












Addressing the Avatar in the Room: A User Study on Older Adults' Experiences with a Wearable Augmented Reality Communication System

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Abstract. Staying socially connected is vital for older adults' well-being. This study explores how wearable augmented reality (AR) can enhance their communication experiences. $N=16$ older adults from Germany used a prototype wearable AR communication system to engage in a conversation task with a realistic avatar representing a remote communication partner. Their experiences, focusing on observed user behavior, perceived usability, user engagement, social presence, and intention to use, were assessed through questionnaires, scales, think-aloud protocols, and interviews. Overall, participants reported positive and engaging experiences. Despite concerns about the headset's ergonomic fit and the avatar's limited emotional expressiveness, a high degree of social presence was achieved. Most participants were willing to use the system, particularly if social isolation became a concern. Our findings demonstrate wearable AR's potential to improve interpersonal communication among older adults and provide design insights to better address their social and usability needs. Specifically, it emphasizes the importance of enhancing the avatar's emotional expressiveness, particularly when interacting with familiar individuals, to effectively engage older adults and foster communication satisfaction.

Keywords: Augmented reality · Avatar · Head-mounted display · Communication · Older adult · User experience

1 Introduction

The rapid development of augmented reality (AR) technologies has opened up new possibilities for interactive and immersive experiences. Among these

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advancements are wearable augmented reality (AR) systems, which use see-through head-mounted displays (HMDs) to seamlessly integrate digital content into the user's physical environment [22]. Recent data from Germany shows that 33% of current smartphone users believe such systems will replace smartphones within the next decade, paving the way for new methods of accessing information on the go [4]. Crucially, they can also facilitate social interaction by allowing users to communicate with avatars representing themselves or others in real time [25]. For older adults, who are often at a higher risk of social isolation and loneliness, interacting with realistic avatars of family members or friends can provide a valuable alternative to sometimes unfeasible face-to-face encounters [11].

Despite such prospects, research on interpersonal communication in AR predominantly targets younger users and business contexts [9]. To bridge this gap, we explored older adults' experiences with a prototype wearable AR communication system during informal avatar-mediated interactions. The insights from this study offer recommendations for optimizing AR interfaces to better address social needs of older adults and support their emotional well-being through meaningful and immersive communication.

1.1 Wearable AR and Interpersonal Communication

Interpersonal communication - the exchange of information and emotions between individuals - plays a crucial role in fostering social connections [31]. Wearable AR can facilitate this process by providing vivid communication experiences through HMDs while preserving the user's connection to their real environment [25]. Unlike handheld devices such as smartphones or tablets, HMDs do not confine the user's field of view to a screen. Instead, they deliver an uninterrupted view of the communication partner represented as an avatar, allowing natural, face-to-face-like interactions [15]. The hands-free design also facilitates a richer transmission of non-verbal signals, enabling clearer emotional expression and reducing possible misunderstandings [11, 21]. This can be especially beneficial for older adults, who typically rely on non-verbal cues more than younger generations due to age-related sensory impairments [6].

Additionally, socially interacting with lifelike avatars via HMDs creates a sense of shared space and strengthens emotional closeness [22, 38]. In family communication, particularly valued by older adults, this can simulate virtual visits from loved ones, offering a deeper sense of intimacy and emotional connection than traditional voice or video calls [24, 37]. At the same time, there are concerns that reliance on virtual communication might exacerbate feelings of social isolation and loneliness due to reduction of face-to-face family visits [2, 11].

1.2 Older Adults' Experiences with Wearable AR

Older adults generally report positive experiences with wearable AR. For instance, HMD-based AR applications featuring virtual coaches make physical exercise engaging and fun, boosting motivation for routine rehabilitation after

injuries or surgeries [5,26]. AR-based solutions can also empower older adults by enhancing their cognitive abilities and assisting them with daily tasks [1,33]. Furthermore, the sheer novelty of AR can generate positive experiences, challenging stereotypes about older adults' reluctance to adopt new technologies [2].

However, despite the recognized need for age-friendly technology design [8], major challenges remain. Discomfort from prolonged HMD use and the steep learning curve of new interfaces can lead to anxiety and frustration, hindering positive experiences and discouraging older adults from using immersive technologies [5,26]. Privacy concerns and financial factors are equally important, as wearable AR systems rely on extensive data collection, including real-time environmental scanning, and may require additional equipment purchases [18,24].

Furthermore, while older adults' experiences with wearable AR systems for physical and cognitive support are well documented, social applications remain underresearched. Evidence from virtual reality (VR) research suggests that avatar-based interactions can enhance older adults' emotional well-being and social engagement (e.g., [19]). Similar or even greater benefits may be achievable with wearable AR, yet empirical studies are scarce.

1.3 The Present Study

The present study explores older adults' experiences with AR-mediated interpersonal communication. User experience (UX) is a person's perceptions and responses gained in the course of interacting with a technical device [36]. For interactive systems like AR, UX can be characterized by the usability of the system and its engagement capabilities.

