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Article

"Like a Virtual Family Reunion": Older Adults Defining Requirements for an Augmented Reality Communication System

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Abstract: Leading a socially engaged life is beneficial for the well-being of older adults. Immersive technologies, such as augmented reality (AR), have the potential to provide more engaging and vivid communication experiences compared to conventional digital tools. This qualitative study adopts a human-centered approach to discern the general attitudes and specific requirements of older adults regarding interpersonal communication facilitated by AR. We conducted semi-structured individual interviews with a sample of $N = 30$ older adults from Germany. During the interviews, participants evaluated storyboard illustrations depicting a fictional AR-enabled communication scenario centered around a grandparent and their adult grandchildren, which were represented as avatars within the AR environment. The study identified technological, emotional, social, and administrative requirements of older adults regarding the AR communication system. Based on these findings, we provide practical recommendations aimed at more inclusive technology design, emphasizing the significance of addressing the emotional needs of older adults, especially the perceived intimacy of AR-based interpersonal communication. Acknowledging and catering to these emotional needs is crucial, as it impacts the adoption of immersive technologies and the realization of their social benefits. This study contributes to the development of user-friendly AR systems that effectively promote and foster social engagement among older adults.

Keywords: augmented reality; communication technologies; older adult; avatar; social engagement

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1. Introduction

Today, 79-year-old grandmother Clara is celebrating her birthday. Unfortunately, her grandchildren are studying in a university town across the country and therefore cannot pay her a physical visit. However, they decide to bridge the distance through a virtual visit. As Clara puts on her augmented reality (AR) headset, her grandchildren materialize in her living room as avatars (see Figure 1). The technology allows them to socially interact, see each other, and engage in a shared celebration, erasing the geographical separation that spans hundreds of kilometers. In a similar way, Clara can reconnect with old friends from her younger years who may live far away and share treasured memories, engage in joint activities such as dancing or playing puzzle games with her loved ones, or even have a small family reunion with all visiting relatives sitting at the dinner table in the form of avatars.

This fictional example illustrates the various ways in which immersive technologies, such as AR systems, can contribute to interpersonal communication. AR is a type of immersive technology that allows virtual objects to be incorporated into a real-life environment in real time [1]. By putting on a see-through AR headset, the user can experience them in a way that feels engaging and natural [2]. These virtual objects can include real-time 3D renderings of other individuals ("avatars") with whom the user can interact socially [1].

AR technology can be particularly helpful for the older generation who often faces challenges related to their social engagement [3,4]. A socially engaged life is characterized

by participating in interpersonal activities and maintaining meaningful connections with other people [5]. However, as children and grandchildren grow up and move out, as social circles become smaller due to the loss of friends and life partners, and as physical and cognitive health declines, it becomes more difficult for older adults to maintain the same level of social engagement [6]. In situations where personal visits become problematic, communicating with an avatar of a real person in AR can be a viable alternative [7]. By conveying and enhancing social signals, AR can resemble typical human–human interpersonal communication, which is not always possible to achieve with existing communication tools such as video conferencing [8–10]. As a result, AR systems hold promise for providing vivid communication experiences and bolstering communication quality across distances, thereby fostering the social engagement of older adults [11].

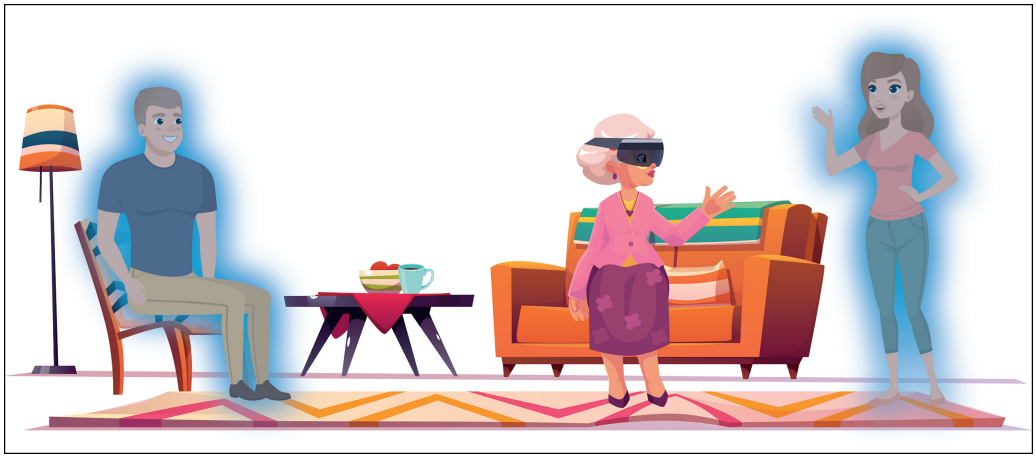

Figure 1. Example of AR-based interpersonal communication: Grandmother Clara receives a virtual visit by her two grandchildren represented as avatars. Own representation. Characters and objects: Adobe Stock (Standard license).

In light of such prospects, it seems fruitful to develop new AR systems specifically tailored to the needs of older adults. However, research on social applications of AR among older users remains very scarce. To address this gap, the present qualitative study aims to explore older adults' attitudes and requirements toward communication in AR to provide a solid base for future technology development as well as to contribute to the body of research on older adults' use of AR.

1.1. Areas of AR Use by Older Adults

AR can contribute to the well-being and quality of life of older adults across multiple domains [3,12]. For instance, AR-based physical exercise and balance training systems have shown an overall positive effect on adherence to training and levels of engagement among older users [13]. During the training program, a computer-generated virtual coach can guide older adults through the exercises and provide immediate feedback [14]. Interaction with a virtual coach generates higher levels of motivation among older users and makes the training experience more enjoyable [15]. Similarly, cognitive AR-based games have the potential to improve older adults' working memory, attention focus, and visual perception memory [16]. In multiplayer scenarios, they can also trigger positive emotional responses and high enjoyment during social interaction with other players [17,18].

Furthermore, AR can be beneficial for instrumental activities and daily support of older adults. Accompanied by voice assistance, visual 3D prompts can be augmented into the living environment and guide older adults through everyday routine tasks such as medication management, meal preparation, or cleaning [19–21]. This way, AR systems can support the independence of those individuals who might otherwise require continuous assistance from medical staff [22].

In addition to supporting physical and cognitive health, AR can also promote the social engagement of older adults [3]. By incorporating augmented elements and avatars of other users into social platforms or communication tools, older adults can connect with family, friends, and communities in more meaningful ways [23]. They can share experiences, participate in virtual gatherings, and explore shared interests through AR-enhanced activities, fostering a sense of belonging, as illustrated in Section 1.

AR implementation in the aforementioned domains presents a diverse range of user experiences (UX) for older adults, encompassing both benefits and challenges. These experiences often diverge from those of younger generations and vary within the group of older adults themselves, even in similar usage scenarios (e.g., [24–26]). This underlines the relevance of designing AR systems that can support age diversity and intergenerational co-design [27].

1.2. Benefits of AR Use by Older Adults

Older adults often describe their experience with AR systems as enjoyable and motivating [15,17]. Whether it is an interaction with a virtual coach or with other users, the immediate auditory and visual feedback that AR allows makes the UX more interactive and fun compared to traditional settings [28]. As a result, AR-enabled physical and cognitive exergames hold greater potential in supporting the physical health of older users. The immersive nature of AR can also increase perceived playfulness, which can be a significant predictor of an individual's well-being [29].

Furthermore, positive UX among older adults is generated by the perceived novelty of AR as a technological solution [15,30]. Older users typically express curiosity about diverse AR systems and appreciate the chance to try an unfamiliar device [17]. Overall, positive emotions such as joy and curiosity play an important role in technology acceptance and adoption by older users [31].

In interpersonal communication scenarios, AR systems can generate a high degree of social presence by enabling avatar-based interaction over distance [32]. Social presence refers to the feeling of connectedness and "being with another" that a person experiences during mediated contact [33,34]. Experimental studies conducted among younger users suggest that social interactions in AR significantly improve nonverbal behavior and perceived social presence among individuals in comparison to conventional communication media [35]. Based on the opinions of young adult grandchildren, similar effects can be achieved in intergenerational AR-based communication thanks to the better transmission of facial expressions and gestures [36]. Empirical studies among older users themselves, however, are lacking.

