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# "I have the Feeling that the Person is Here": Older Adults' Attitudes, Usage Intentions, and Requirements for a Telepresence Robot

**Melisa Conde**[1] · **Veronika Mikhailova**[1] · **Nicola Döring**[1]

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**Abstract**
The social integration of older adults has been shown to be vital for successful aging. Innovative communication technologies, such as telepresence robots, can protect older adults against loneliness and social isolation by helping them stay connected to their social networks. This human-centered qualitative study aims to identify the attitudes (research question 1, RQ1), intentions to use (RQ2), and requirements (RQ3) of older adults for robot-mediated communication (RMC) via a telepresence robot. Semi-structured individual interviews were conducted with $N=30$ older adults from Germany, who evaluated storyboard illustrations depicting a fictional RMC scenario between a grandparent and their adult grandchild. The study identified 3 attitude groups towards telepresence robots among participants: positive, negative, and conflicting attitudes (RQ1). Furthermore, based on their intentions of use, participants were classified into reluctant future users ($n=12$), future non-users ($n=10$), and enthusiastic future users ($n=8$) (RQ2). Finally, the study identified technological, social, and age-related requirements of older adults for a telepresence robot (RQ3). Practical recommendations are provided based on these findings, such as leveraging older adults' current technology-related skills, adapting technologies to older adults' lifestyles and social networks, and designing technologies that contribute to older adults aging in place. This study contributes to the human-centered design of telepresence robots that support the social integration of older adults.

**Keywords** Aging · Human-centered design · Innovative technologies · Robot-mediated communication (RMC) · Social robot · Telepresence robot

## 1 Introduction

Clara is 64 years old and has lived half of her life in Germany. She was born in another country, 12,500 km away, where she still has family members– including her beloved younger sister Sylvia. Over the years, Clara and Sylvia have traveled back and forth to meet each other in person. But what really kept their relationship alive over the years is their almost daily, one-hour-long video calls. Clara is usually doing something around the house (cooking, cleaning, or knitting) when she talks to Sylvia via the Facetime app. She has to be creative when it comes to placing her smartphone on an appropriate surface so she can multitask. Although Clara tries her best, she says Sylvia sometimes has to look at her kitchen ceiling for 15–20 min while she is peeling and chopping vegetables for dinner without interrupting the conversation.

When Clara is shown pictures of a telepresence robot (see Fig. 1), she is curious. The idea of a robot that follows her around the house, shows her sister's face on a screen, and allows her to talk for hours without having to hold a device in her hand sounds like science fiction. Nonetheless, she would love to try it with Sylvia.

It is estimated that by 2030, one in six people in the world will be aged 60 years or over [1]. Life changes that usually accompany the aging process (retirement, widowhood, reduced mobility, health issues, etc.) put older adults at risk of suffering loneliness and social isolation. Both conditions are currently considered major public health concerns [2] and have been linked to quality of life, general health, cognitive function, and mortality, among others [3].

Therefore, several potential solutions aimed at fostering the *social integration* of older adults are being developed and researched. There is evidence that innovative

✉ Nicola Döring
nicola.doering@tu-ilmenau.de

[1] Media Psychology and Media Design Group, Technische Universität Ilmenau, Ilmenau, Thuringia, Germany

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**Fig. 1** The telepresence robot of the CO-HUMANICS project in the living lab of Technische Universitat Ilmenau

communication technologies– including *telepresence robots*– have the potential to reduce loneliness and social isolation in older people [4], mainly when used to enhance existing relationships [5].

Telepresence robots are a subset of social robots that are designed to enable interpersonal communication over distance. Telepresence robots consist of a remotely controllable mobile platform with video conferencing equipment that allows *remote users* to move around a local environment and interact socially with *local users* (those sharing a physical space with the robot) [6]. Yet, despite the potential benefits of innovative communication technologies for social integration, the older population consistently adopts these tools at lower rates compared to younger age groups [7].

To overcome this technology adoption barrier, human-centered design is essential when creating technologies for the aging population. Considering the physical and psychological characteristics of older adults and adapting technologies to their life conditions, has proven effective for technology acceptance [8, 9].

Against this backdrop, the current study aims to identify the attitudes, intentions of use, and requirements older adults in Germany have towards telepresence robot-based interpersonal communication that fosters social integration.

## 2 Related Work

### 2.1 Robotic Technologies for the Aging Population

Robotics is currently one of the fastest-growing fields in the technology industry [10]. Technological rapid advances paired with demographic changes have prompted researchers to focus on robots as possible solutions to aged care problems and as significant entities in assisting older adults [11].

Previous research has shown robots to be helpful for caregivers in certain areas of aged care such as information technology, remote and health monitoring, and online daily services [12, 13]. Additionally, robotic systems have been created to aid older adults in daily activities such as cleaning, grasping/retrieving objects, getting into and out of bed, meals, mobility, and handling tools and equipment (like home appliances, door keys, trays, etc.) [14–17].

Among the wide array of robots being researched in the context of aging, *social robots* have gained notoriety given their capabilities to interact with ordinary users and to assist them in everyday life [18, 19]. Research focused on social robots generally includes direct interactions through conversation [20], cooperation [21] and gaming [22], or indirect interactions as aids for users' day-to-day activities [23].

A comprehensive literature review on robotic technologies for older adults showed that telepresence robots are among the most researched social robots [12]. Furthermore, by bringing a sense of connectedness between older adults and their loved ones, telepresence robots have proved effective against issues like loneliness and social isolation [4, 12].

### 2.2 Telepresence Robots for Older Adults

Telepresence robots can connect older adults to their social networks, such as their relatives, friends, and healthcare workers by allowing them to engage in *robot-mediated communication* (RMC) while being in different physical locations [19]. RMC can be defined as people communicating with and through robots teleoperated by humans [24].

In the context of RMC, telepresence robots are being increasingly used to provide support, promote healthy aging, monitor health, and foster the social well-being of older adults [25–27],

Furthermore, telepresence robots have been tested in several studies– with positive results– as tools to help the social engagement of older people [28–30]. Among the positive effects that have been found are the promotion of human-human interaction [24, 31–33] and the aid in maintaining social engagement with family, friends, and healthcare providers [34, 35].

