick. 2009. The value of values: Resourcing co-design of ubiquitous computing. *CoDesign* 5, 4 (2009), 245–273. https://doi.org/10.1080/15710880902920960 arXiv:https://doi.org/10.1080/15710880902920960

[19] Sofia Hussain and Elizabeth B.-N. Sanders. 2012. Fusion of horizons: Co-designing with Cambodian children who have prosthetic legs, using generative design tools. *CoDesign* 8, 1 (2012), 43–79. https://doi.org/10.1080/15710882.2011.637113

[20] Kori Inkpen, Brett Taylor, Sasa Junuzovic, John Tang, and Gina Venolia. 2013. Experiences2Go: sharing kids' activities outside the home with remote family members. In *Proceedings of the 2013 conference on Computer supported cooperative work - CSCW '13*. ACM Press, San Antonio, Texas, USA, 1329. https://doi.org/10.1145/2441776.2441926

[21] Clarissa Ishak, Carman Neustaedter, Dan Hawkins, Jason Procyk, and Michael Massimi. 2016. Human Proxies for Remote University Classroom Attendance. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*. ACM Press, Santa Clara, California, USA, 931–943. https://doi.org/10.1145/2858036.2858184

[22] Visit Faroe Islands. 2020. *Remote Tourism.* Retrieved 2022-12-05 from https://visitfaroeislands.com/en/about1/marketing-development-campaigns/remote-tourism

[23] Ben Jelen, Anne Freeman, Mina Narayanan, Kate M. Sanders, James Clawson, and Katie A. Siek. 2019. Craftec: Engaging Older Adults in Making through a Craft-Based Toolkit System. In *Proceedings of the Thirteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Tempe, Arizona, USA) *(TEI '19)*. Association for Computing Machinery, New York, NY, USA, 577–587. https://doi.org/10.1145/3294109.3295636

[24] Brennan Jones, Anna Witcraft, Scott Bateman, Carman Neustaedter, and Anthony Tang. 2015. Mechanics of Camera Work in Mobile Video Collaboration. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15*. ACM Press, Seoul, Republic of Korea, 957–966. https://doi.org/10.1145/2702123.2702345

[25] Tejinder K. Judge, Carman Neustaedter, and Andrew F. Kurtz. 2010. The family window: the design and evaluation of a domestic media space. In *Proceedings of the 28th international conference on Human factors in computing systems - CHI '10*. ACM Press, Atlanta, Georgia, USA, 2361. https://doi.org/10.1145/1753326.1753682

[26] Shunichi Kasahara, Shohei Nagai, and Jun Rekimoto. 2017. JackIn Head: Immersive Visual Telepresence System with Omnidirectional Wearable Camera. *IEEE Transactions on Visualization and Computer Graphics* 23, 3 (March 2017), 1222–1234. https://doi.org/10.1109/TVCG.2016.2642947

[27] Shunichi Kasahara and Jun Rekimoto. 2014. JackIn: integrating first-person view with out-of-body vision generation for human-human augmentation. In *Proceedings of the 5th Augmented Human International Conference on - AH '14*. ACM Press, Kobe, Japan, 1–8. https://doi.org/10.1145/2582051.2582097

[28] Shunichi Kasahara and Jun Rekimoto. 2015. JackIn head: immersive visual telepresence system with omnidirectional wearable camera for remote collaboration. In *Proceedings of the 21st ACM Symposium on Virtual Reality Software and Technology - VRST '15*. ACM Press, Beijing, China, 217–225. https://doi.org/10.1145/2821592.2821608

[29] Tadakazu Kashiwabara, Hirotaka Osawa, Kazuhiko Shinozawa, and Michita Imai. 2012. TEROOS: a wearable avatar to enhance joint activities. In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12*. ACM Press, Austin, Texas, USA, 2001. https://doi.org/10.1145/2207676.2208345

[30] Seungwon Kim, Sasa Junuzovic, and Kori Inkpen. 2014. The Nomad and the Couch Potato: Enriching Mobile Shared Experiences with Contextual Information. In *Proceedings of the 18th International Conference on Supporting Group Work - GROUP '14*. ACM Press, Sanibel Island, Florida, USA, 167–177. https://doi.org/10.1145/2660398.2660409

[31] Don Kimber, Patrick Proppe, Sven Kratz, Jim Vaughan, Bee Liew, Don Severns, and Weiqing Su. 2015. Polly: Telepresence from a Guide's Shoulder. In *Computer Vision - ECCV 2014 Workshops*, Lourdes Agapito, Michael M. Bronstein, and Carsten Rother (Eds.). Vol. 8927. Springer International Publishing, Cham, 509–523. https://doi.org/10.1007/978-3-319-16199-0_36

[32] Sofie Kinch, Minna Pakanen, Kasper Heiselberg, Christian Dindler, Anne-Mette Iversen, and Peter Gall Krogh. 2022. An exploratory study of using speculative artefacts in co-design. *CoDesign* (2022), 1–19.