1.3. Challenges of AR Use by Older Adults

Despite its benefits, AR presents challenges for older adults' effective use. The wearability of head-mounted displays (HMDs) is a common issue across different AR systems. In qualitative assessments, older users often refer to AR headsets as being "wobbly", "bulky", "monstrous" and too heavy to wear for an extended period of time [13,21]. Additionally, older adults may experience motion sickness or cybersickness during AR system use, although the extent of this problem is not entirely clear [37].

Usability is another obstacle to the effective use of AR systems by older adults. Age-related physical changes cause a decline in sensation, perception, and cognition, making it more difficult for older adults to learn how to operate a new unfamiliar device [38,39]. As a result, the design and interface of AR systems may not always be easy and intuitive for older users [40]. This can result in feelings of frustration and anxiety among older adults who might struggle with system controls or overall handling of the technology [13,15]. This obstacle is typically addressed by providing older adults with an extensive introductory training session before using the technology. However, such sessions also can become stressful and overwhelming for older users [13].

Last but not least, the older adults' overall (non-)acceptance of immersive technologies such as AR is still a debated topic. Although many experimental studies indicate that older adults are excited, curious, and interested in emerging technologies (e.g., [26,41,42]), this user demographic still faces frequent stereotypes of being skeptical, fearful, unwilling, and even incapable of using new technological advances [43,44]. Due to these misconceptions, older adults are often underrepresented in AR-related studies. However, as more older adults embrace modern technologies, their digital exclusion is becoming less prevalent, and more attention is being given to them as potential technology users [41,45].

1.4. Current Study

The present study explores the potential of AR systems to promote more immersive and engaging communication experiences for older adults. Guided by the human-centered design approach, it aims to describe older adults' general attitudes toward AR as a communication medium and identify their specific requirements to foster sustainable and inclusive technology development.

Attitudes are evaluations of objects, persons, or concepts along a positive to a negative dimension that are derived from an individual's experience or situation [46]. They can have a strong influence on an individual's behavioral patterns, including technology acceptance and adoption [47,48]. For the user group of older adults, positive attitudes toward communication technologies are typically related to their perceived benefits, while negative attitudes are related to inconvenience during use and safety concerns [49]. Understanding both positive and negative attitudes of older adults toward AR-based interpersonal communication can help to identify the key focal points for the development of AR-based communication systems and foster their better acceptance and adoption. Additionally, personal attitudes can provide valuable insights into older adults' behavioral intentions regarding the use of such systems. Thus, the study first aims at answering the following research question (RQ):

> **RQ1**: What general attitudes do older adults have regarding innovative communication in the form of augmented reality (AR)-enabled interpersonal communication?

While attitudes typically cover general personal evaluations, user requirements are the formal descriptions of the precise functions, characteristics, or properties of a technology that must be provided to satisfy the user's needs [50,51]. Formulated from the user's perspective, they provide guidelines and recommendations for engineers and designers involved in technology development [52]. User requirements can include multiple task- or usability-related attributes of the system (e.g., its software possibilities) as well as cover its affective characteristics that focus on the user's expected perceptions of the technology [53]. The latter can be especially relevant for the user group of older adults, whose technology adoption is often based on positive emotions such as enjoyment, curiosity, and trust [31,54]. Furthermore, considering the heterogeneity of older adults as a user group, specifying their precise requirements during the initial stage of technology design enables its customization and promotes inclusivity of the final communication system [38,55]. Against this background, the following research question was formulated:

> **RQ2**: What specific requirements do older adults have for innovative digital communication via an augmented reality (AR) system to be developed to foster social engagement?

2. Materials and Methods

This qualitative interview study presents findings from a subset of data collected in a larger investigation of older adults' requirements toward existing (video conferencing) and emerging (AR, social robotics) communication technologies. The study is pre-registered: https://osf.io/8q9za (accessed on 10 December 2023). The full instrument, dataset, interview transcripts and materials are publicly available at the server of Open Science Foundation (OSF): https://osf.io/fxp6r (accessed on 10 December 2023).

Figure 2 provides an overview of the study methodology.

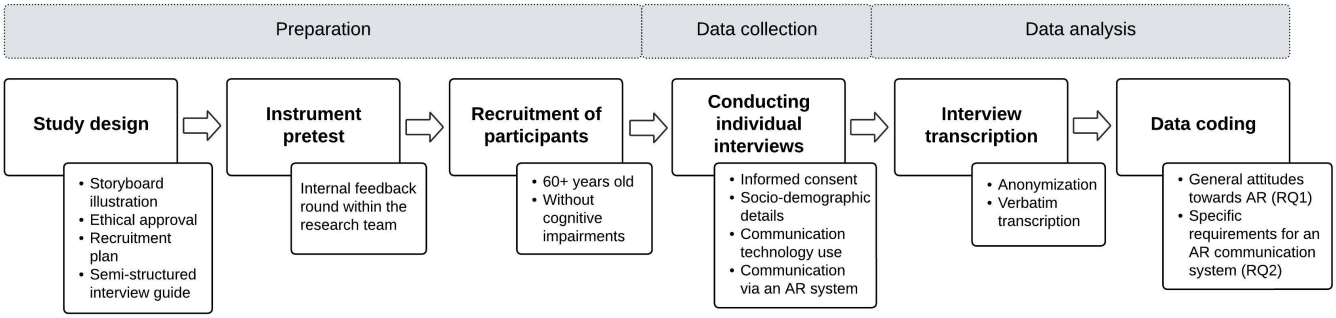

Figure 2. An overview of the study methodology.

2.1. Study Design

The study entailed semi-structured qualitative interviews with older adults. Although there is no unified definition of an "older" person, we adopted the World Health Organization's standard and defined an older adult as a person above 60 years old [56]. The study design is comparable to other qualitative studies exploring users' attitudes toward AR published in this journal (e.g., [57,58]).

2.2. Instrument

An interview guide was developed to assist during the interview process and ensure consistency. The present study is based on the data collected from two interview blocks:

1. General information. Conversation topics included older adults' current living situation, typical communication partners, modern technology use, and general attitudes toward communication media. Participants were asked about how often and with whom they usually talk via communication media, whether their communication practices changed since retirement, and which communication media they enjoy most or least and why. Information collected within this block aimed to provide a detailed understanding of older adults' personalities and attitudes toward existing and innovative communication technologies.
2. Communication via an AR system. This block contained topics aimed at evaluating interpersonal communication via an AR system such as its usability (e.g., perceived ease of use, most and least desired functions), perceived social presence (how close or far away do they imagine they would feel from another person during such communication), and social engagement possibilities (e.g., maintaining existing and establishing new social contacts via an AR communication system).

Since we expected that some of our participants might not be familiar with the term "augmented reality", a two-part storyboard illustration was created to assist them in evaluating AR-based communication. The storyboard depicted a hypothetical communication scenario between a grandparent and their young adult grandchildren using a wearable AR system (see Figure 3).

The storyboard aimed to introduce participants to concepts such as AR, AR headset (referred to as "AR glasses" for better understanding by older adults), and avatars. Two sets of storyboards were created: one featuring a female main character (Grandma Clara) and the other featuring a male main character (Grandpa Felix). The images were accompanied by short textual explanations.

The first part of the scenario showed communication from the perspective of a grandparent, and the second part showed communication from the perspective of a grandchild. Illustrating the perspectives of both communication partners was necessary to provide interviewees with detailed information about how such AR-based communication takes place.