### 2.3 Telepresence Robots and Social Integration of Older Adults

*Social integration* refers to the extent that an individual is living an interpersonally engaged and active lifestyle while maintaining meaningful relationships with others [36]. Being socially engaged and integrated later in life can reduce the occurrence and onset of dementia, improve cognitive functioning, reduce memory decline and levels of depression, and enhance perceived happiness, life satisfaction, and positive affect [37, 38]. Nevertheless, there are several barriers to social integration in old age: physical (e.g., reduced mobility and increased frailty), cognitive (e.g., memory or cognitive decline and dementia), financial (e.g., retirement or low income), and/or cultural/societal (e.g., economic, geographical, and social environment and whether it fosters social interaction for older adults) [39].

Although it has been shown that older adults are increasingly open to using mainstream communication technology for social connection, face-to-face and phone communication remains prevalent in grandparent-grandchild relationships [40] and technology acceptance among the aging population remains a challenge [41, 42].

Older adults are a heterogeneous group, therefore if technologies such as telepresence robots are to be accepted, there needs to be a fit between user and technology, and complex psychological mechanisms and individual characteristics of older users must be considered [8]. Additionally, the design of robots must fit into the ecology of older people, support their values, and adapt to all members of their social network [9].

To increase the acceptance of telepresence robots, researchers are now employing human-centered approaches that invite older adults into the design and evaluation process [43]. Research encourages engineers and designers to collaborate with older adults as design partners to ensure that their desires, preferences, and boundaries are taken into account [44].

Previous research has mainly focused on the use of *commercially available telepresence robots* in the context of elderly care and has shown comparatively low adoption rates among older adults [45]. Therefore, our study focuses on the requirements of older adults for a *new telepresence robot specifically designed for older adults*.

## 3 Present Study

The present study is part of the CO-HUMANICS (Co-Presence of Humans and Interactive Companions for Seniors) project, in which innovative communication technologies, namely a telepresence robot and an augmented reality system for older people will be developed. The CO-HUMANICS project aims to foster social integration of older adults by creating technologies that adapt to their requirements while allowing them to communicate effectively and enjoyably.

Although several robots have already been tested– with promising results– among the aging population [46], some barriers call for the development of a telepresence robot customized for older adults.

Robot usability of existing telepresence robots is still not optimal for older people. The complexity of some functions has proven to be too great for older users as well as their social networks (mostly related to the system navigation). Related to this topic is the organizational barrier to the implementation of said robots. Training through demonstrations and presentations has proven extremely time-consuming. Additionally, given that the studied telepresence robots have mostly been used in the medical or assistive context, there is a lack of direct evidence that they are effective for the social integration of older adults. Previous studies have shown indirect effects on loneliness and social isolation but mostly due to communication between older adults and others in assistive contexts. Furthermore, older adults have raised topics related to robot control. Existing telepresence robots can be controlled exclusively by remote users. Several studies have shown that older adults request control of the robot as well as the freedom to initiate and end communication as they please, which is not part of the existing telepresence robots' functions [46].

Furthermore, research has shown that robot designs tend to be influenced by stereotypes of older people as lonely, fragile, and in need of care. This has resulted in stark differences between the priorities of users and roboticists and therefore in low technology acceptance [47, 48].

Lastly, cultural aspects of technology acceptance and views on aging cannot be obviated. The CO-HUMANICS project is being carried out in Germany, and therefore participants are influenced by German cultural perspectives. For example, research has shown that Germans rated robots less trustworthy than Chinese or Korean people did [49]. Robot acceptance in industrial settings has shown to be notably different in Germany when compared to China, Japan, or the USA [50]. Furthermore, McConatha et al. [51] compared young adults from the US and Germany with regard to their attitudes towards aging (e.g., psychological concerns associated with aging and fear of age-related losses) and found that young Americans view aging more positively than Germans.

To inform the design of social robots and promote their use, it is important to consider how older adults adopt and use new technologies as well as the motivations and the process by which they come to accept or reject them [41, 52].

In the present CO-HUMANICS study, older adults are presented in the role of local users while family and friends are in the role of remote users. Although future studies will reverse user roles, the focus of this study is older adults as *local users*.

This paper focuses on researching three main topics that have proven relevant in older adults' technology acceptance:

a) *Attitude towards technology*: positive or negative feelings about the appliance of a technology [41].
b) *Intention of use*: the intention to use the system over a longer period [41].
c) *User requirements*: any function, constraint, or other property that must be provided to satisfy the user's needs [53].

To gain insights into these topics, the present study aims at answering the following research questions:

**RQ1:** What ***attitudes*** do older adults have towards robot-mediated communication via a telepresence robot?

**RQ2:** How do older adults describe their ***intentions to use*** robot-mediated communication via a telepresence robot?

**RQ3:** What ***requirements*** do older adults have for robot-mediated communication via a telepresence robot to be developed?

## 4 Methods

To obtain qualitative data related to older adults' attitudes, usage intentions, and user requirements for RCM via a telepresence robot, semi-structured qualitative interviews were conducted. The data included in this study is a subset of a larger study investigating older adults' current experiences and requirements towards videoconferencing and innovative technologies (namely, a telepresence robot and an augmented reality system). The interviews were conducted face-to-face by two researchers (first and second author) in locations chosen by the participants (university campus, cafés, and participants' place of residence). The average duration of the interviews was 43 min (range: 21–82 min; see Table 1). The sample size of $N = 30$ was based on previous qualitative studies and user requirement analyses in the field of human-computer interaction involving older adults (e.g [25, 54–56]).

Data for the present study was obtained from two blocks of questions that relate to the following main topics: (1) Participants' *personal situation* (work, family life, communication habits, social network, living situation, etc.) and (2) *robot-mediated communication* (participants' first impressions, perceived usability, intention to use a telepresence robot, social integration, etc.). Some of the posed questions included: "how would you describe your social life?", "how often do you communicate with friends or family?", "how often do you communicate face-to-face and/or via communication technologies?"(questions of block 1), and "what is your first impression of the shown robot-mediated communication scenario?", "with whom would you like to communicate if you had a telepresence robot?", "what functions would you like to see in a telepresence robot?", and "how would you compare robot-mediated communication with other forms of technology- mediated communication?" (questions of block 2).

The study is preregistered at https://osf.io/8q9za and the interview guide, scenario visualization, anonymized interview transcripts, and sociodemographic participant data can be accessed at https://osf.io/fxp6r/.

### 4.1 Participants

The study sample included $N = 30$ older adults between the ages of 60 and 74 years ($M_{age}$ = 67.1, $SD_{age}$ = 4.3, 37% women; see Table 1). All interviews were conducted in Germany between May and October 2022. Older adults were recruited through personal contacts of the researchers and during an academic technology-related lecture aimed at older adults. Inclusion criteria for participants were: 60 years or older (based on the World Health Organization's definition for older adults; [57]), living independently, having no cognitive impairments, and being active communication technology users.