Usability, a key challenge for older adults adopting new technologies [13], is the extent to which a product allows users to efficiently achieve their goals within a specific context [17]. For wearable AR systems, it includes factors like HMD fit, display and auditory qualities, and interaction techniques [20].

User engagement, on the other hand, emphasizes the emotional and cognitive dimensions of an interactive system. Defined as the depth of user's cognitive, temporal, affective, and behavioral investment, it enhances user-system interaction, making it exciting and fun [29]. Engagement often builds upon usability; however, it also requires additional elements such as aesthetic appeal and emotional connection [29]. For older adults, engagement becomes crucial as a playful and enjoyable experience is an important condition for their adoption of immersive technologies [12].

Additionally, a positive UX enhances social presence - the sense of being with another in a mediated environment [35]. Social presence is vital in mediated communication - it strengthens connectedness, reduces psychological distance, and boosts communication satisfaction [3]. This is particularly valuable for older adults who often rely on communication technologies to maintain close family ties, which requires intimacy and emotional involvement [37].

Finally, for AR communication systems to benefit older adults' social needs, they should be willing to adopt such systems, which can be encouraged by pos-

itive UX. Against this backdrop, this study seeks to address five research questions (RQs):

RQ1: How *successfully* can older adults use a wearable AR communication system?

RQ2: How do older adults perceive the *usability* of a wearable AR communication system?

RQ3: How *engaging* do older adults perceive experiences with a wearable AR communication system?

RQ4: How do older adults perceive the *social presence* provided by a wearable AR communication system?

RQ5: How do older adults express their *intention to use* a wearable AR communication system?

2 Methods

To answer the study's RQs, we created a prototype AR communication system that allows two users to communicate with each other via generic avatars, and evaluated it in a user study with older adults (see Fig. 1).

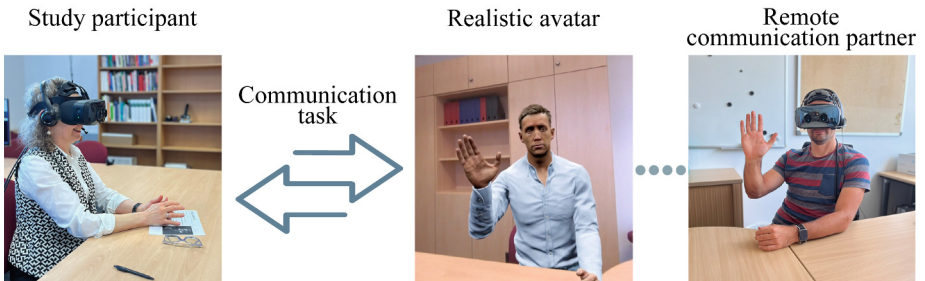


Fig. 1. The setup of the user study.

2.1 AR Communication System Prototype

Hardware and Software. The system was developed in Unity 2022.3.8f1, using the Varjo XR-3 HMD for visualization and a Logitech H390 headset for microphone input and audio playback. SteamVR tracking supported HTC VIVE trackers to mark the table surface and the chair where the avatar would be positioned. The HMD's built-in head and eye tracking and integrated Ultraleap sensor for hand tracking, captured movement data, which, along with microphone input, animated the avatar's head, eyes, and hands. Network synchronization was achieved using Photon Fusion with its voice plugin for audio transmission. Unity's Audio Spatializer was used to enhance realism, attaching the audio source to the avatar's head. Figure 2 provides an overview of the system architecture.

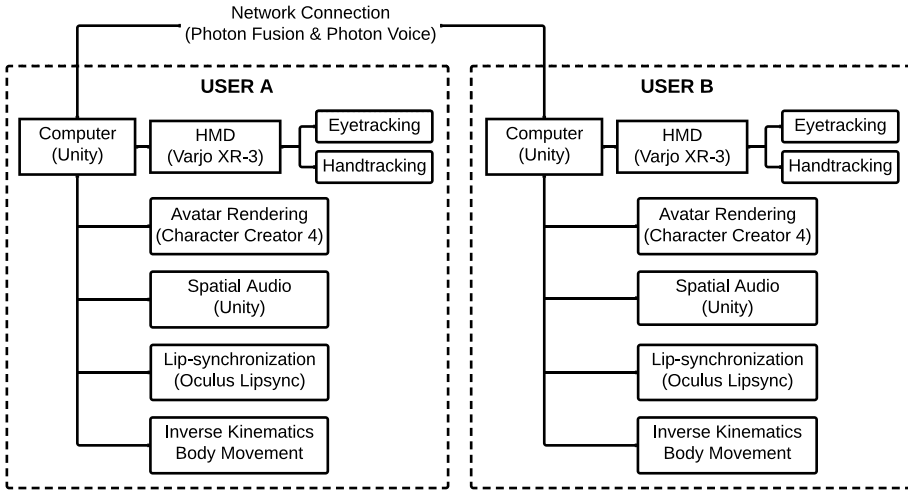


Fig. 2. An overview of the prototype wearable AR system architecture.