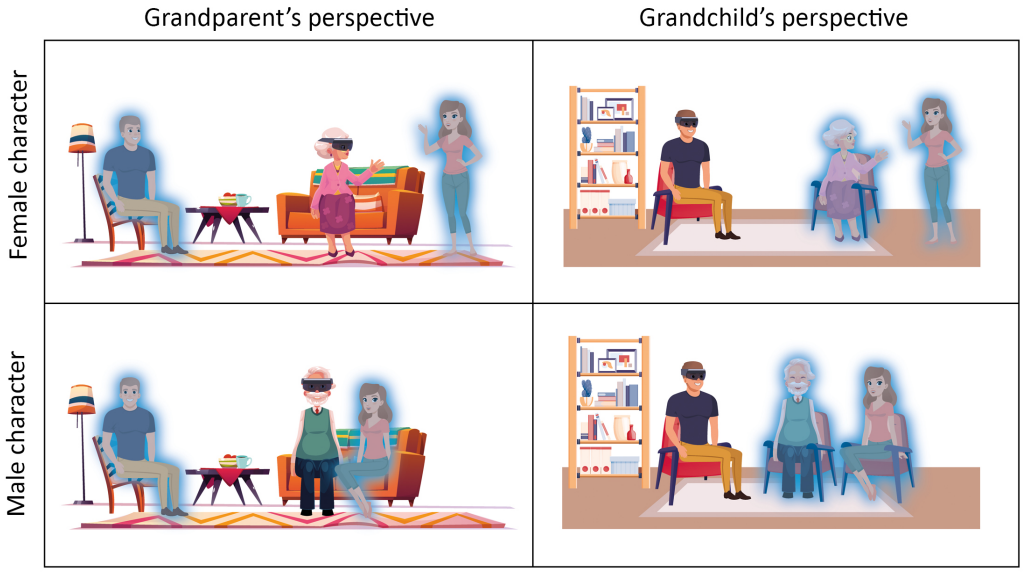

Figure 3. Storyboard illustration of AR-based communication shown to participants. Own representation. Characters and objects: Adobe Stock (standard license). The images were accompanied by textual explanations.

The interview guide was pretested to ensure that it was clear and easily understandable for participants. The pretest round was conducted internally among the research team. Based on the feedback received, the guide was refined and improved to ensure that it effectively captured the information needed.

2.3. Participants and Procedure

Participants were recruited through personal contacts of researchers and invitation flyers distributed at information events. Recruited older adults were encouraged to invite their friends to participate in the interview study as well. Considering the goals of the study, only active, independently living older adults without cognitive impairments were invited to participate.

A total of N = 30 older adults from Germany took part in individual face-to-face interviews. Participants were between 60 and 74 years old (M_{age} = 67.1, SD_{age} = 4.3, 37% women; see Table 1). The sample size of the study was predetermined based on previous qualitative studies and requirement analyses in the field of human–computer interaction involving older adults (e.g., [59–61]).

All interviewed older adults were active communication technology users. As seen in Table 1, they regularly used smartphones, and a vast majority relied on instant messaging services such as WhatsApp, Telegram, and Signal to connect with their social circles. Most participants used digital communication tools to connect with their friends and family at least several times a week in the past month.

Interviews were conducted between May and October 2022 in the German language by two trained female researchers (first and second author). Based on participants' wishes, conversations took place at diverse locations such as university offices, cafés, or participants' homes. The average interview duration was 43 min (range: 21–82 min; see Table 1); breaks and refreshments were offered to participants as needed. All interviews were audio-recorded.

Table 1. Description of the study participants.

No.	Pseudonym	Age	Gender	Household Size [1]	Education	Mediated Communication Frequency [2]	Communication Technology Use	Communication Application Use	Interview Duration (Min)
1.	Helmut	60	m	2	High	Several times a week	Landline phone, smartphone, laptop/PC	Instant messaging, video conference, social media	44
2.	Matthias	60	m	2	Low	Weekly	Smartphone	Instant messaging	66
3.	Sara	61	w	2	Medium	Several times a week	Landline phone, smartphone	SMS, instant messaging	27
4.	Anke	62	w	3	Medium	Daily	Landline phone, smartphone	SMS, instant messaging, video conference, social media	39
5.	Frank	62	m	2	High	Several times a week	Landline phone, smartphone, tablet	SMS, instant messaging, video conference	28
6.	Horst	62	m	2	High	Several times a day	Landline phone, smartphone, laptop/PC	SMS, video conference, email	21
7.	Rolf	63	m	2	High	Several times a day	Landline phone, smartphone	SMS, instant messaging, video conference	36
8.	Susanne	64	w	2	High	Several times a week	Landline phone, smartphone, laptop/PC	Instant messaging, video conference	67
9.	Birgit	64	w	2	High	Daily	Landline phone, smartphone	Instant messaging	22
10.	Stefan	65	m	2	High	Daily	Landline phone, smartphone, laptop/PC	Instant messaging, video conference	27
11.	Gerd	65	m	2	High	Several times a week	Landline phone, smartphone, laptop/PC	SMS, instant messaging, video conference	31
12.	Ute	66	w	2	Medium	Several times a week	Landline phone, smartphone, tablet	SMS, instant messaging, video conference	37
13.	Heinz	66	m	2	High	Several times a week	Landline phone, smartphone, laptop/PC	SMS, instant messaging, video conference	37
14.	Hans	67	m	1	High	Daily	Landline phone, smartphone	SMS, instant messaging, video conference, social media	41
15.	Reinhard	67	m	2	High	Several times a week	Landline phone, smartphone, tablet, laptop/PC	SMS, instant messaging, video conference	73
16.	Claudia	67	w	3	High	Several times a day	Landline phone, smartphone, laptop/PC	Instant messaging, video conference	34
17.	Karl	67	m	2	High	Several times a week	Landline phone, smartphone, tablet, laptop/PC	SMS, instant messaging, video conference, email	34
18.	Monika	67	w	2	High	Several times a week	Landline phone, smartphone	Instant messaging	45
19.	Peter	68	m	2	Low	Less than weekly	Landline phone, smartphone, laptop/PC	Instant messaging, video conference, social media	46
20.	Katja	69	w	2	Medium	Several times a week	Landline phone, smartphone	Instant messaging	33
21.	Jörg	69	m	2	Medium	Several times a week	Smartphone, tablet, laptop/PC	SMS, instant messaging, social media	67
22.	Karina	71	w	2	High	Several times a week	Landline phone, smartphone	Instant messaging, video conference	38
23.	Andreas	71	m	2	High	Several times a week	Landline phone, smartphone	Instant messaging, video conference	45
24.	David	72	m	2	High	Daily	Landline phone, smartphone, tablet, laptop/PC	Instant messaging, video conference	48
25.	Gisela	72	w	2	High	Weekly	Landline phone, smartphone	Instant messaging, video conference	72
26.	Petra	72	w	2	High	Several times a week	Smartphone	SMS, instant messaging	21
27.	Uwe	72	m	2	Medium	Weekly	Smartphone	Instant messaging	29
28.	Gerhard	73	m	2	Medium	Daily	Landline phone, smartphone, laptop/PC	SMS, instant messaging	32
29.	Simon	74	m	2	High	Several times a day	Landline phone, smartphone, tablet, laptop/PC	SMS, instant messaging, video conference, social media	82
30.	Martin	74	m	2	Medium	Several times a week	Landline phone, smartphone, tablet, laptop/PC	SMS, instant messaging, video conference	67

Note. Study participants are listed in ascending order by age. All names are aliases. [1] Number of people living in the same household, including the study participant. [2] In the past four weeks.

After participants were greeted and gave informed consent to the study participation, their general sociodemographic details, such as age, gender, and mediated and non-mediated communication practices, were collected with a brief written questionnaire. Next, the oral interviews proceeded following the developed interview guide. During the personal interviews, male interviewees were shown the grandfather storyboard illustration, and female interviewees were shown the grandmother storyboard illustration (see Figure 3). This gender match aimed at enhancing participants' identification with the respective AR-enabled communication scenario.

The interviews ended with the possibility for participants to ask questions and provide open feedback.

2.4. Data Analysis

The audio-recorded interviews were verbatim transcribed, anonymized, and further analyzed using MAXQDA version 22.4.0 [62].

Qualitative analysis followed the recommendations of Rädiker and Kuckartz [63]. First, all the text segments relevant to answering the RQs were coded and grouped into broad categories based on their main topics. Broad categories corresponded to each interview conversation block. Only full sentences were coded. Repeated statements by the same participant were treated as unique.

Next, broad categories were examined to identify potential themes or patterns within them, and further categories and subcategories were created where appropriate. Categories and subcategories developed for the general information conversational block (e.g., a category "Attitude toward technologies" with subcategories "Positive" and "Negative") were used to provide background information about participants and contextualize further findings. AR-related categories and subcategories (e.g., a category "System" with subcategories "HMD", "Avatar design", "Usability", and "General functionality") were used to identify general attitudes and extract the exact requirements of older adults toward AR-based communication.