### 4.2 Materials

The following materials were developed for the present study: (a) entry questionnaire, (b) semi-structured interview, and (c) stimuli (storyboards of robot-mediated communication scenarios).

The *entry questionnaire* included information related to the older adults' age, gender, number of people living in the home, education, frequency of communication, and most used devices and applications. A summary of the collected data can be seen in Table 1.

The *semi-structured interview* comprised five blocks of which two were used to extract data for the present study:

a) General information: This block contained information related to the topics of work situation, living situation, social network situation, and communication habits.

**Table 1** Description of the study sample

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

**Table 1** (continued)

| No. | Age | Pseudonym | Gender | Number of People in Household | Education | Mediated Communication Frequency* | Communication Technology Use | Communication Application Use | Interview Duration (min) |
|---|---|---|---|---|---|---|---|---|---|
| 28. | 73 | Gerhard | m | 2 | Medium | Daily | Landline phone, smartphone, laptop/PC | SMS, instant messaging | 32 |
| 29. | 74 | Simon | m | 2 | High | Several times a day | Landline phone, smartphone, tablet, laptop/PC | SMS, instant messaging, video conference, social media | 82 |
| 30. | 74 | Martin | m | 2 | Medium | Several times a week | Landline phone, smartphone, tablet, laptop/PC | SMS, instant messaging, video conference | 67 |

*Note Abbreviations* (m) man, (w) woman, (PC) personal computer, (SMS) short message service. Study participants are listed in ascending order by age. All names are aliases

*– in the past four weeks

b) Robot-mediated communication: This block contained information related to older adults' first impression of the presented communication scenario, initial ideas of how to adopt the technology, intention of use of a telepresence robot, usability (e.g., learning curve, desired functions, etc.), feelings of social presence during robot-mediated communication, and fostering of social inclusion via a telepresence robot.

In line with the human-centered design approach of the study, the semi-structured interviews aimed at exploring older adults' attitudes, intentions of use, and user requirements for a telepresence robot while also taking into account their personal opinions, preferences, living situation, etc.

A pretest of the interview was conducted within the research team and the instrument was later refined based on the obtained feedback.

The *stimuli* used for the study were four printed and laminated full-color storyboards (8 pages each, size A4) describing a robot-mediated communication scenario. Two storyboards depicted a female grandparent and two depicted a male grandparent. All four storyboards depicted a male adult grandchild. The scenarios showed two different perspectives: that of the grandparent and that of the adult grandchild (see Fig. 2).

Women were shown an older female character while men were shown an older male character to foster identification among participants. Each storyboard contained scenes depicting the grandparent and the grandchild engaged in a conversation in the living room and then moving to the kitchen where the older person was followed by the robot. The telepresence robot was controlled by the younger person in all scenarios. Each participant viewed two storyboards, one from the grandparent's perspective and one from the grandchild's perspective.

Before showing the storyboard images, the interviewers explicitly explained that the new telepresence robot can be used with different communication partners such as family members, friends, doctors, educators etc. Then the interviewers showed the storyboard and pointed out that communicating with grandchildren was just one example. This example was chosen because many older adults can relate to it [45].

### 4.3 Data Collection and Analysis

All 30 interviews were conducted in German language and were audio recorded. After participants were greeted by the interviewing researcher, a short description and aim of the study were given to them. A consent form was then read and signed by each interviewee. Afterward, the entry questionnaire was provided and filled out personally by the participant.

Before the interview, older adults were informed of the possibility of taking breaks as needed and were offered snacks and refreshments. It was explained to interviewees that all answers and opinions were valuable and that their honesty would be greatly appreciated. Participants were encouraged to speak freely and at length about the topics covered in the interviews.

The interview was conducted using the elaborated guide and additional questions and topics were explored based on the participants' answers. At the end of each interview, older people were asked for additional opinions or topics they wanted to discuss, and short feedback on the study was requested. The feedback showed that all participants understood the questions, were comfortable during the interview, and felt free to express their opinions openly.

Audio files of the interviews were backed up, anonymized, and later transcribed by a native German speaker. Transcriptions were analyzed following the methodology described in [58] using the software MAXQDA version 22.4.0.

First, categories were created based on the research questions of the study and the general information block of the interview. Text segments directly related to the participants'