[33] Sven Kratz, Daniel Avrahami, Don Kimber, Jim Vaughan, Patrick Proppe, and Don Severns. 2015. Polly Wanna Show You: Examining Viewpoint-Conveyance Techniques for a Shoulder-Worn Telepresence System. In *Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct - MobileHCI '15*. ACM Press, Copenhagen, Denmark, 567–575. https://doi.org/10.1145/2786567.2787134

[34] Sven Kratz, Don Kimber, Weiqing Su, Gwen Gordon, and Don Severns. 2014. Polly: "being there" through the parrot and a guide. In *Proceedings of the 16th international conference on Human-computer interaction with mobile devices & services - MobileHCI '14*. ACM Press, Toronto, ON, Canada, 625–630. https://doi.org/10.1145/2628363.2628430

[35] Annica Kristoffersson, Silvia Coradeschi, and Amy Loutfi. 2013. A Review of Mobile Robotic Telepresence. *Advances in Human-Computer Interaction* 2013 (2013), 1–17. https://doi.org/10.1155/2013/902316

[36] Claudia Kuster, Nicola Ranieri, Henning Zimmer, Jean-Charles Bazin, Chengzheng Sun, Tiberiu Popa, Markus Gross, et al. 2012. Towards next generation 3D teleconferencing systems. In *2012 3DTV-Conference: The True Vision-Capture, Transmission and Display of 3D Video (3DTV-CON)*. IEEE, 1–4.

[37] Gun A. Lee, Theophilus Teo, Seungwon Kim, and Mark Billinghurst. 2017. Sharedsphere: MR collaboration through shared live panorama. In *SIGGRAPH Asia 2017 Emerging Technologies on - SA '17*. ACM Press, Bangkok, Thailand, 1–2. https://doi.org/10.1145/3132818.3132827

[38] Tuck Wah Leong and Ole Sejer Iversen. 2015. Values-Led Participatory Design as a Pursuit of Meaningful Alternatives. In *Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction* (Parkville, VIC, Australia) *(OzCHI '15)*. Association for Computing Machinery, New York, NY, USA, 314–323. https://doi.org/10.1145/2838739.2838784

[39] Minori Manabe, Daisuke Uriu, Takeshi Funatsu, Atsushi Izumihara, Takeru Yazaki, I-Hsin Chen, Yi-Ya Liao, Kang-Yi Liu, Ju-Chun Ko, Zendai Kashino, Atsushi Hiyama, and Masahiko Inami. 2020. Exploring in the City with Your Personal Guide:Design and User Study of T-Leap, a Telepresence System. In *19th International Conference on Mobile and Ubiquitous Multimedia* (Essen, Germany) *(MUM 2020)*. Association for Computing Machinery, New York, NY, USA, 96–106. https://doi.org/10.1145/3428361.3428382

[40] Akira Matsuda, Kazunori Nozawa, Kazuki Takata, Atsushi Izumihara, and Jun Rekimoto. 2020. HapticPointer: A Neck-worn Device that Presents Direction by Vibrotactile Feedback for Remote Collaboration Tasks. In *Proceedings of the Augmented Humans International Conference*. ACM, Kaiserslautern Germany, 1–10. https://doi.org/10.1145/3384657.3384777

[41] Marvin Minsky. 1980. Telepresence. (1980).

[42] Kana Misawa, Yoshio Ishiguro, and Jun Rekimoto. 2012. Ma petite chérie: what are you looking at?: a small telepresence system to support remote collaborative work for intimate communication. In *Proceedings of the 3rd Augmented Human International Conference on - AH '12*. ACM Press, Megève, France, 1–5. https://doi.org/10.1145/2160125.2160142

[43] Kana Misawa and Jun Rekimoto. 2015. ChameleonMask: a human-surrogate system with a telepresence face. In *SIGGRAPH Asia 2015 Emerging Technologies on - SA '15*. ACM Press, Kobe, Japan, 1–3. https://doi.org/10.1145/2818466.2818473

[44] Kana Misawa and Jun Rekimoto. 2015. ChameleonMask: Embodied Physical and Social Telepresence using Human Surrogates. In *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA '15*. ACM Press, Seoul, Republic of Korea, 401–411. https://doi.org/10.1145/2702613.2732506

[45] Kana Misawa and Jun Rekimoto. 2015. Wearing another's personality: a human-surrogate system with a telepresence face. In *Proceedings of the 2015 ACM International Symposium on Wearable Computers - ISWC '15*. ACM Press, Osaka, Japan, 125–132. https://doi.org/10.1145/2802083.2808392