Avatar. The avatar was created with Character Creator 4 Software Suite. It represents a White man in his mid-thirties, dressed in sneakers, jeans, and a light-blue semi-formal shirt (see Fig. 1).

We used Oculus LipSync for mouth animation and the HMD's eye tracking data for eye movement. The pelvis and feet of the avatar remained fixed in a seated position, allowing only the upper body to move. Fallback transformations ensured smooth transitions in hand tracking when the hands moved out of the Ultraleap sensor's view, resting naturally on the table during idle moments. Final IK¹ was used to animate the remaining body parts.

The avatar was rendered using Unity's High-Definition Render Pipeline. To enhance realism, virtual light sources were positioned above the avatar to simulate the room's actual lighting setup. White balance, exposure, and ISO on the HMD were manually set to fixed values for consistent appearance of the avatar in our study environment, and room blinds were closed to prevent lighting disruptions. To create a natural appearance of the avatar seated at a table, we used the HMD's depth sensor to ensure that it could be occluded both by the table and the user's hands. A VIVE tracker on the chair in front of the user established accurate avatar positioning and proper hand placement relative to the table. The avatar remained hidden until the chair tracker was detected, preventing it from spawning in unnatural poses and ensuring a smooth start to the interaction.

2.2 Study Design

The user study had a non-experimental design and combined quantitative (standardized questionnaires and scales) and qualitative (observations, concurrent

¹ <http://root-motion.com/> Last accessed: 31 January 2025.

think-aloud protocols, semi-structured oral interviews) data collection methods. It involved participants wearing an HMD and engaging in a conversation task with a remote and unfamiliar communication partner (a member of the research team) represented by an avatar (see Fig. 1). The task was a modified version of the celebrity guessing game “Who am I?”, commonly used in technology evaluation studies [10, 34]. In this game, the participant and the remote communication partner were provided with a card containing brief information about a famous individual. The objective was to guess the celebrity on a partner’s card by asking only “yes” or “no” questions.

The study was approved by the ethics committee of Technische Universität Ilmenau on November 21, 2023. Study participants provided written informed consent, including media release forms. All materials are publicly available on <https://osf.io/cg3as/>.

2.3 Participants

Participants were recruited from prior studies in the CO-HUMANICS (Co-Presence of Humans and Interactive Companions for Seniors) project [7, 24], personal contacts of researchers, and a local sports organization. To meet the eligibility criteria, participants had to be 60 years old or above, express an interest in technology, live independently, and have no cognitive impairments.

$N = 16$ older adults from Germany participated in the study. Participants were between 60 and 78 years old ($M_{age} = 71.1$, $SD_{age} = 4.4$, 56% women; see Table 1). They regularly used communication media, primarily instant messaging services like WhatsApp and Telegram, to stay connected with friends and family. While none had prior experience with AR-based interpersonal communication, their overall technology acceptance was above average ($M = 3.67$, $SD = 0.79$; scale range 1–5).

2.4 Procedure

The study was conducted in German at a university lab in February 2024. First, participants were briefed on the study’s goals, procedure, and the rules of the celebrity guessing game. Next, they completed an entry questionnaire that collected socio-demographic details, information on their mediated communication practices, and prior social AR experiences. Their attitudes towards technologies were assessed using the Technology Acceptance subscale of the Technology Commitment scale [27, scale from 1 = low to 5 = high; Cronbach’s $\alpha = .90$; $GLB = .96$].

Next, the principal investigator overseeing the user test assisted participants in putting on the sanitized HMD and headphones. Participants wearing large vision glasses were asked to remove them beforehand, as the Varjo XR-3’s design might not accommodate larger frames comfortably.

Once participants indicated they were comfortable, an avatar representing the remote communication partner appeared in front of them, seated on a chair behind the desk. The avatar was controlled by a male research team member from another room. The participants did not see their own avatars, but

Table 1. Socio-demographic characteristics of study participants. All names are aliases. Reported frequency of mediated contacts is based on the past four weeks.