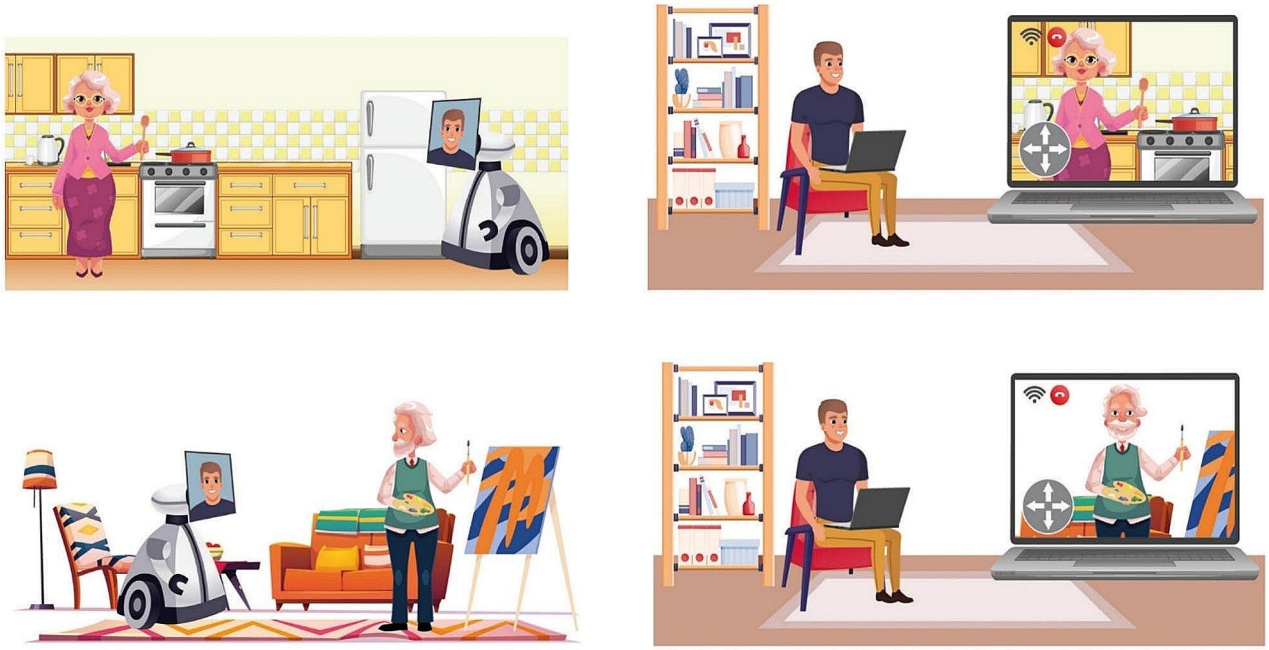

**Fig. 2** Example of storyboard images used to illustrate robot-mediated communication. The top two images show the grandmother–grandson communication scenario (from both perspectives) while the bottom two images show the grandfather–grandson communication scenario (from both perspectives). Own representation. Characters and objects: Adobe Stock (Standard license)

general information and each research question were coded and grouped by topic. Next, a second round of coding was conducted, and new categories and subcategories were created. For data obtained from the general information block, the creation of categories and subcategories aimed at providing contextual and personal information about the interviewees to enrich the technology-related data. A final round of coding was conducted to refine, improve, and finalize the categories and subcategories. For the present paper, robot-specific information was used to identify older adults' attitudes, intentions of use, and user requirements for robot-mediated communication via a telepresence robot. All relevant quotes accompanying the study's results were translated from German to English using translation software and were quality-checked by the researchers. During the data analysis, only full sentences were coded and repeated statements by the same participant were treated as unique.

## 5 Results

In the following sections, the three research questions will be answered.

### 5.1 Attitudes towards Telepresence Robots

From assistive to telepresence, from industrial to pet-like, robots were already familiar to all participants thanks to different media outlets (movies, television, news stories, etc.) and some previous face-to-face encounters. For instance, 66-year-old Ute knew that *"In Japan, this is something that is already being tried very extensively, namely these robots that are to be used in hospitals"*, while 62-year-old Anke added, *"I've already seen something like that on TV"*. Frank, who is 62 years old and is used to attending work-related conferences, had first-hand experience with a robot: *"I said 'hello' to a robot and (it said) 'good afternoon, what would you like to see? What would you like to know?' and stuff like that."*

As a result, when presented with our illustrations of telepresence robot-mediated communication scenarios, most participants connected them to their past experiences with robots or robot-related media representations. Consequently, they were– according to our RQ1– able to provide definitive attitudes towards telepresence robots and their capabilities (see Fig. 3).

For some respondents, the ability of the telepresence robot to follow them around their home while they were

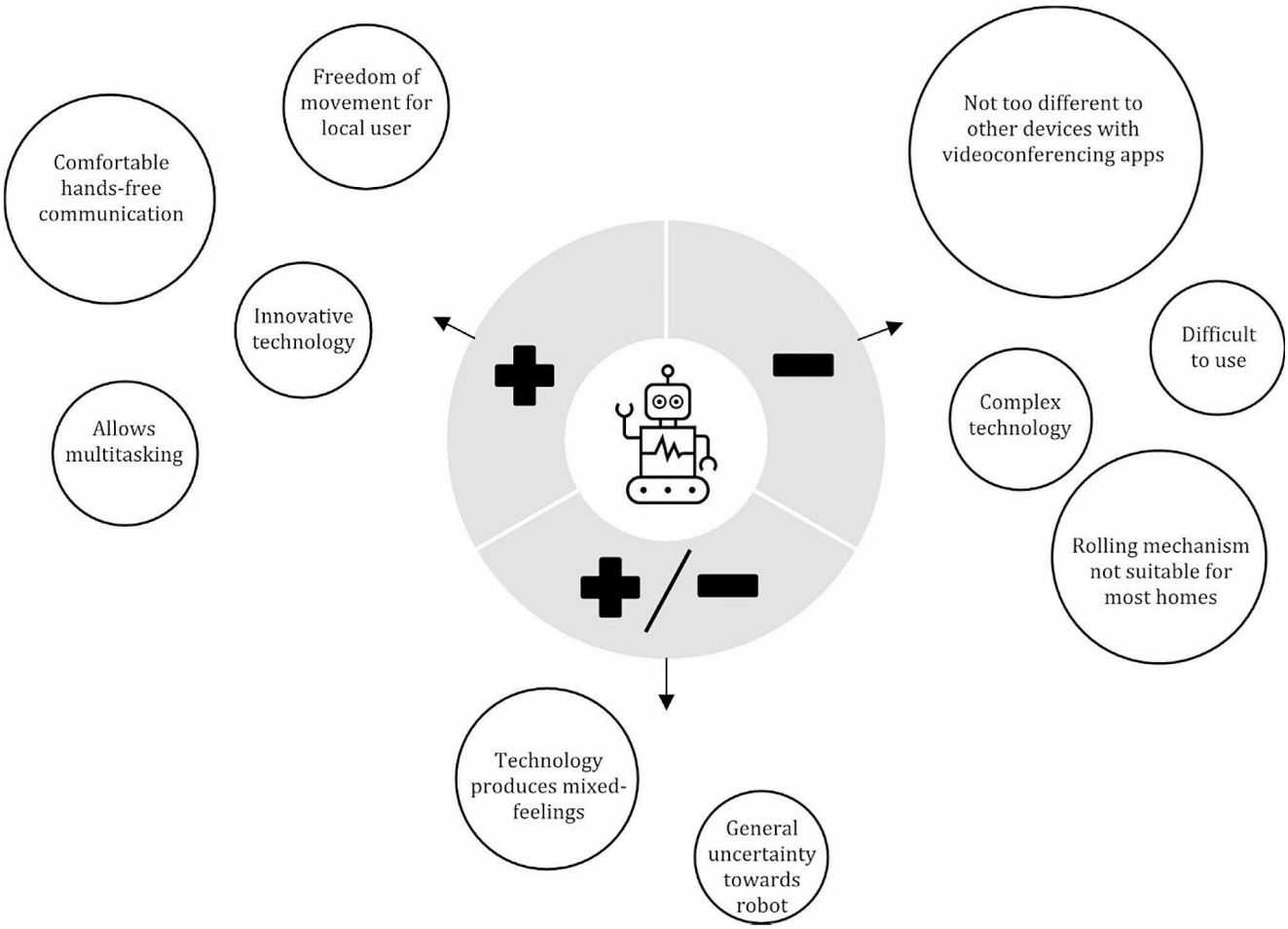


**Fig. 3** Arguments supporting positive (+), negative (-), and conflicting (+/-) attitudes towards telepresence robots

participating in a teleconference was the strongest initial selling point. Furthermore, hands-free comfortable communication, the possibility of multitasking while using the telepresence robot, and being up to date with modern communication technologies that will be mainstream in the future were also seen as beneficial by participants. Users who placed real value in these characteristics showed a general *positive attitude* towards the telepresence robot and the presented robot-mediated-communication scenario. Reinhard, who is 67 years old and uses technological devices to communicate with loved ones several times a week, considered that a telepresence robot would allow for easy and comfortable communication:

> I could take a laptop or a tablet and make video calls and walk around with it… [but] I don't have to do it because the robot does it for me and then I can keep talking…that's higher quality, let's say.