[46] Jorg Muller, Tobias Langlotz, and Holger Regenbrecht. 2016. PanoVC: Pervasive telepresence using mobile phones. In *2016 IEEE International Conference on Pervasive Computing and Communications (PerCom)*. IEEE, Sydney, NSW, 1–10. https://doi.org/10.1109/PERCOM.2016.7456508

[47] Shohei Nagai, Shunichi Kasahara, and Jun Rekimoto. 2015. Directional communication using spatial sound in human-telepresence. In *Proceedings of the 6th Augmented Human International Conference on - AH '15*. ACM Press, Singapore, Singapore, 159–160. https://doi.org/10.1145/2735711.2735818

[48] Carman Neustaedter, Jason Procyk, Anezka Chua, Azadeh Forghani, and Carolyn Pang. 2020. Mobile Video Conferencing for Sharing Outdoor Leisure Activities Over Distance. *Human–Computer Interaction* 35, 2 (March 2020), 103–142. https://doi.org/10.1080/07370024.2017.1314186

[49] Catherine S. Oh, Jeremy N. Bailenson, and Gregory F. Welch. 2018. A Systematic Review of Social Presence: Definition, Antecedents, and Implications. *Frontiers in Robotics and AI* 5 (Oct. 2018), 114. https://doi.org/10.3389/frobt.2018.00114

[50] Rui Pan and Carman Neustaedter. 2017. Streamer.Space: A Toolkit for Prototyping Context-Aware Mobile Video Streaming Apps. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA '17*. ACM Press, Denver, Colorado, USA, 1947–1954. https://doi.org/10.1145/3027063.3053083

[51] Rui Pan, Samarth Singhal, Bernhard E. Riecke, Emily Cramer, and Carman Neustaedter. 2017. "MyEyes": The Design and Evaluation of First Person View Video Streaming for Long-Distance Couples. In *Proceedings of the 2017 Conference on Designing Interactive Systems - DIS '17*. ACM Press, Edinburgh, United Kingdom, 135–146. https://doi.org/10.1145/3064663.3064671

[52] Kevin Pfeil, Pamela Wisniewski, and Joseph J LaViola Jr. 2019. An Analysis of User Perception Regarding Body-Worn 360° Camera Placements and Heights for Telepresence. In *ACM Symposium on Applied Perception 2019*. 1–10.

[53] Kevin P. Pfeil, Neeraj Chatlani, Joseph J. LaViola, and Pamela Wisniewski. 2021. Bridging the Socio-Technical Gaps in Body-Worn Interpersonal Live-Streaming Telepresence through a Critical Review of the Literature. *Proc. ACM Hum.-Comput. Interact.* 5, CSCW1, Article 120 (April 2021), 39 pages. https://doi.org/10.1145/3449194

[54] Alina Pommeranz, Christian Detweiler, Pascal Wiggers, and Catholijn Jonker. 2012. Elicitation of situated values: need for tools to help stakeholders and designers to reflect and communicate. *Ethics and Information Technology* 14, 4 (2012), 285–303.

[55] Jason Procyk, Carman Neustaedter, Carolyn Pang, Anthony Tang, and Tejinder K. Judge. 2014. Exploring video streaming in public settings: shared geocaching over distance using mobile video chat. In *Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14*. ACM Press, Toronto, Ontario, Canada, 2163–2172. https://doi.org/10.1145/2556288.2557198

[56] Irene Rae, Gina Venolia, John C. Tang, and David Molnar. 2015. A Framework for Understanding and Designing Telepresence. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing - CSCW '15*. ACM Press, Vancouver, BC, Canada, 1552–1566. https://doi.org/10.1145/2675133.2675141

[57] Bektur Ryskeldiev, Toshiharu Igarashi, Junjian Zhang, Yoichi Ochiai, Michael Cohen, and Jens Herder. 2018. Spotility: Crowdsourced Telepresence for Social and Collaborative Experiences in Mobile Mixed Reality. In *Companion of the 2018 ACM Conference on Computer Supported Cooperative Work and Social Computing - CSCW '18*. ACM Press, Jersey City, NJ, USA, 373–376. https://doi.org/10.1145/3272973.3274100

[58] Elizabeth B-N Sanders and Pieter Jan Stappers. 2008. Co-creation and the new landscapes of design. *Co-design* 4, 1 (2008), 5–18.

[59] Elizabeth B.-N. Sanders and Pieter Jan Stappers. 2014. Probes, toolkits and prototypes: three approaches to making in codesigning. *CoDesign* 10, 1 (2014), 5–14. https://doi.org/10.1080/15710882.2014.888183 arXiv:https://doi.org/10.1080/15710882.2014.888183

[60] Samarth Singhal and Carman Neustaedter. 2017. BeWithMe: An Immersive Telepresence System for Distance Separated Couples. In *Companion of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing - CSCW '17 Companion*. ACM Press, Portland, Oregon, USA, 307–310. https://doi.org/10.1145/3022198.3026310

[61] Mel Slater, Martin Usoh, and Anthony Steed. 1994. Depth of presence in virtual environments. *Presence: Teleoperators & Virtual Environments* 3, 2 (1994), 130–144. Publisher: MIT Press.