In a final step, identified requirements were grouped based on their similarities and presented with detailed explanations and verbatim quotes. Original quotes from the interview transcripts were translated from German to English language for this publication. The translation was quality-checked.

2.5. Ethical Considerations

Participation in the study was voluntary, and all participants signed an informed consent form. All collected data were anonymized during the transcription process, and all personal details of participants that could lead to uncovering their identity or the identities of their friends and family were removed. Any photos from the interviews were taken and published with the explicit written consent of the study participants. The study was approved by the Ethics Committee of Technische Universität Ilmenau on 19 July 2021.

3. Results

3.1. General Attitudes of Older Adults toward AR (RQ1)

Interviews demonstrated that the term "augmented reality" was unfamiliar to most participants, and none had any previous practical experience with an AR system. Therefore, older adults' general attitudes toward AR-based communication were solely based on the presented storyboard illustrations (see Figures 1 and 3).

Overall, interviewees had diverging attitudes regarding the very idea of avatar-based interpersonal communication. Reactions varied from very negative (e.g., *"When I think that someone is suddenly sitting at the table with me, I find that kind of creepy"*—Rolf, 63 years old) to very positive (e.g., *"It's like a virtual family reunion. That's really cool, I like it"*—Peter, 68 years old).

Despite some negative initial evaluations, the majority of participants answered affirmatively when asked if they would like to try such communication technology in the future.

Figure 4 provides an overview of the most typical evaluations of AR-based interpersonal communication in the interview transcripts.

Figure 4. Older adults' initial evaluations of AR-based interpersonal communication. The wordcloud was generated with MAXQDA and displays the 30 most commonly used words that the interviewees used to describe their first impressions of AR-based interpersonal communication, which were based on presented storyboard illustrations. The words are sized according to the frequency of their use by different participants.

3.2. Specific Requirements of Older Adults for an AR Communication System (RQ2)

Data analysis revealed four main dimensions of older adults' requirements for the AR system to be developed: (1) technological, (2) emotional, (3) social, and (4) administrative requirement dimensions. Identified dimensions, their description, requirement subdimension, and examples are summarized in Table 2.

3.2.1. Technological Requirements

The technological requirements of older adults covered general functionality and technical characteristics of an AR system, regarding both the hardware and software. Requirements for hardware included wishes to have an AR headset that is lightweight, comfortable to wear, and will not interfere with wearable health aids, such as vision glasses or hearing devices. Furthermore, the possibility to freely move around during AR-based communication was an important requirement. For example, 62-year-old Anke expressed concerns that she would not be able to walk around the house with an AR headset on in the same way she does with her smartphone:

> *"The question is, if I leave the room, will the avatars all go with me? I need to be able to move. That is, the [AR] glasses should be always like 'Ok, I'm going to go into the kitchen now', and the two avatars run along with me."*

As for the software, participants raised questions regarding the start of AR-based communication and how they will know that someone tries to connect with them. The main requirement was to make this process as transparent and effortless as possible. David is 72 years old and has been an active technology user his whole life both in his personal and professional activities. He is very excited with the whole idea of an AR-based communication scenario but remains pragmatic regarding practical aspects of operating the system:

> *"When someone calls me, I should just press a button somewhere and accept the call. And if I want to call someone, I should somehow be able to select this person or several people. I don't know, how will this be realized? Do you need an additional device, an app on a mobile phone, or something else?"*

Table 2. Requirements of older adults for AR-based communication.

Dimension	Description	Requirement Subdimension	Example
Technological	Requirements related to general functionality and usability of the AR communication system	Ease of use	*"I know it works when I turn it on and I don't have to do much. There's always a lot of talk about 'it's very simple, you plug it in, and it works', but it's not."* (Rolf, 63 years old)
		Realistic avatar design	*"Not only the face like when you have a video conference, but [the avatar] sits with you. I think that's critical, especially for older people."* (Sara, 61 years old)
		The wearability of AR headset	*"It might be difficult to put on these [AR] glasses because in older age you also wear glasses yourself. And you might also have a hearing aid, which could be problematic."* (Katja, 69 years old)
		Effortless contact initiation	*"How can [another person] be reached then? Is it on the mobile phone, is there a message 'Get your [AR] glasses, someone wants to talk to you'?"* (Jörg, 69 years old)
		Mobility	*"There should be no wires connected, so that I can walk around the room."* (David, 72 years old)
Emotional	Requirements related to the user's emotional state during AR system use	Intimacy	*"If I want to have contact, then I want to have contact the way I see you [the interviewer] now [during this face-to-face interaction]. The way I can look into your eyes. That would be important to me."* (Uwe, 72 years old)
		Positive affect	*"The thought of my son living in [another city] and suddenly he's sitting here opposite me, that's creepy."* (Rolf, 63 years old)
Social	Requirements related to social activities during AR system use	Joint activities	*"You can do something together, build something, and both of you can see the Legos, for example [. . .] or do a puzzle together."* (Helmut, 60 years old)
		Multiparty interaction	*"It's like a virtual family reunion. That's really cool, I like it."* (Peter, 68 years old)
Administrative	Requirements related to organization and ownership of the AR system	Affordability	*"Of course, it has to be affordable. [. . .] It's no use if only the rich and the famous can use it."* (Jörg, 69 years old)
		Privacy	*"The others don't need to know what my room looks like."* (Frank, 62 years old)

Note. User requirements dimensions are presented in descending order based on their observed prevalence; however, no quantitative analysis was conducted with the transcripts of the qualitative interviews. All names are aliases.

David continues his interview with comments regarding the expected appearance of an avatar both in terms of the general quality of its rendering and possible design. Like all the other participants who commented on these aspects, he insists that an avatar should resemble a real person as closely as possible:

> *"If I have the advantage that I really see [an avatar] as an actual person, then I think I would also put on these [AR] glasses."*

Technological requirements comprised the clear majority of all collected evaluations despite some of the participants not having any technical background.

3.2.2. Emotional Requirements

Enabling positive feelings and emotions during AR-based interpersonal communication was an important requirement for participants. Having had no previous experience with AR, interviewees expressed concerns about feeling uncomfortable or scared during such communication. Related to this was the anticipated low perceived feeling of intimacy between the communication partners. For example, Petra stresses that eye contact and tangibility are particularly important for her to experience closeness to another person during a conversation. She is 72 years old, lives with her spouse, and enjoys talking on the phone with her children who live in another town. In her interview, she tries to imagine how it would feel to talk to an avatar instead of a real person:

> *"I would feel very uncomfortable. This is something you can't touch. [Avatars] are there, I see them, sure. But it's a completely different feeling. If I had my children here, for example, I could hold their hand. [With an avatar] I can't do that, I would be reaching into the void. So that's different from the feeling, from the conversation, from everything."*

68-year-old Peter, who also lives with his spouse and has adult children who live in another town, recognizes the same challenges. However, he doesn't consider them to be critical. Instead, he sees the possibility to communicate with an avatar as a great alternative to a personal meeting and a noticeable improvement compared to other digital media such as video conferencing:

> *"Of course, the hugging or the cuddling or the kissing is still missing. But I think especially when you don't have the opportunity to travel or go somewhere every week, and the older you get, the more difficult that becomes, then [AR] can be a great thing, a good substitute. You can see this moving person practically directly in your room or maybe you can even feel them, I don't know. But if I were sitting here now and communicating [in AR] with my [family member] and he is sitting right there at the table, it would be something completely different from the screen where you only see a face and nothing else. I think that would be very nice."*

Overall, the emotional requirements of older adults covered such feelings as perceived warmth and intimacy during AR-based communication; however, positive emotions like playfulness and joy were also addressed.