In contrast, some interviewees considered that the telepresence robot was not so different from a smartphone or computer with a videoconferencing application. Although the ability to follow the local user was recognized as a nice addition, the telepresence robot was seen as too complex for the additional benefits it would bring.

Moreover, the telepresence robot was deemed difficult to use and unable to fit in most home environments. Participants who shared these views usually showed general *negative attitudes* towards the telepresence robot.

For instance, Hans is 67 years old and lives alone. Even though he uses communication technologies every day he does not see many advantages to using a telepresence robot: *"Compared to a mobile phone with messenger, it only has one additional function, that it drives itself. Far too much effort, too little benefit"*. Similarly, when asked for his impressions of the robot-mediated communication scenario, 60-year-old Helmut commented *"I can't understand the point at all."*

Still, another group of participants stated that they had *conflicting attitudes* toward the telepresence robot, and they could not decide if they liked the technology or not.

Like all other interviewees, 67-year-old Hans was familiar with robots. However, when asked about the robot-mediated communication scenario he did not have a clear opinion: *"I have seen something similar [to telepresence robots] but I have mixed feelings about them."* Similarly, 68-year-old Peter has both a positive and negative opinion of the technology: *"[The telepresence robot] is very complicated, but nice."* Finally, 62-year-old Anke very openly stated: *"I don't know yet if I think it [the telepresence robot] is that great."*

In summary, participants' attitudes toward telepresence robots fall into three categories: positive attitudes, negative attitudes, and conflicting attitudes.

## 5.2 Intentions to Use a Telepresence Robot

Based on their expressed intentions to use a telepresence robot for communication purposes– related to our RQ2– participants were divided into 3 groups: (a) reluctant future users ($n=12$), (b) future non-users ($n=10$), and (c) enthusiastic future users ($n=8$) (see Table 2).

*Reluctant future users* ($n=12$) are those participants who said they would adopt a telepresence robot only if a change in their life circumstances (usually health-related) required them to do so: difficulty leaving their home, health or mobility issues, an increase in geographical distance to friends and family, etc.

Uwe, 72 years old and living with his wife, would not use a telepresence robot at the moment. However, he would consider using one under specific circumstances: *"As long as I have my wife, no. If I were alone, I could imagine [using] it. Especially if my health was not in good shape, if I had trouble to leave the house."* A similar opinion was voiced by 66-year-old Heinz:

> Let's say that my mobility would have to be very limited for me to use that thing [the telepresence robot]. I don't want to rule it out completely, but I would have to be very drastically, very limited in mobility to use it.

Susanne, who is 64 years old, lives with her husband, and uses communication technologies several times a week said she does not currently need a telepresence robot. However, she can imagine several future scenarios where she could use one: *"For example, if I were sick and an old woman, then I might need that [a telepresence robot]. If I don't feel as safe anymore, maybe. If I need help and I'm alone and if I'm not feeling well."*

Furthermore, participants who expressed that, under no circumstances, would they be willing to adopt a telepresence robot were categorized as *future non-users* ($n=10$). Among the reasons for rejecting the technology, interviewees mentioned that they did not need additional communication tools and that they were satisfied with the way they were communicating (referring to both technology-based and face-to-face communication).

For 73-year-old Gerhard and his wife, telepresence robots are something for the next generation:

> Personally, I don't think we need it anymore. Landline phone, laptop, smartphone, that's quite enough for us. That doesn't interest me that much, the robot stuff, they should do that when I am no longer here, I don't need that anymore.

*"Another device? I don't think so"* was 65-year-old Gerd's answer when queried about using a telepresence robot.

**Table 2** Older adults grouped by usage intentions of a telepresence robot

| Type of User | Description | Example Quotes |
|---|---|---|
| Reluctant Future Users ($n=12$) | This group of study participants would only consider using a telepresence robot for communication if their current life conditions required them to do so. The most mentioned life changes were severe illness, immobility, loneliness, and a large geographical distance between them and their friends and/or family. | *"It depends on your current personal situation. If you have needs for establishing contact and there is no other way to do it, you have to come to terms with such a thing [a telepresence robot]. I would have to be in a situation where I am physically limited but mentally fit."* (Andreas, 71 years old) |
| Future Non-Users ($n=10$) | This group of study participants does not see benefits in using a telepresence robot now or in the future. Older adults in this category are satisfied with their current social lives and with the devices/applications they use at the moment. | *"Well, at the moment, I don't think I need anything like that [a telepresence robot]. I'm not lonely, I have a large circle of acquaintances, my children are nearby, my family is nearby."* (Rolf, 63 years old) |
| Enthusiastic Future Users ($n=8$) | This group of study participants would adopt telepresence robot-mediated communication in the near future. They are curious about innovative communication technologies and would like to try them. They see telepresence robots as future mainstream technologies that may become part of everyday life for all generations. | *"I think that this [telepresence robot] has a future. It would be a solution that I can accept."* (Simon, 74 years old) *"I find that really nice [the telepresence robot]. That will come in a matter of time and I would use it."* (Peter, 68 years old) |

*Note* User types are presented in descending order based on their observed prevalence, however, no quantitative analysis was conducted with the transcripts of the qualitative interviews. $N=30$

While Stefan, also 65 years old, had a similar reaction: *"I don't want to have such a box [robot] in my apartment"*, he said.

Finally, *enthusiastic future users* ($n=8$) are those participants who expressed they would be interested and willing to immediately use a telepresence robot if it was made available to them. This group of participants saw innovative communication technologies as a natural next step in the evolution of communication technologies and was open to integrating them into their daily lives.