Nº	Name	Age	Gender	Hearing aid	Vision aid	Frequency of mediated contacts	Form of mediated contacts
1	Amelie	60	Female	-	+	Several daily	SMS, instant messaging, video conferencing, social media
2	Lukas	66	Male	-	+	Several weekly	Instant messaging
3	Sebastian	68	Male	-	+	Several weekly	SMS, instant messaging
4	Jonas	69	Male	+	+	Several weekly	SMS, instant messaging, video conferencing
5	Mia	69	Female	-	+	Several weekly	SMS, instant messaging, video conferencing
6	Emma	69	Female	-	+	Several weekly	instant messaging
7	Anna	71	Female	-	+	Several weekly	SMS, instant messaging, video conferencing, email
8	Finn	71	Male	-	+	Weekly	Instant messaging, video conferencing
9	Sophia	72	Female	-	+	Several weekly	Instant messaging
10	Lara	72	Female	-	-	Several weekly	SMS, instant messaging
11	Marie	72	Female	-	+	Several weekly	Instant messaging
12	Hannah	74	Female	+	+	Several weekly	Instant messaging
13	Leon	74	Male	-	+	Several weekly	Instant messaging, video conferencing
14	Felix	76	Male	-	+	Daily	SMS, instant messaging, video conferencing, social media
15	Noah	76	Male	-	+	Weekly	SMS, instant messaging
16	Lena	78	Female	-	-	Several weekly	Instant messaging, social media

instead saw their real bodies. After a brief introduction, the avatar invited participants to play the celebrity guessing game, which lasted five minutes. During the farewell, the remote communication partner offered participants an avatar-mediated handshake.

After removing the HMD, participants completed a post-test questionnaire assessing their overall satisfaction with the experience (rated from 1 = very unsatisfied to 5 = very satisfied) and perceived social presence [28, 35, scale from 1 = low to 5 = high; Cronbach's $\alpha=.85$, $GLB=.90$]. Lastly, they took part in individual semi-structured interviews to elaborate on their experiences. The interview guide covered participants' overall impressions, perceived usability, engagement, social presence, and intention to use.

Each user session was video-recorded, capturing both the room and the participants' view. Participants were encouraged to verbalize their thoughts and opinions during the experience. Additionally, the principal investigator took observation notes throughout the test. Post-test interviews were audio-recorded.

2.5 Data Analysis

Participants' responses to the questionnaires underwent descriptive statistical analysis in R version 4.3.3. Results were presented in the form of absolute and relative frequencies and mean values with corresponding standard deviations.

Oral interviews and think-aloud protocols were transcribed verbatim, anonymized, and analyzed qualitatively in MAXQDA 2022 with a focused analysis approach [32]. First, the transcripts were reviewed to gain familiarity with the content. Supporting variables (e.g., use of hearing aids and vision glasses) were appended to contextualize the findings. Next, a hierarchical coding structure was established combining deductive and inductive approaches, with broad categories aligned with research questions and subcategories derived from the literature and the interview guide. To validate the initial coding framework, two trained coders independently coded data from one participant, achieving strong inter-coder reliability (Cohen's $\kappa = .71$, 86% agreement). Discrepancies were resolved through discussion and the coding instructions were adjusted. Subsequently, the primary investigator systematically coded all data, restructuring and refining the coding framework iteratively until no new patterns emerged.

The final categories and subcategories were supported by verbatim quotes translated from German to English for this publication.

3 Results

Overall, the 16 study participants were satisfied with their experiences ($M=4.44$, $SD=0.51$; scale range 1–5). Qualitative observations revealed frequent laughter, smiles, and a visible sense of contentment among the participants.

3.1 RQ1: How Successfully Can Older Adults Use a Wearable AR Communication System?

All participants successfully completed the conversation task. Despite encountering minor technical glitches (e.g., two participants encountered issues with eye tracking loss necessitating system recalibration), all participants were able to effectively perceive, hear, and engage with an avatar.

3.2 RQ2: How Do Older Adults Perceive the Usability of a Wearable AR Communication System?

Study participants found the system easy to use. Their insights into the AR system's technical features were categorized into common AR-related usability dimensions [20]: 1) HMD ergonomics; 2) Visual quality; 3) System performance; 4) Audio quality; 5) Physical safety; 6) Application interface; and 7) Navigation (see Table 2).

Table 2. Usability dimensions mentioned by the 16 study participants in oral interviews and think-aloud protocols ($N=74$ statements). Percentage values are rounded.

Usability dimension	Description	Example quote	n	%
HMD ergonomics	The HMD fit, adjustability, weight distribution, and perceived user comfort	<i>“The biggest problem I see is the weight [of the HMD]. It needs to be reduced because it’s very uncomfortable when you have it on for a long time.”</i> (Leon, 74 years old)	32	43
Visual quality	Display clarity, sharpness, brightness, field of view, and visual fidelity	<i>“The room looks a bit blurry, but that’s probably because of my age. I can see the furniture I can also see my glasses. I can also read [the celebrity game card].”</i> (Emma, 69 years old)	17	23
System performance	Perceived speed, efficiency, and reliability of system responses	<i>“We were able to communicate, we were able to play the game. Everything was fine without any interference.”</i> (Jonas, 69 years old)	11	15
Audio quality	Sound quality, clarity, volume, and appropriateness	<i>“In the beginning [the sound] was quiet. Then the volume was adjusted and it became louder. Yes, once you adjust it, I think it’s okay.”</i> (Jonas, 69 years old)	7	10
Physical safety	Physical distress during use of the system, including cybersickness, fatigue, or strain	<i>“I didn’t have any discomfort from the system or feel strained or anything like that. I actually felt good. We could have continued [with the game].”</i> (Leon, 74 years old)	7	10
Application interface	Intuitiveness and design of the software interface	Did not come up during data analysis	–	–
Navigation	System interaction techniques	Did not come up during data analysis	–	–