3.2.3. Social Requirements

Among social requirements, the main focus of participants was on being able to perform joint activities in AR. Older adults shared multiple ideas of how they could use the presented technology to gather with family members at a dinner table, play a game together, or even receive direct assistance. The common requirement in such scenarios was the possibility to meet with several people at once. At the beginning of her interview, 64-year-old Susanne was skeptical toward AR and referred to it as "something out of the science fiction movie"; however, as the conversation progressed, she started coming up with ideas of how such communication can be used:

> *"You can just call up your friend and say 'Hey, come over and let's play music together'."*

Some participants also expressed the wish to be able to use AR to connect to people outside their social circles, such as medical personnel. Peter, who was excited about AR

from the very beginning, shared multiple ways he could use AR to make his everyday life more comfortable:

> *"I could imagine not having to sit in the doctor's waiting room for three hours, but just getting an appointment where you have to put on your [AR] glasses. [. . .] You're asked what's wrong with you and does it hurt here or there, and then you get the medicine. This way you've saved I don't know how many kilometers and how many hours."*

He also speaks about the benefits that AR can bring to people who are alone and do not have many social contacts. According to Peter, for such people, AR can be a way to stay socially engaged even after the loss of a partner:

> *"I still have my wife and my wife still has me. But just imagine, if I'm no longer there and she's all alone. Then [AR] is brilliant, she won't perish. And it's often the case when people grow old together and one of them dies. There are so many ways of not, how shall I put it, cutting that person off socially."*

This perspective was common among participants. Even the most skeptical ones, like Petra, agreed that their attitude could change if they did not have many possibilities to interact face-to-face with other people and had to rely on technology-mediated interpersonal communication:

> *"I don't want to use [AR]. But this is what I think today. But what I'll think in ten years, when I'm all alone, might be different. We [she and her life partner] still live together. Of course, that can also change."*

Older adults' social requirements mainly revolved around communicating with people they already know. The idea of using this form of communication to establish connections with new people was largely dismissed.

3.2.4. Administrative Requirements

Apart from the actual process of interpersonal communication, older adults expressed requirements regarding organizational and practical aspects of using and owning an AR system. The affordability of an AR headset was among the most urgent administrative requirements. *"How much does it cost? As much as a Mercedes Benz?"*— jokingly asked Peter (68 years old).

Data protection and privacy were also a big concern among participants. Gerhard, a 73-year-old senior resident of a small town, is not the biggest fan of communication technologies. His family lives in the same town as him, so he prefers to meet with them in person. However, he still actively participates in a family WhatsApp group where the whole family regularly exchanges short text messages and photos. He explains that his main concern with modern technologies in general, and with AR in particular, is data protection and privacy. Although the idea of communication in AR does not excite him too much, he does not oppose it. However, he has very strict requirements regarding the handling of his personal data:

> *"The problem is always with the protection of personal rights. For example, when you communicate with your mobile phone, laptop, or computer, or order something, you almost always know that you will be bombarded with advertising, and that bothers me a lot. I would like to see my personal rights respected. [. . .] I can imagine communication with the [AR] glasses with another person somewhere in Hamburg or Berlin or I don't know where, it doesn't matter, but only if my personal rights are preserved and I am not, as I said, bombarded with advertising or anything else."*

Overall, the comparison of a prospective AR system with existing communication technologies and media devices such as smartphones, laptops as well as social media platforms was commonly addressed as part of older adults' administrative requirements.

4. Discussion

The study aimed to identify general attitudes and specific requirements that older adults have toward AR-enabled interpersonal communication. To answer the study's research questions, individual qualitative interviews were conducted among the sample of $N = 30$ older adults in Germany. Participants spoke about their use of modern communication technologies and evaluated potential AR-based interpersonal communication based on storyboard illustrations.

4.1. General Attitudes of Older Adults toward AR (RQ1)

Interviews showed that study participants had positive experiences with communication technologies and regularly used modern communication devices and digital media such as video conferencing and instant text messaging services to connect with their social circles. Opinions on the presented AR-based communication scenarios, however, were divided. Many interviewees were skeptical about the very idea of having to socially interact with an avatar of another person, calling avatars "creepy" and "ghost-like". Others, on the other hand, were excited about such a communication form, referring to it as being "remarkable" and "absolutely genius". Previous studies often emphasized the diverse nature of older adults as a user group [25,55]; thus, such mixed attitudes toward AR-based communication were expected. The ambivalent evaluations can also be attributed to participants' complete lack of prior knowledge and practical hands-on experience with AR.

However, it should be noted that even the most skeptical older adults met the presented communication scenarios with curiosity. Moreover, the majority expressed an interest in trying such an AR system in the future, even if they could not see themselves using it in the long term. Such feedback speaks against the frequent stereotype of older adults being disinterested in technology at all due to their age [44]. Observations made in the present study demonstrated high engagement of older adults who were eager to share their views and opinions on the innovative AR system as well as discuss requirements for it in detail. This underscores the appropriateness of adopting a human-centered design approach and collecting user requirements when designing communication technologies intended for older adults.

4.2. Specific Requirements of Older Adults for an AR Communication System (RQ2)

Older adults had technological, emotional, social, and administrative requirements for a prospective AR communication system.

Technological requirements comprised a vast majority of all collected evaluations. As expected, ease of use was a central requirement for an AR communication system to be developed. Previous research has repeatedly emphasized the importance of considering the physical, social, and mental changes that occur with age when designing technologies with good usability [39]. Older adults themselves acknowledged these changes by addressing the relevance of the system's compatibility with assistive medical devices such as hearing aids and vision glasses.

Interestingly, despite all interviewees being over 60 years old, they did not personally associate themselves with the term "older adult" and did not view themselves as belonging to this particular user group. Instead, in a similar manner to how children and grandchildren often express concerns regarding the technology competence of older members of their families (e.g., [36]), study participants commented on the ability of their parents and those who are older than them to handle such an AR system:

> *"I don't think my mother will understand [AR], sometimes she doesn't even understand video conference. Because she is so old."* (Sara, 61 years old)

Such observations can partly be explained by the technology-related educational or professional background of some participants. Nevertheless, this highlights the fact that age itself does not seem to be a determining factor for technological aptitude, as participants

considered themselves perfectly capable of operating a new communication system, should they choose to:

> *"I don't think it would be too difficult [to use AR]. You do it once or twice, and then it would become second nature, just like using a mobile phone."* (Sara, 61 years old)

Consistent with prior research emphasizing the significance of positive emotions in facilitating successful technology use among older adults (e.g., [31,54]), study participants demonstrated an array of affective needs regarding interpersonal communication in AR. In particular, interviewees expressed concerns with the level of intimacy that can be achieved in AR due to the lack of tangible experience. Translating participants' affective perceptions of the hypothetical communication scenarios into precise requirements and practical recommendations for later stages of technology development can pose challenges [53]. However, they play a vital role in generating social presence, which is necessary for the effective design of technologies intended to enhance social engagement [64]. One way to increase the feeling of social presence conveyed in AR can be through the thoughtful avatar design that incorporates lifelike gesture movements and gaze. Furthermore, contributing to a decade-long debate in the research community on the degree of realism that an avatar or a virtual human should have (e.g., [65–67]), this study's participants unanimously agreed that an avatar should depict their communication partner as realistically as possible to provide an immersive experience.

The social requirements expressed by the interviewees primarily revolved around two key aspects: the envisioned use scenarios of the forthcoming AR system and the potential communication partners involved. In this regard, there was a consensus among participants that AR holds significant potential as a tool for preserving social connections, particularly for those individuals who experience social isolation and loneliness. Although these topics were not explicitly addressed in the interview guide, the majority of participants discussed the challenges that many individuals face in staying socially engaged in older age and how the presented AR system can help to overcome these challenges. Potential benefits of immersive technologies for the mental and social health and well-being of older adults have been a fruitful research topic in the past few years [3,12]; however, they still remain largely theoretical. Since this study's participants were all in good mental and physical health, had friends and family with whom they maintained regular contact, and most were living together with a partner, they generally considered themselves disengaged from the topic of loneliness. Nevertheless, AR-based communication was met with high hopes regarding fostering social engagement and helping those in a less fortunate social situation maintain social contacts:

> *"I can imagine something like this for people who don't have anyone anymore, who don't get around much. Then you can chat a bit [with an avatar] and then you have the feeling of being with someone."* (Claudia, 67 years old)

Although based on the evaluations of the hypothetical communication scenarios, such feedback indicates that AR can indeed be an appropriate technology to foster social engagement of older adults, particularly when allowing for multiparty interaction.