Anke will soon become a grandmother for the first time. She currently uses a landline and a smartphone to communicate with family but could easily imagine using a telepresence robot to be present in her grandchild's first months:

> If [daughter] had the baby now, [using the telepresence robot in the daughter's home] would certainly be great. It would be great to practically be in the middle of it all. I could be in the apartment and see [daughter] with the baby. I would probably find that really good. When [daughter] bathes the baby and so on, I would be there.

Anke has another daughter living abroad and can also imagine using the telepresence robot in the daughter's home to communicate with her: *"With my older daughter […] far away, in [country]. I think that's also great to have something like that."*

Similarly, 67-year-old Karl communicates with loved ones several times a week using his landline phone, smartphone, tablet, and laptop/PC. He could see himself using a telepresence robot in the future and he pondered that it will soon be a mainstream communication device: *"Surely, we will also use it, it is what will be available and used. There were so many who complained about the mobile phone and now they use it quite intensively."* Additionally, Karl recognizes a telepresence robot could adapt to his current life situation and could help him stay connected:

> Relatives, children, and such, are usually far away. They all have their own lives and yes [a telepresence robot] can shorten the time to meet virtually. To eat together […] to meet once in a while. Yes, I could imagine it.

In general terms, participants can be classified into three groups based on their intentions to use a telepresence robot: reluctant future users ($n=12$), future non-users ($n=10$), and enthusiastic future users ($n=8$). Some participants envisioned the telepresence robot operating not only in their own home, but also in the home of the remote communication partner.

## 5.3 User Requirements for a Telepresence Robot

Based on the data, the user requirements of older adults towards a telepresence robot (RQ3) were clustered into three types of requirements: (a) *technology-related requirements*, (b) *social integration requirements*, and (c) *successful aging requirements*. A summary of these requirements can be seen in Table 3.

### 5.3.1 Technology-Related Requirements

The first group of requirements for a telepresence robot was exclusively technology-related. Participants expressed concerns linked to the following themes: *size, anthropomorphism, robot control, ease of use, adaptiveness to living environment, and privacy/data protection.*

Older adults described the optimal *size* of a telepresence robot with relative terms such as "medium", "manageable", and "unobtrusive". When probing further, they explained the telepresence robot should fit comfortably in their home.

Susanne lives with her husband and has 2 grown children who live in different cities. Even though she lives in a relatively big house, she sees the robot's size as something important: *"You need a robot that doesn't take up too much space. Not too big, not too small"*. Simon, 74 years old and self-declared technology enthusiast, also points out the importance of size: *"The question now is how big is it? How much space does it take? It has to be manageable for me"*.

Although there was no consensus on the ideal degree of *anthropomorphism*, the topic was constantly brought up by older people. In general, participants said they would prefer a robot with certain human characteristics. At the same time, they made it clear that the robot's capabilities were indeed more important than its appearance. When speaking about the topic, Simon commented *"It [the robot] could also have feet, that would also be a possibility, so it doesn't have to roll everywhere"*. Martin, who is 74 years old and lives alone, also voiced his preference for an anthropomorphic robot: "*If the robot would look a little bit more human, it will probably be prettier."*

An additional recurring theme during the interviews was the importance of intuitive and straightforward *robot control*. David is 72 years old, lives with his wife, and communicates daily using technological devices (landline phone, smartphone, tablet, and laptop/PC). Although he is familiar with communication technologies, he would prefer that the telepresence robot's controls were simplified: *"It has to be easy for older people to control […] one or two big buttons, 'on' and 'off', that is enough. You could then see in your normal telephone that you are receiving a call because it would blink."*

**Table 3** User requirements of older adults for a telepresence robot

| Dimension | Description | Requirements | Example Quote |
|---|---|---|---|
| Technology Related | Requirements related to the physical appearance, usability, technical capabilities, and characteristics of the telepresence robot | Size | *"[It should] take up little space, be unobtrusive."* (Birgit, 64 years old) |
| | | Anthropomorphism | *"It should look like a person […] because people are more likely to accept it than if it were– let's say– an animal."* (Gisela, 72 years old) |
| | | Robot control | *"You should be able to control it relatively easily with voice commands."* (Reinhard, 67 years old) |
| | | Ease of use | *"It should be easy to use because if it is, it would probably be used by people who are not trained to use [such technologies]."* (Martin, 74 years old) |
| | | Adaptiveness to living environment | *"For us, it would be a hurdle, we have two floors and the robot would have to get to the top one."* (David, 72 years old) |
| | | Privacy/data protection | *"Data protection comes into play since the robot can also follow the person."* (Karl, 67 years old) |
| Social Integration | Requirements related to the social aspects of robot-mediated communication | Perceived social presence | *"The robot better conveys that a person is there, compared to when I just see an image on a mobile phone."* (Uwe, 72 years old) |
| | | Companionship | *"People who are very lonely, I could imagine would welcome that [the robot]. Then one is no longer so alone, completely alone."* (Petra, 72 years old) |
| | | Social contact maintenance | *"To better re-establish the connection to the outside world, that [the robot] would be a good possibility."* (Karina, 71 years old) |
| | | Social activities | *"At the moment [I could use it] with my grandchild. In daily life, also cooking food, to talk about school."* (Birgit, 64 years old) |
| Successful Aging | Requirements related to older users' characteristics and life conditions | Autonomy | *"I want to control what I do myself. When I turn on my laptop, I control that, no one else is doing it for me."* (Susanne, 64 years old) |
| | | Surveillance | *"In my home, I like to feel unobserved as a rule."* (Helmut, 60 years old) |
| | | Trust | *"It shouldn't happen then that the robot has power over me and possibly manipulates me."* (Petra, 72 years old). |
| | | Anxiety | *"This big robot– it's relatively big and bulky– might be a nuisance in the household and it can malfunction sometimes."* (Hans, 67 years old) |
| | | Health/emergency care functions | *"For example, a robot can adapt to a person with dementia by showing them maybe a film from thirty, forty years ago."* (Simon, 74 years old) |
| | | Social influence | *"I would definitely use that for my parents."* (Frank, 62 years old) |
| | | Costs | *"I'm just wondering, how much does a robot like that cost?"* (Petra, 72 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

Among the proposed methods for controlling the robot were the use of a remote control and voice control: *"I should be able to operate it from a distance… like the television"* requested Susanne. *"Basically, similar to driving an automatic car"* said 74 -year-old Simon, describing the way to control the telepresence robot.