HMD Ergonomics. The majority of participants raised concerns about the fit of the HMD, particularly its weight and size: *“I only had [the HMD] on for five minutes, but you start to sweat. It’s like a pair of diving goggles or airtight goggles that sit really tight. You notice it even after a short time. If you put them on for longer, the effect would probably be even stronger”* (Jonas, 69 years old).

The adjustability of the HMD was another issue. For example, 72-year-old Marie struggled with adjusting the strap of the HMD to fit her head comfortably, despite assistance from the research team: *“You saw it yourself - I had to regulate [the HMD] a lot. (...) If you have mobility restrictions, for example in your hands, then it might be difficult to handle it yourself”*.

Despite common complaints about the comfort of wearing the HMD, participants agreed that for the study’s duration (approximately five minutes), the discomfort was manageable.

Visual Quality. Given that almost all participants normally wore vision glasses which they were asked to remove prior to the test, they emphasized the need for the HMD to accommodate their regular vision aids or have integrated lenses to avoid blurry vision. However, none of the participants felt that this negatively affected their experiences: *“In the beginning, when I put on [the HMD], everything looked a bit blurry. I don’t know if that has anything to do with the fact that I normally wear glasses, because I only really need them for nearsightedness. But when the avatar appeared and the conversation started, [the issue] was actually all gone. So it might have something to do with the system, but it wasn’t anything unpleasant”* (Mia, 69 years old).

Regarding other visual characteristics of the HMD’s display, such as brightness, resolution, and field of view, participants noted that their ability to see through the display felt “normal” and that the avatar appeared clear and sharp.

System Performance. Participants were satisfied with the system’s performance. The system’s latency also received positive evaluations, which was particularly relevant for the communication flow between the participant and the avatar. Only one participant, 76-year-old Felix, who has an extensive background in informatics, mentioned minor delays in the avatar’s movements during his interview: *“Sometimes, there was a slight delay in [the avatar’s] movements. When he was thinking, he looked down like this [imitating the avatar looking down and briefly freezing]. It seemed a little bit odd, but only very slightly”*.

Audio Quality. Participants found the audio quality natural and similar to real-life hearing; however, as reflected in the think-aloud protocols, some participants initially found the avatar’s voice too quiet. The research team adjusted audio volume for each participant upon request. Two participants wore hearing aids during the test, but these caused no technical issues, sound quality problems, or observed inconveniences.

Physical Safety. None of the study participants reported cybersickness, fatigue, or physical distress during or after the use of the AR system. At the same time, some suggested that this might be due to the limited duration of use and the seated position. For instance, 69-year-old Jonas was asked after the user test if he experienced any dizziness or other negative physical sensations: *“No, but I was also sitting down. Maybe it’s different when you’re walking around, I don’t know what it’s like. (...) We haven’t tried that, but sitting down is fine”*.

Additionally, two participants paid attention to the cable connected to the HMD, noting that it might restrict their ability to move around the room. However, these concerns could not be tested under the present study’s conditions.

3.3 RQ3: How Engaging Do Older Adults Perceive Experiences with a Wearable AR Communication System?

The following themes determined the participants' engagement during the user test: 1) Affective state; 2) Avatar representation; 3) Interactivity; and 4) Awareness. Within each theme, several categories emerged (see Fig. 3).

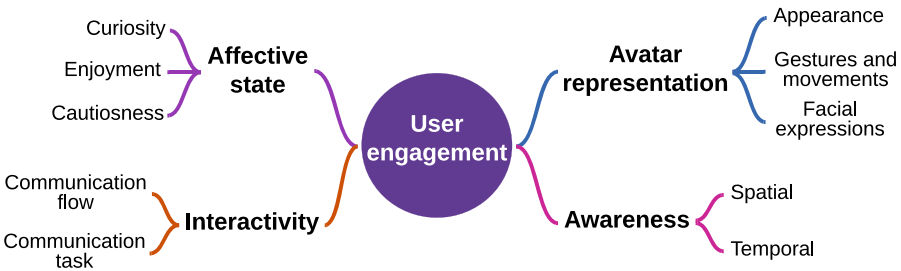


Fig. 3. Main themes and corresponding categories related to user engagement during interpersonal communication in AR.

Affective State. Participants expressed predominantly positive emotions during their use of the AR communication system, with the feelings of *curiosity* and *enjoyment* being prevalent.