[62] Jonathan Steuer. 1992. Defining virtual reality: Dimensions determining telepresence. *Journal of communication* 42, 4 (1992), 73–93.

[63] Anthony Tang, Omid Fakourfar, Carman Neustaedter, and Scott Bateman. 2017. Collaboration with 360° Videochat: Challenges and Opportunities. In *Proceedings of the 2017 Conference on Designing Interactive Systems - DIS '17*. ACM Press, Edinburgh, United Kingdom, 1327–1339. https://doi.org/10.1145/3064663.3064707

[64] Hiroaki Tobita. 2017. Gutsy-Avatar: Computational Assimilation for Advanced Communication and Collaboration. In *2017 First IEEE International Conference on Robotic Computing (IRC)*. IEEE, Taichung, Taiwan, 8–13. https://doi.org/10.1109/IRC.2017.82

[65] Yuichi Tsumaki, Fumiaki Ono, and Taisuke Tsukuda. 2012. The 20-DOF miniature humanoid MH-2: A wearable communication system. In *2012 IEEE International Conference on Robotics and Automation*. IEEE, St Paul, MN, USA, 3930–3935. https://doi.org/10.1109/ICRA.2012.6224810

[66] Andrés Vargas González, Senglee Koh, Katelynn Kapalo, Robert Sottilare, Patrick Garrity, Mark Billinghurst, and Joseph LaViola. 2019. A Comparison of Desktop and Augmented Reality Scenario Based Training Authoring Tools. In *2019 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*. 339–350. https://doi.org/10.1109/ISMAR.2019.00032

[67] Gina Venolia, John C. Tang, Kori Inkpen, and Baris Unver. 2018. Wish you were here: being together through composite video and digital keepsakes. In *Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services*. ACM, Barcelona Spain, 1–11. https://doi.org/10.1145/3229434.3229476

[68] Dimitrios Ververidis, Panagiotis Migkotzidis, Efstathios Nikolaidis, Eleftherios Anastasovitis, Anastasios Papazoglou Chalikias, Spiros Nikolopoulos, and Ioannis Kompatsiaris. 2022. An authoring tool for democratizing the creation of high-quality VR experiences. *Virtual Reality* 26, 1 (2022), 105–124.

[69] Greg Walsh, Elizabeth Foss, Jason Yip, and Allison Druin. 2013. *FACIT PD: A Framework for Analysis and Creation of Intergenerational Techniques for Participatory Design.* Association for Computing Machinery, New York, NY, USA, 2893–2902. https://doi.org/10.1145/2470654.2481400

[70] Bob G Witmer and Michael J Singer. 1998. Measuring presence in virtual environments: A presence questionnaire. *Presence* 7, 3 (1998), 225–240. Publisher: MIT Press.

[71] Dapeng Wu, Y.T. Hou, Wenwu Zhu, Ya-Qin Zhang, and J.M. Peha. 2001. Streaming video over the Internet: approaches and directions. *IEEE Transactions on Circuits and Systems for Video Technology* 11, 3 (2001), 282–300. https://doi.org/10.1109/76.911156

[72] Svetlana Yarosh, Kori M. Inkpen, and A.J. Bernheim Brush. 2010. Video playdate: toward free play across distance. In *Proceedings of the 28th international conference on Human factors in computing systems - CHI '10*. ACM Press, Atlanta, Georgia, USA, 1251. https://doi.org/10.1145/1753326.1753514

[73] Svetlana Yarosh, Anthony Tang, Sanika Mokashi, and Gregory D Abowd. 2013. " almost touching" parent-child remote communication using the sharetable system. In *Proceedings of the 2013 conference on Computer supported cooperative work*. 181–192.

[74] Jacob Young, Tobias Langlotz, Matthew Cook, Steven Mills, and Holger Regenbrecht. 2019. Immersive Telepresence and Remote Collaboration using Mobile and Wearable Devices. *IEEE Transactions on Visualization and Computer Graphics* 25, 5 (May 2019), 1908–1918. https://doi.org/10.1109/TVCG.2019.2898737

[75] Jacob Young, Tobias Langlotz, Steven Mills, and Holger Regenbrecht. 2020. Mobileportation: Nomadic Telepresence for Mobile Devices. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 4, 2 (June 2020), 1–16. https://doi.org/10.1145/3397331

Received January 2023; revised July 2023; accepted November 2023