General *ease of use* was also required in connection with the robot's general functions. Interestingly, when discussing this topic further, it became evident that many participants were confident that a telepresence robot would be easy to use for them. Based on their current technology use, older people considered that their skills could be transferable to a

robot, making its operation simple for anyone already familiar with communication technologies.

*The social robot, I can see that it is manageable. It's probably even manageable for eighty- and ninety-year-olds*," says 62-year-old Anke. Similarly, 60-year-old Matthias said: *"It is certainly easy [to control] because everyone can use a smartphone nowadays.*

An additional requirement expressed by participants was the ability of the robot to *adapt to their living environment*. When older people tried to imagine using a telepresence robot in their home, issues such as reduced space for movement, stairs, closed doors, and numerous pieces of furniture were major concerns. Frank is 62 years old, lives with his wife, and is in contact with technology in his work environment. He was worried about the ability of the robot to seamlessly fit into a small space: *"In a small flat […] the robot might not be able to get everywhere. Maybe the robot could also get in the way."* Karina is 71 years old and has been retired for 6 years. She used to work in an office and has two grown children. She worried about reduced living spaces and how technology could be adapted to them: *"But then I say to myself, we're always downsizing. And how is it possible to use something like that [telepresence robot] in such facilities, I still have no idea"*. Similar concerns were voiced by Gerd: *"And when you walk through these old buildings, they have different heights, sometimes up to a ten-centimeter difference. And that will be a problem."*

Effective functions that ensure *privacy and data protection* were also important for interviewed older people. The same apprehensions participants had towards other communication technologies were transferred to the telepresence robot. Although some participants made the point that safety measures should not be exaggerated (for example, being asked for a password every time they used the robot) at least basic safety measures were required before they would be willing to try a new device.

Anke, for example, said she would be worried about privacy and data safety if she owned a robot:

> Who is watching? Who is there? It's the same with mobile phones and everything. In principle, it's like that everywhere. That's the general problem, yes, that you are more or less observed everywhere. And if I now have someone following me around and spying on my flat? I would have my doubts about how secure that is. Well, I can't assess that now, I don't know.

Finally, she added jokily: *"He [the robot] wouldn't be allowed in the bathroom and he wouldn't be allowed to go to the toilet either"*, when speaking about privacy protection.

#### 5.3.2 Social Integration Requirements

A second group of requirements revolved around the topic of social integration: *perceived social presence, companionship, social contact maintenance, and social activities*. When discussing the potential of a telepresence robot for fostering social integration, participants had a hopeful outlook.

Most interviewees agreed that communicating via a telepresence robot would help them feel closer to their communication partner, especially when compared to voice-only technologies (for example, telephone). Although the videoconferencing capabilities of the robot were considered similar to those of a computer or smartphone, the movement of the robot gave robot-mediated communication an increased *perception of social presence* among older people. According to Karina:

> You somehow have the feeling, well with me that would be the case too, that I don't just see the person on the screen, but, yes, a bit like he is near me. Through the robot, I have more of the feeling that a person is here.

Also related to the movement and embodiment of the telepresence robot was the added benefit of *companionship*. Participants described that the mere physical presence of a moving device could help older adults feel less isolated or lonely. According to 69-year-old Katja: *"I think it's good that it [the telepresence robot] moves. You have the feeling that there is someone here"*.

Furthermore, interviewees considered the telepresence robot as an effective tool for *social contact maintenance*. Older people who were used to communicating through technology ventured that a robot could fulfill their needs for keeping in touch with loved ones. On the contrary, participants mentioned that establishing new social contacts through a telepresence robot was not something that interested them. They made it clear that they reserved the use of communication technologies for staying in touch with friends and family and were wary of using them to communicate with strangers. Simon thinks using a telepresence robot could contribute to taking care of the user's social network: *"It would certainly not be a technical problem at all [to communicate through the robot], since we are networked worldwide. So, I think such a communication […] would make life more beautiful. Social contacts must come and go"*. Gisela, who is 72 years old and uses communication technologies daily, also recognized the potential of using a telepresence robot: *"So you have communication and I think that's very important […] I think that protects you from loneliness"*.

Martin, on the other hand, expressed doubts about using a telepresence robot to expand his contact network: *"[To contact] strangers I'd rather not [use the robot] unless it's a care service […] the fire brigade, Red Cross, or something like that. Otherwise, I don't see the need."* Frank has a similar opinion: *"Making new [contacts], that's… I don't know if it works that way. I think older people are more skeptical about that. Difficult."*

The requirement for a telepresence robot to allow for shared *social activities* was also mentioned. Almost all participants had previous experience with videoconferencing applications, and many had taken part in social activities with the help of these applications. Therefore, their expectations for robot-mediated joint activities were usually high.

Birgit is 64 years old and lives with her husband in a small town. She has grandchildren who visit her regularly and share school and leisure activities with her. Birgit said she could include the telepresence robot in her daily life by using it for shared activities with her grandson: *"He comes here once a week and we do math homework together. Maybe it would be possible to talk about that [through the robot]".*

#### 5.3.3 Successful Aging Requirements

A third group of requirements was related to successful aging and aging conditions of the interviewed older adults: *autonomy, surveillance, trust, anxiety, health/emergency care functions, social influence, and costs*.

Older adults placed great importance on maintaining their *autonomy* while using a telepresence robot. When discussing the presented robot-mediated-communication scenario, some of them mentioned that the younger person controlling the robot from a distance and initiating the call made the communication seem one-sided and placed them in a passive role.

For example, according to Gisela:

> I wouldn't like it if I was just called, if I can't influence it myself. I would like to be able to call my grandson and say that I have this, that for example. I don't want to wait […] it must not be a one-way street.

Similarly, when discussing the presented communication scenario, Stefan also raised the topic of autonomy.

> What bothered me was that the grandfather is portrayed here as the one who has to be looked after and the grandson has freedom. He can control this robot, he can determine what happens. Grandpa can't do that, Maybe the assumption is he can't do it anymore because he's old and can't cope with it, but I found that a bit one-sided.

The constant presence of the robot in their home while their communication partners could connect and disconnect through their smartphones or computers made some participants feel *watched or surveilled*. Associated with this perception was the loss of control over their own space and actions. Susanne said: "*I couldn't imagine having a robot here [in her home] watching me"*. Feelings of being surveilled were associated with family members or care personnel, as opposed to privacy and data protection issues that were related to unknown third parties.