Participants' curiosity was evident through the numerous questions they asked the research team about the AR system, both during and after the user test, while enjoyment was primarily related to the experienced fun. For instance, 71-year-old Finn could hardly contain his excitement after using the AR communication system. As soon as the primary investigator helped him take off the HMD, he exclaimed: “*When he tried to shake my hand, did you see it on the camera? Did you see how close that was? Awesome, right? It was really great*”.

Only two study participants experienced a certain level of *cautiousness* towards the AR system. All others described their interaction with the avatar as entertaining and thrilling.

Interactivity. Regarding the interactive aspect of their experience, study participants addressed the *communication flow* between themselves and the avatar and the *conversation task* itself.

There was no uniform agreement among participants on whether the conversation flow between them and the communication partner represented by the avatar was fluid enough. However, overall, they were able to perceive the mediated conversation as a normal interaction between two individuals. Amelie (60 years old) praised the quick reaction time of the avatar and its overall behavior: “*He reacted immediately. He was communicating. I thought, the reaction would*

be somehow delayed because it's a machine, or it's like a machine. I don't know, but it was a really immediate, lightning reaction. No matter what I said, [the avatar] also had this sense of humor, so everything was there".

The celebrity guessing game itself, while not directly tied to the AR system, notably enhanced overall participant engagement as well, encouraging interaction with the remote communication partner: *"I suddenly felt like playing with him, like beating him. That's why I made an effort to find out [the celebrity]. So I was then **in** the game"* (Lara, 72 years old).

Avatar Representation. The avatar was the main focus for the study participants while wearing the HMD and its visual characteristics, namely *appearance, gestures and movements, and facial expressions* impacted their engagement.

Participants' opinions on whether the avatar looked like a real human and whether they liked its appearance were divided. While some participants found the avatar's look very artificial, others, conversely, were impressed by its realism. At the same time, the gestures, movements, and facial expressions of the avatar did not meet the participants' expectations and were found distracting: *"I heard that he was happy, that he was laughing, but the face didn't reflect it. (...) The avatar is still a bit rigid, it moves its eyes and mouth a bit, but it doesn't have this reaction, the way we usually communicate. When we talk now, and you nod and smile, that's what's missing, this response to what you hear"* (Emma, 69 years old).

Participants noted that for more engaging experience the avatar should be able to look, move, and react in a more human-like manner, particularly when representing someone they know personally.

Awareness. Participants' perceptions of themselves and their surroundings while using the AR system were reflected in perceived *spatial and temporal awareness*.

The spatial awareness addressed the study participants' perception of the physical environment while wearing the HMD. Participants perceived it without difficulty and appreciated that the room remained real rather than being an artificially generated space. For some, however, it took some adjusting to the fact that they received a virtual visit from an avatar: *"I was like in a movie. I looked down, and I saw my hand through [the avatar's] hand, and then it became real to me that we were in the same room. (...) At first, I thought I was gone. But when I saw my hand, I realized: [the avatar] had come to me, not I to him"* (Amelie, 60 years old).

Impressions about the participants' temporal awareness during the conversation task were mainly gathered through qualitative observations. When the allocated time for the task came to an end, participants were instructed to ask their final question and say goodbye to the avatar. However, some participants became so absorbed in the game that they required multiple reminders about the time limit, resulting in an average game duration of 7–8 minutes for approximately half of the participants.

3.4 RQ4: How Do Older Adults Perceive the Social Presence Provided By a Wearable AR Communication System?

Participants reported a high degree of social presence during avatar-mediated communication ($M=4.05$, $SD=0.67$; scale range 1–5). Qualitative analysis revealed four related themes: 1) Naturalness; 2) Co-presence; 3) Nonmediation; and 4) Emotional closeness (see Table 3).

Table 3. Perceived social presence of 16 study participants during AR-mediated communication (based on $N=50$ statements from oral interviews and think-aloud protocols)

Theme	Description	Example quote	n	%
Naturalness	The degree to which the communication mirrored face-to-face communication and/or occurred without hindrances or perceived artificiality.	<i>“It’s quite something. Not just talking to someone - you could have done it over the phone. But it’s quite different to have someone in front of you who reacts a bit like that.”</i> (Mia, 69 years old)	23	46
Co-presence	Perception of sharing a physical space with an avatar.	<i>“I see the room through the [AR] glasses and there’s just someone overlaid. So I didn’t have the feeling that the person was somewhere else. (...) You really feel that [the avatar] is in the same room.”</i> (Jonas, 69 years old)	15	30
Nonmediation	Perception of the wearable technology during mediated communication.	<i>“I didn’t actually notice [HMD] anymore. I was focused on the avatar: How is he looking at me, what is he saying, what is he asking. I didn’t notice the [AR] glasses at all. They were no longer there.”</i> (Finn, 71 years old)	6	12
Emotional closeness	Perceived intimacy, closeness, and personal relationship between the participant and remote communication partner represented by an avatar.	<i>“You almost had the feeling that you had a personal relationship. If [the conversation] had lasted any longer, you could have built it up somehow.”</i> (Lara, 72 years old)	6	12

Naturalness. Study participants directly and indirectly compared avatar-mediated and face-to-face communication. Some, like 74-year-old Leon, remained reserved and pragmatic: *“Of course, the easiest way [to communicate] is to be face-to-face. That stage hasn’t been reached yet. But once you’ve adjusted to this avatar and know that he’s not an actual person, but that he only represents this person, then you can have a good conversation with him”.*

Others, however, said that the interaction with the avatar resembled a regular interaction with a human. The lack of emotional expression in the avatar’s facial features and its somewhat abrupt body movements were identified as key factors hindering the perceived naturalness of the experience.