Last but not least, older adults expressed administrative requirements for the AR communication system. Among these, associated costs and safeguarding personal data were most prevalent. Privacy and security concerns and the resulting lack of trust can contribute to older adults' underuse of communication technologies, as well as impede current users from fully embracing the technology's potential [5,54]. Therefore, addressing such ethical considerations as informed consent, data protection, and other potential vulnerabilities associated with immersive technologies during technology design and implementation processes is essential. However, contrary to the common stereotype of older users being skeptical of new technological advances [43,44], the study participants did not distrust the potential AR communication system. Instead, they simply sought more transparent information about data-handling protocols prior to usage. Thus, privacy and security concerns should not be regarded as barriers to the adoption of the prospective AR communication

system but rather as matters to be addressed through enhanced information transparency. Providing participants with comprehensive information about the system's privacy and data-protection protocols can enhance their sense of security and perceived control during AR-based interpersonal communication. This, in turn, can facilitate more enjoyable UX and foster greater acceptance and adoption of the novel communication system.

4.3. Limitations and Outlook

The study provides valuable insights into older adults' perspectives on AR-enabled interpersonal communication. However, its limitations need to be acknowledged.

Firstly, the present study relies on semi-structured individual interviews to gather participants' attitudes and requirements toward AR-based communication. Thus, there may be potential for subjectivity and bias in participants' responses. Future studies should incorporate quantitative methods of data collection, such as surveys or observation, to provide a more holistic understanding of older adults' experiences, preferences, and behaviors concerning AR technologies, contributing to the validation of the findings.

Furthermore, the study's sample consisted of active, independently living older adults from Germany with a keen interest in technology. While such sampling was necessary for the goals of the study, it challenges the generalizability of the results to different cultural, socioeconomic, and geographic contexts. Future studies could expand on the findings of the present study by including a more diverse sample of older adults.

Another limitation was the use of scenario evaluation based on static storyboard illustrations instead of animations or video demonstrations. Storyboards are commonly used in user requirements analyses [68]. Nevertheless, they may have affected participants' overall understanding of an AR system, since none of the participants had any prior practical experience with similar systems.

The findings of the study provide recommendations for the design and development of communicative AR systems for older adults. These recommendations include incorporating joint tasks or games (e.g., completing a puzzle), shared auditory experiences (e.g., playing a musical instrument or singing together), and opportunities to interact with multiple photorealistic avatars simultaneously (e.g., gathering several family members in one room).

In light of the prevalent technological requirements highlighted in this study, we also recommend prioritizing the usability of the systems to be developed and consider the technological familiarity of prospective users and their possibly limited prior experience or exposure to such immersive technologies. Additionally, ongoing usability testing and user feedback loops are crucial for refining the communicative AR systems for older adults over time.

5. Conclusions

The present interview study explores the potential of AR-based communication systems to enhance social connections among older adults and provides valuable insights and practical recommendations for technology designers and researchers working with this demographic.

The findings illustrate that older adults acknowledge the potential benefits of AR systems for enhancing their social engagement. However, specific requirements must be met to encourage their acceptance and the use of these digital tools. A key consideration lies in addressing the emotional requirements of older adults in AR-mediated interpersonal communication, as these significantly influence their willingness to adopt such systems. The integration of emotional design into the development of AR systems is therefore essential to enhance the overall UX, ultimately leading to improved interpersonal communication.

Successfully integrating these recommendations into the development of AR systems can pose challenges as it requires close collaboration across multiple disciplines and stakeholder groups. Thus, we explicitly recommend establishing interdisciplinary collaborations involving experts in gerontology, communication and computer science, UX design, and technology development. Such cooperations should involve active engagement with

older adults themselves to ensure the inclusivity and effectiveness of the proposed features. Furthermore, fostering partnerships with healthcare professionals and organizations can also contribute to the integration of these systems into broader healthcare and social support frameworks, promoting the overall well-being of older adults in diverse settings.

Lastly, the study's findings highlight a noteworthy level of engagement and enthusiasm among participants when discussing an innovative AR-based communication system. Challenging common stereotypes of older adults being disinterested in new technological advances, this emphasizes the viability of involving this user group in the early stages of technology development. By acknowledging the diverse needs and emotional considerations of older adults, future advancements can pave the way for creating inclusive and user-friendly AR communication systems tailored to their unique requirements.

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References

1. Li, Y.; Ch'ng, E.; Cobb, S.; See, S. Presence and communication in hybrid virtual and augmented reality environments. *Presence Teleoperators Virtual Environ.* **2019**, *28*, 29–52. [CrossRef]
2. Cipresso, P.; Giglioli, I.A.C.; Raya, M.A.; Riva, G. The past, present, and future of virtual and augmented reality research: A network and cluster analysis of the literature. *Front. Psychol.* **2018**, *9*, 2086. [CrossRef] [PubMed]
3. Lee, L.N.; Kim, M.J.; Hwang, W.J. Potential of augmented reality and virtual reality technologies to promote wellbeing in older adults. *Appl. Sci.* **2019**, *9*, 3556. [CrossRef]
4. Döring, N.; Conde, M.; Brandenburg, K.; Broll, W.; Gross, H.M.; Werner, S.; Raake, A. Can communication technologies reduce loneliness and social isolation in older people? A scoping review of reviews. *Int. J. Environ. Res. Public Health* **2022**, *19*, 11310. [CrossRef] [PubMed]
5. Bixter, M.T.; Blocker, K.A.; Rogers, W.A. Enhancing social engagement of older adults through technology. In *Aging, Technology and Health*; Pak, R., McLaughlin, A.C., Eds.; Academic Press: San Diego, CA, USA, 2018; pp. 179–214. [CrossRef]
6. Barbosa Neves, B.; Franz, R.; Judges, R.; Beermann, C.; Baecker, R. Can digital technology enhance social connectedness among older adults? A feasibility study. *J. Appl. Gerontol.* **2019**, *38*, 49–72. [CrossRef]
7. Burholt, V.; Windle, G.; Gott, M.; Morgan, D.J. Technology-mediated communication in familial relationships: Moderated-mediation models of isolation and loneliness. *Gerontologist* **2020**, *60*, 1202–1212. [CrossRef] [PubMed]
8. Kim, K.; Bruder, G.; Maloney, D.; Welch, G. The influence of real human personality on social presence with a virtual human in augmented reality. In Proceedings of the ICAT-EGVE 2016—International Conference on Artificial Reality and Telexistence and Eurographics Symposium on Virtual Environments, Little Rock, AR, USA, 7–9 December 2016; Reiners, D., Iwai, D., Steinicke, F., Eds.; The Eurographics Association: Goslar, Germany, 2016. [CrossRef]
9. Nijholt, A. Social augmented reality: A multiperspective survey. In Proceedings of the 2021 Joint 10th International Conference on Informatics, Electronics & Vision (ICIEV) and 2021 5th International Conference on Imaging, Vision & Pattern Recognition (icIVPR), Kitakyushu, Japan, 16–20 August 2021; pp. 1–8. [CrossRef]