Co-presence. All participants in the study agreed that they felt sharing the same physical space with the avatar during the study. Mia (69 years old) described feeling so absorbed in her experience that she almost believed she could physically interact with it: *“I was sitting opposite him. I saw his feet under the table. I could have even poked him. I just don’t know if he would have reacted. It came across as very real”*.

Similarly, 71-year-old Finn suggested that avatar-based meeting with multiple individuals could be more efficient than video conferences because everyone could gather at a virtual table, simulating the experience of being in the same room: *“It’s not a video, screen, or computer monitor. It’s a completely different thing, a completely different feeling. I can imagine if there is a meeting with several people and you have a big round table. Everyone takes their place at it and discusses something. That must be much more eventful, much more effective”*.

Nonmediation. Study participants unanimously agreed that, despite initial concerns about the HMD’s fit, the technology faded into the background once the mediated conversation started. For example, Amelie (60 years old) shared her experience upon starting the celebrity guessing game: *“The [AR] glasses felt very heavy on my frontal bones. But when I started talking, I’d already forgotten that I was wearing them. (...) They didn’t bother me at all because I had my attention on [the avatar] and the game”*.

Emotional Closeness. The study design didn’t involve any exchange of personal experiences between communication partners, but some participants still felt a sense of closeness to the conversation partner through his avatar or envisioned one in a comparable scenario. For example, Finn (71 years old) described a hypothetical situation where he could use an avatar to support his adult son in his new career journey: *“We’re sitting here at the table and we’re talking. And you can encourage him. You can tell him: ‘Come on, you’ve done it before, you can do it again’. And it’s almost personal what’s going on. It’s no longer the case that when I skype with him and it’s just a little picture where you can barely recognize the person. Yes, sure, you can make it big on the monitor, but you still don’t see it like when I have an avatar here and he’s talking to me”*.

3.5 RQ5: How Do Older Adults Express Their Intention to Use a Wearable AR Communication System?

Overall, study participants were likely to use the AR communication system in the future. Ten participants (63%) indicated that they could see themselves using such a system, one responded negatively, and five expressed openness to using it if their life circumstances were to change.

For example, Anna (71 years old) currently lives with her partner; both are healthy and can travel long distances to visit friends and family, so she doesn’t feel the need for AR-mediated communication at this time. However, she acknowledges that her circumstances could change: *“I could perhaps imagine*

it for older people who live in a care home, who have no contacts, who don't receive any visits and that they can certainly talk to an avatar for half an hour or an hour a day, depending on what their needs are. So for people who are really lonely, I could imagine that. I wonder if I'll ever reach that state? I hope not, but you never know".

As for the participants who were eager to adopt the AR communication system right away, enhanced communication capabilities across distances and a general enthusiasm for embracing new technology were named as primary motivators.

4 Discussion

The study explored the potential of AR-based interpersonal communication for older adults by evaluating their experiences with a prototype wearable AR system. $N=16$ older adults from Germany played a celebrity guessing game with a remote communication partner represented by an avatar and shared their experiences through questionnaires, observations, think-aloud protocols, and individual interviews.

4.1 Perceived Usability

Overall, study participants had positive experiences with the AR communication system. Notably, none experienced cybersickness or fatigue. Cybersickness in see-through AR is typically rare or results in only mild symptoms, particularly when users are seated [16]. We were concerned that older age of our study participants might intensify these symptoms, but this did not occur.

No critical usability issues were reported by the participants. However, in the present study, they relied on research team guidance to operate the prototype, including application initiation, avatar control, and system calibration. Therefore, participants' usability evaluations largely centered on the HMD, the only component they operated independently. For instance, the adjustment of the HMD strap highlighted some age-related challenges, such as mobility limitations. Additionally, the HMD's weight and size were excessive for some participants, leading to discomfort during the conversation task. These findings align with existing research that emphasizes the importance of ergonomic design in technology intended for older adults [8], especially given that in real-life communication the HMD will likely be worn for prolonged periods.

Furthermore, most participants were unable to wear their vision glasses with the headset due to the HMD's limitations. This could be less problematic in private use where individuals can choose compatible spectacles; however, in a lab setting this becomes a critical challenge for researchers working with this user demographic, as recruiting older adults with specific sizes of vision aids may be impractical. Older adults typically require corrective eyewear more frequently than younger generations [30], so this issue is not limited to the present study.