10. Hirskyj-Douglas, I.; Kantosalo, A.; Monroy-Hernández, A.; Zimmermann, J.; Nebeling, M.; Gonzalez-Franco, M. Social AR: Reimagining and interrogating the role of augmented reality in face to face social interactions. In Proceedings of the Companion Publication of the 2020 Conference on Computer Supported Cooperative Work and Social Computing, New York, NY, USA, 17–21 October 2020; pp. 457–465. [CrossRef]
11. Rogers, W.A.; Blocker, K.A.; Dupuy, L. Current and emerging technologies for supporting successful aging. In *The Cambridge Handbook of Cognitive Aging: A Life Course Perspective*; Thomas, A., Gutchess, A., Eds.; Cambridge University Press: Cambridge, UK, 2020; pp. 717–736. [CrossRef]
12. Seifert, A.; Schlomann, A. The use of virtual and augmented reality by older adults: Potentials and challenges. *Front. Virtual Real.* **2021**, *2*, 51. [CrossRef]
13. Blomqvist, S.; Seipel, S.; Engström, M. Using augmented reality technology for balance training in the older adults: A feasibility pilot study. *BMC Geriatr.* **2021**, *21*, 144. [CrossRef]
14. Kouris, I.; Sarafidis, M.; Androutsou, T.; Koutsouris, D. HOLOBALANCE: An augmented reality virtual trainer solution forbalance training and fall prevention. In Proceedings of the 2018 40th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Honolulu, HI, USA, 18–21 July 2018; pp. 4233–4236. [CrossRef]
15. Mostajeran, F.; Steinicke, F.; Ariza Nunez, O.J.; Gatsios, D.; Fotiadis, D. Augmented reality for older adults: Exploring acceptability of virtual coaches for home-based balance training in an aging population. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems, Honolulu, HI, USA, 25–30 April 2020; pp. 1–12. [CrossRef]
16. Han, K.; Park, K.; Choi, K.H.; Lee, J. Mobile augmented reality serious game for improving old adults' working memory. *Appl. Sci.* **2021**, *11*, 7843. [CrossRef]
17. Chen, Y.F.; Janicki, S. A cognitive-based board game with augmented reality for older adults: Development and usability study. *JMIR Serious Games* **2020**, *8*, e22007. [CrossRef]
18. Simão, H.; Bernardino, A. User centered design of an augmented reality gaming platform for active aging in elderly institutions. In Proceedings of the 5th International Congress on Sport Sciences Research and Technology Support (icSPORTS 2017), Madeira, Portugal, 30–31 October 2017; pp. 151–162. [CrossRef]
19. Ikeda, S.; Asghar, Z.; Hyry, J.; Pulli, P.; Pitkanen, A.; Kato, H. Remote assistance using visual prompts for demented elderly in cooking. In Proceedings of the 4th International Symposium on Applied Sciences in Biomedical and Communication Technologies, Barcelona, Spain, 26–29 October 2011; pp. 1–5. [CrossRef]
20. Lazic, K.S.; Achilleos, A.; Parker, S.; Mettouris, C.; Yeratziotis, A.; Papadopoulos, G.A.; Theodorou, C.; Pecyna, K. GUIDed: An augmented reality assisted-living and social interaction platform for older adults. In *ICT for Health, Accessibility and Wellbeing, Proceedings of the IHAW 2021, Larnaca, Cyprus, 8–9 November 2021*; Communications in Computer and Information Science; Pissaloux, E., Papadopoulos, G., Achilleos, A., Velázquez, R., Eds.; Springer: Cham, Switzerland, 2021; Volume 1538, pp. 66–79. [CrossRef]
21. Rohrbach, N.; Gulde, P.; Armstrong, A.R.; Hartig, L.; Abdelrazeq, A.; Schröder, S.; Neuse, J.; Grimmer, T.; Diehl-Schmid, J.; Hermsdörfer, J. An augmented reality approach for ADL support in Alzheimer's disease: A crossover trial. *J. NeuroEng. Rehabil.* **2019**, *16*, 66. [CrossRef] [PubMed]
22. Lehman, S.; Graves, J.; Mcaleer, C.; Giovannetti, T.; Tan, C.C. A mobile augmented reality game to encourage hydration in the elderly. In *Human Interface and the Management of Information. Information in Applications and Services, Proceedings of the HIMI 2018, Las Vegas, NV, USA, 15–20 July 2018*; Lecture Notes in Computer Science; Yamamoto, S., Mori, H., Eds.; Springer: Cham, Switzerland, 2018; Volume 10905, pp. 98–107. [CrossRef]
23. Achilleos, A.; Mettouris, C.; Yeratziotis, A.; Starosta-Sztuczka, J.; Moza, S.; Hadjicosta, A.; Georgiou, S.; Theodorou, C.; Loizou, C.T.; Pecyna, K.; et al. Lessons learned from older adults fusing of an augmented reality, assisted living and social interaction platform. *SN Comput. Sci.* **2023**, *4*, 378. [CrossRef] [PubMed]
24. Krasovsky, T.; Weiss, P.L.; Kizony, R. Older adults pay an additional cost when texting and walking: Effects of age, environment, and use of mixed reality on dual-task performance. *Phys. Ther.* **2018**, *98*, 549–559. [CrossRef] [PubMed]
25. Peek, S.T.M.; Luijkx, K.G.; Rijnaard, M.D.; Nieboer, M.E.; van der Voort, C.S.; Aarts, S.; van Hoof, J.; Vrijhoef, H.J.M.; Wouters, E.J.M. Older adults' reasons for using technology while aging in place. *Gerontology* **2016**, *62*, 226–237. [CrossRef] [PubMed]
26. Tang, L.; Zhou, J. Usability assessment of augmented reality-based pedestrian navigation aid. In *Digital Human Modeling and Applications in Health, Safety, Ergonomics and Risk Management. Posture, Motion and Health, Proceedings of the HCII 2020, Copenhagen, Denmark, 19–24 July 2020*; Lecture Notes in Computer Science; Duffy, V., Ed.; Springer: Cham, Switzerland, 2020; Volume 12198, pp. 581–591. [CrossRef].
27. Silva, S.; Braga, D.; Teixeira, A. AgeCI: HCI and age diversity. In *Universal Access in Human-Computer Interaction. Aging and Assistive Environments, Proceedings of the UAHCI 2014, Crete, Greece, 22–27 June 2014*; Lecture Notes in Computer Science; Antona, M., , Stephanidis, A.C., Eds.; Springer: Cham, Switzerland 2014; Volume 8515, pp. 179–190. [CrossRef]
28. Chao, Y.Y.; Scherer, Y.K.; Montgomery, C.A. Effects of using Nintendo Wii™ exergames in older adults: A review of the literature. *J. Aging Health* **2015**, *27*, 379–402. [CrossRef] [PubMed]
29. Parker, C.; Kennedy-Behr, A.; Wright, S.; Brown, T. Does the self-reported playfulness of older adults influence their wellbeing? An exploratory study. *Scand. J. Occup. Ther.* **2023**, *30*, 86–97. [CrossRef]
30. Yoo, I.; Kong, H.J.; Joo, H.; Choi, Y.; Kim, S.W.; Lee, K.E.; Hong, J. User experience of augmented reality glasses-based tele-exercise in elderly women. *Healthc. Inform. Res.* **2023**, *29*, 161–167. [CrossRef]