This presents a significant challenge for technology designers. While much research focuses on developing inclusive and accessible AR applications, the available hardware options are typically limited, and new developments rarely target older users. Our findings highlight that a lightweight, adjustable HMD is essential for better representation of older adults in user studies.

4.2 Perceived Engagement

The study demonstrated high user engagement, reflected in participants' enthusiasm and curiosity. Participants were absorbed in their interaction with the avatar, disregarding their physical surroundings, the HMD, and the time constraints of the user test. While this enthusiasm may stem from the nature of the celebrity game, its combination with spatial awareness indicates that both the game and the AR system were engaging.

However, all participants noted the limitations in the avatar's appearance such as lack of human-like non-verbal cues and facial expressions. Non-verbal behaviors are fundamental to effective interpersonal communication [28], especially for older adults, who rely on these cues more than younger generations [6]. At the same time, there is evidence that human-like features become less critical when interacting with unfamiliar conversation partners [39]. This was echoed in our findings, where participants clearly enjoyed the playfulness of the interaction with an avatar of an unfamiliar person, but expressed a preference for more detailed facial expressions and a closer visual resemblance in future interactions with family members and friends. Given that communication with friends and family is a primary motivation for older adults to use digital communication tools [37], this feedback must be prioritized in designing future AR communication systems, while also preserving perceived playfulness - a crucial factor in older adults' acceptance and adoption of new technologies [12].

4.3 Perceived Social Presence

Participants reported high social presence while using the AR communication system. The four key themes identified during data analysis - naturalness, co-presence, nonmediation, and emotional closeness - align with established dimensions of social presence in mediated communication research but also highlight areas for improvement.

There was no consensus among participants on whether the AR-mediated communication felt natural or rather artificial, mainly due to the avatar's deficiencies in facial expressions. However, they still experienced co-presence, feeling as if they shared the same space with the avatar. Co-presence is often treated as a separate concept from social presence, but it can also be described as its core component [3]. In our study, experiencing a shared space with an avatar of another person led participants to perceive the experience as a virtual visit rather than a distant connection, fostering a sense of togetherness that made communication feel more personal and less mediated.

Such experiences can be a significant indicator of an effective AR system, as they create an illusion of direct and spontaneous interactions without being constantly reminded of the technological device [14]. However, our participants used the HMD for only five minutes, whereas conversations between older adults and their close social circles typically last longer [23]. With prolonged use, discomfort of the HMD could disrupt perceived nonmediation, potentially reducing social presence. Drawing such conclusions requires additional empirical investigation beyond the scope of the present study; however, some participants already envisioned using AR for conversations with family members. This suggests that, with further development, AR systems can foster deeper emotional connections.

4.4 Intention to Use

The vast majority of the study participants were open to using the AR system in the future, particularly if social isolation or loneliness became a concern. Older adults primarily use communication technologies to maintain connections with family members [37]; thus, participants currently living with partners or children were understandably less inclined to adopt the AR communication system, especially given the associated learning curve and the need for additional equipment. However, their conditional willingness to use such a system suggests that the perceived benefits of AR communication could outweigh the initial challenges once it aligns with their evolving needs.

5 Limitations and Outlook

The present study faced several limitations. Firstly, many of our participants had prior involvement in the CO-HUMANICS project activities. While their repeated participation is encouraging and demonstrates strong interest in the AR system, it may also introduce bias towards more favorable evaluations. Furthermore, the communication task did not involve exchanging any personal information between the communication partners. This may have restricted the depth of interaction, limiting the ability to fully evaluate the system's potential for meaningful communication experiences.

Future studies should examine older adults' UX with AR-mediated communication with minimal researcher intervention to better simulate real-world use and improve the understanding of the system's usability in self-use contexts, as well as explore dyadic conversations with familiar partners to provide insights into the role of familiarity in user engagement and perceived social presence.

6 Conclusion

The study highlights the prospects and challenges of wearable AR systems to support communication needs of older adults. Our participants' curiosity,

engagement, and enjoyment demonstrate the system's ability to deliver immersive experiences, while high perceived social presence underscores AR's capacity to foster emotional connectedness necessary for meaningful communication.

However, while the system's novelty captured participants' interest, sustained use will likely depend on improving its usability and comfort, particularly concerning the ergonomics of HMDs and their compatibility with vision aids. Enhancing the emotional expressiveness of avatars through more realistic facial expressions will also be key, as older adults rely heavily on non-verbal cues during interpersonal communication.

Finally, the participants' conditional willingness to use the system suggests that AR may be most effective in targeted scenarios, such as supporting individuals living alone or facing social isolation. Designing for particular needs and contexts can enhance perceived usefulness, increasing the likelihood of adoption among diverse groups of older adults.

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