31. Ramírez-Correa, P.; Grandón, E.E.; Ramírez-Santana, M.; Belmar Órdenes, L. Explaining the use of social network sites as seen by older adults: The enjoyment component of a hedonic information system. *Int. J. Environ. Res. Public Health* **2019**, *16*, 1673. [CrossRef]
32. Piumsomboon, T.; Lee, G.A.; Hart, J.D.; Ens, B.; Lindeman, R.W.; Thomas, B.H.; Billinghurst, M. Mini-Me: An adaptive avatar for mixed reality remote collaboration. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, Montreal, QC, Canada, 21–26 April 2018; pp. 1–13. [CrossRef]
33. Lombard, M.; Ditton, T. At the heart of it all: The concept of presence. *J. Comput.-Mediat. Commun.* **1997**, *3*, JCMC321. [CrossRef]
34. Short, J.; Williams, E.; Christie, B. *The Social Psychology of Telecommunications*; John Wiley & Sons Ltd.: London, UK, 1976.
35. Miller, M.R.; Jun, H.; Herrera, F.; Yu Villa, J.; Welch, G.; Bailenson, J. Social interaction in augmented reality. *PLoS ONE* **2019**, *14*, e0216290. [CrossRef]
36. Döring, N.; Mikhailova, V.; Brandenburg, K.; Broll, W.; Gross, H.M.; Werner, S.; Raake, A. Digital media in intergenerational communication: Status quo and future scenarios for the grandparent-grandchild relationship. *Univers. Access Inf. Soc.* **2022**. [CrossRef] [PubMed]
37. Margrett, J.A.; Ouverson, K.M.; Gilbert, S.B.; Phillips, L.A.; Charness, N. Older adults' use of extended reality: A systematic review. *Front. Virtual Real.* **2022**, *2*, 760064. [CrossRef]
38. Czaja, S.J.; Boot, W.R.; Charness, N.; Rogers, W.A. *Designing for Older Adults: Principles and Creative Human Factors Approaches*, 3rd ed.; CRC Press: Boca Raton, FL, USA, 2019. [CrossRef]
39. Harrington, C.N.; Koon, L.M.; Rogers, W.A. Design of health information and communication technologies for older adults. In *Design for Health*; Sethumadhavan, A., Sasangohar, F., Eds.; Academic Press: Cambridge, MA, USA, 2020; pp. 341–363. [CrossRef]
40. Derby, J.L.; Chaparro, B.S. Use of augmented reality by older adults. In *Human Aspects of IT for the Aged Population. Technologies, Design and User Experience, Proceedings of the HCII 2020, Copenhagen, Denmark, 19–24 July 2020*; Lecture Notes in Computer Science; Gao, Q., Zhou, J., Eds.; Springer: Cham, Switzerland 2020; Volume 12207, pp. 125–134. [CrossRef]
41. Baker, S.; Kelly, R.M.; Waycott, J.; Carrasco, R.; Hoang, T.; Batchelor, F.; Ozanne, E.; Dow, B.; Warburton, J.; Vetere, F. Interrogating social virtual reality as a communication medium for older adults. *ACM Hum.-Comput. Interact.* **2019**, *3*, 1–24. [CrossRef]
42. Vieira, E.R.; Civitella, F.; Carreno, J.; Junior, M.G.; Amorim, C.F.; D'Souza, N.; Ozer, E.; Ortega, F.; Estrázulas, J.A. Using augmented reality with older adults in the community to select design features for an age-friendly park: A pilot study. *J. Aging Res.* **2020**, *2020*, 8341034. [CrossRef] [PubMed]
43. Barnard, Y.; Bradley, M.D.; Hodgson, F.; Lloyd, A.D. Learning to use new technologies by older adults: Perceived difficulties, experimentation behaviour and usability. *Comput. Hum. Behav.* **2013**, *29*, 1715–1724. [CrossRef]
44. Mariano, J.; Marques, S.; Ramos, M.R.; Gerardo, F.; Da Cunha, C.L.; Girenko, A.; Alexandersson, J.; Stree, B.; Lamanna, M.; Lorenzatto, M.; et al. Too old for technology? Stereotype threat and technology use by older adults. *Behav. Inf. Technol.* **2022**, *41*, 1503–1514. [CrossRef]
45. Leist, A.K. Social media use of older adults: A mini-review. *Gerontology* **2013**, *59*, 378–384. [CrossRef]
46. Fabrigar, L.; Wegener, D.T. Attitude structure. In *Advanced Social Psychology: The State of the Science*; Baumeister, R.F., Finkel, E.J., Eds.; Oxford University Press: Oxford, UK, 2010; pp. 177–216.
47. Guyer, J.; Fabrigar, L. The attitude-behavior link: A review of the history. In *International Encyclopedia of Social and Behavioral Sciences*; Wright, J., Berry, J., Eds.; Elsevier: Amsterdam, The Netherlands, 2015; pp. 183–189.
48. Venkatesh, V.; Morris, M.G.; Davis, G.B.; Davis, F.D. User acceptance of information technology: Toward a unified view. *MIS Q.* **2003**, *27*, 425–478. [CrossRef]
49. Mitzner, T.L.; Boron, J.B.; Fausset, C.B.; Adams, A.E.; Charness, N.; Czaja, S.J.; Dijkstra, K.; Fisk, A.D.; Rogers, W.A.; Sharit, J. Older adults talk technology: Technology usage and attitudes. *Comput. Hum. Behav.* **2010**, *26*, 1710–1721. [CrossRef]
50. Abbott, R. *An Integrated Approach to Software Development*; Wiley: New York, NY, USA, 1986.
51. Kujala, S.; Kauppinen, M.; Rekola, S. Bridging the gap between user needs and user requirements. In *Advances in Human-Computer Interaction I: Proceedings of the Panhellenic Conference with International Participation in Human-Computer Interaction, PC-HCI 2001, Patras, Greece, 7–9 December 2001*; Avouris, N., Fakotakis, N., Eds.; Typorama: Patras, Greece, 2001; pp. 45–50.
52. Bevan, N.; Carter, J.; Earthy, J.; Geis, T.; Harker, S. What are user requirements? Developing an ISO standard. In *Human-Computer Interaction. Theories, Methods, and Human Issues, Proceedings of the HCI International 2018, Las Vegas, NV, USA, 15–20 July 2018*; Lecture Notes in Computer Science; Kurosu, M., Ed.; Springer: Cham, Switzerland, 2018; Volume 10901, pp. 3–13. [CrossRef]
53. Coelho, D.A. Specification of affective user experience in product design. In Proceedings of the 5th International Conference on Applied Human Factors and Ergonomics AHFE 2014, Krakow, Poland, 19–23 July 2014; pp. 2216–2224.
54. Braun, M.T. Obstacles to social networking website use among older adults. *Comput. Hum. Behav.* **2013**, *29*, 673–680. [CrossRef]
55. Lindenberger, U.; Lövdén, M.; Schellenbach, M.; Li, S.C.; Krüger, A. Psychological principles of successful aging technologies: A mini-review. *Gerontology* **2008**, *54*, 59–68. [CrossRef] [PubMed]
56. World Health Organization. Active Ageing: A Policy Framework. 2002. Available online: https://apps.who.int/iris/handle/10665/67215 (accessed on 10 December 2023).
57. Wyss, C.; Degonda, A.; Bührer, W.; Furrer, F. The impact of student characteristics for working with AR technologies in higher education—Findings from an exploratory study with Microsoft HoloLens. *Information* **2022**, *13*, 112. [CrossRef]
58. Rapti, S.; Sapounidis, T.; Tselegkaridis, S. Enriching a traditional learning activity in preschool through augmented reality: Children's and teachers' views. *Information* **2023**, *14*, 530. [CrossRef]

59. Bedaf, S.; Marti, P.; Amirabdollahian, F.; de Witte, L. A multi-perspective evaluation of a service robot for seniors: The voice of different stakeholders. *Disabil. Rehabil. Assist. Technol.* **2018**, *13*, 592–599. [CrossRef]
60. Vaportzis, E.; Clausen, M.G.; Gow, A.J. Older adults perceptions of technology and barriers to interacting with tablet computers: A focus group study. *Front. Psychol.* **2017**, *8*, 1687. [CrossRef]
61. Vorwerg, S.; Stamm, O.; Müller-Werdan, U. Movement training in augmented reality for older adults with essential hypertension: A qualitative study determining training requirements. *Games Health J.* **2020**, *9*, 436–445. [CrossRef]
62. VERBI Software. MAXQDA 2022. Available online: https://www.maxqda.com (accessed on 10 December 2023).
63. Rädiker, S.; Kuckartz, U. *Focused Analysis of Qualitative Interviews with MAXQDA*; MAXQDA Press: Berlin Germany, 2020.
64. Riva, G.; Baños, R.M.; Botella, C.; Wiederhold, B.K.; Gaggioli, A. Positive technology: Using interactive technologies to promote positive functioning. *Cyberpsychol. Behav. Soc. Netw.* **2012**, *15*, 69–77. [CrossRef] [PubMed]
65. Nowak, K.L.; Fox, J. Avatars and computer-mediated communication: A review of the definitions, uses, and effects of digital representations on communication. *Rev. Commun. Res.* **2018**, *6*, 30–53. [CrossRef]
66. Schwind, V.; Wolf, K.; Henze, N. Avoiding the uncanny valley in virtual character design. *Interactions* **2018**, *25*, 45–49. [CrossRef]
67. Seymour, M.; Yuan, L.; Dennis, A.R.; Riemer, K. Have we crossed the uncanny valley? Understanding affinity, trustworthiness, and preference for realistic digital humans in immersive environments. *J. Assoc. Inf. Syst.* **2021**, *22*, 591–617. [CrossRef]
68. Maguire, M.; Bevan, N. User requirements analysis: A review of supporting methods. In *Usability. IFIP WCC TC13 2002. IFIP—The International Federation for Information Processing*; Hammond, J., Gross, T., Wesson, J., Eds.; Springer: Cham, Switzerland, 2002; Volume 99, pp. 133–148. [CrossRef]