*Trust* issues were also a concern of participants. The robot engaging in unethical behavior or acting of its own accord without the user having control over it were topics that came up during the interviews. Reinhard, for example, expressed concerns over the telepresence robot doing things without his knowledge:

> It [the robot] should not be too autonomous so that it does not do things that actually go beyond its area of responsibility. It must work within narrow limits so that it cannot, it must not start any activities that the owner does not know about.

Anke thinks about the robots she has seen in the media and then exhibits some distrust: *"Ah, I don't know, do I want that? Afterward, like in the film, they take on a life of their own."*

Feelings of *anxiety* related to the use of new technology were also discussed by older adults. Themes related to robot maintenance, technical support, software updates, etc. were brought up during the interviews usually as questions to which participants had no answers.

Susanne transfers to the telepresence robot the technical issues she sometimes encounters while using her computer: *"I won't trust it to work all the time. Maybe the same thing happens as with my laptop, that sometimes it doesn't work or hangs or doesn't get my emails anymore, because somehow something doesn't work".* Similar concerns were in Reinhard's mind when he talked about the robot's maintenance: *"Of course, the robot, if it is there, must be easy to maintain, I would say. It has to go to its charging station by itself."*

*Health and emergency care* functions were considered essential for a telepresence robot aimed at older people, even if its main purpose was to mediate communication. According to participants, an "emergency button" permanently connected to health care professionals or caretakers was a required function. Other capabilities such as reminders to take medication, playing music, and mental training

were also mentioned as desired functions. *"I could definitely imagine a kind of emergency button,"* said Martin. While Reinhard commented: *"A senior living alone in their home and then having a robot take over certain parts of their daily chores or at least reminding them that [something] needs to be done."*

*Social influence* proved to be a strong factor in technology acceptance among older adults. According to participants, most technologies they currently use were introduced to them by their partners, children, or grandchildren. Additionally, those who introduced them to these technologies trained them on how to use them and provided constant technical support when needed. In line with these experiences, many interviewees admitted that they would likely adopt a telepresence robot if their loved ones asked them to use one. For example, even though Lena was skeptical about a telepresence robot, she mentioned she would adopt one if her grandson asked her to do so:

> If he [grandchild] were to give me this [the telepresence robot] now, and if he were to go abroad now, and he said, I bought you something, we can use this […] I would make an effort to use it then.

**Table 4** Overview of focus areas and results of the present study

| Area of focus | Description | Results |
|---|---|---|
| Attitudes | Positive or negative feelings about the appliance of a telepresence robot | Participants' attitudes were classified into 3 groups:<br>1. Positive attitudes<br>2. Negative attitudes<br>3. Conflicted attitudes |
| Intentions to use | Intention to use a telepresence robot over a longer period | Participants were divided into 3 groups based on their intention to use a telepresence robot:<br>1. Reluctant future users ($n=12$)<br>2. Future non-users ($n=10$)<br>3. Enthusiastic future users ($n=8$) |
| Requirements | Any function, constraint, or other property that must be provided to satisfy the user's needs | Participants' requirements were classified into 3 dimensions:<br>1. Technology related (size, anthropomorphism, robot control, ease of use, adaptiveness to living environment, privacy/data protection)<br>2. Social integration (perceived social presence, companionship, social contact maintenance, social activities)<br>3. Successful aging (autonomy, surveillance, trust, anxiety, health/emergency care functions, social influence, costs) |

The issue of cost was also perceived as a big barrier to the adoption of a telepresence robot. Noting that older people have a set– and often limited– income once they retire, many participants saw the need to make the technology affordable for them. According to Anke, *"the question then becomes, who is going to pay for this thing?"*, while Katja mentioned that the question was not the willingness to adopt a robot but rather *"whether one can actually afford it"*.

#### 5.3.4 Summary of Requirements

In summary, participants' requirements for a telepresence robot can be classified into 3 types: (a) technology-related requirements, (b) social integration requirements, and (c) successful aging requirements.

Technology-related requirements are connected to the telepresence robot's physical appearance, usability, technical capabilities, and characteristics. Older adults spoke about elements such as size, anthropomorphism, robot control, ease of use, adaptiveness to living environment, and privacy/data protection.

Social integration requirements are those related to older adults' maintenance of their social networks. Topics that older adults considered relevant were: perceived social presence, companionship, social contact maintenance, and social activities.

Lastly, successful aging requirements are linked to participants' age-related characteristics, life conditions, and aging-in-place necessities. Older adults mentioned the following themes during the interviews: autonomy, surveillance, trust, anxiety, health/emergency care functions, social influence, and costs.

A short overview of the study's results can be found in Table 4.

## 6 Discussion

The present study aimed to explore older adults' attitudes, intention of use, and user requirements for a telepresence robot. Qualitative interviews ($N=30$) were conducted, during which participants discussed their current use of communication technologies and evaluated potential RMC via a telepresence robot based on scenario illustrations.

### 6.1 Older Adults' Attitudes towards Telepresence Robots

To answer RQ1, participants' responses were classified into the following groups: (a) *positive attitudes*, (b) *negative attitudes*, and (c) *conflicting attitudes*.

All participants were familiar with different types of robots, which may have influenced their attitudes towards the hypothetical scenario depicted in the stimuli (storyboards). This is in line with previous research, which has shown that fictionalized portrayals of robots might be a key source of experience from which older adults form their impressions and attitudes toward robots [59, 60]. It is therefore relevant to explore older adults' previous knowledge of robots to anticipate potential negative and positive attitudes and to address them during the design process to facilitate technology acceptance.

Users who showed *positive attitudes* towards the telepresence robot valued the ability of the robot to follow the user, the hands-free and comfortable communication, the opportunity to multitask while maintaining a conversation, and the prospect of keeping up to date with innovative technologies that may soon become mainstream. Establishing a fit between the user and technology, which also includes the user's psychological mechanisms and individual characteristics, leads to technology adoption [8]. The present study provides evidence that what older adults deem valuable are those functions that adapt to their lifestyle and life conditions.

On the other hand, participants who had *negative attitudes* towards the telepresence robot mentioned shortcomings such as functions comparable to those of any device with videoconferencing capabilities, a high degree of technological complexity, difficulty of use, and the robot's inability to adapt to all physical spaces. Older adults considered that a robot with additional functions (smart assistant, reminder function, emergency button, etc.) would be more attractive than a robot exclusively designed to mediate communication. This should be considered during the design process since a telepresence robot that is perceived to be of little use in daily life has a low probability of being adopted [30].

Finally, some participants expressed *conflicting attitudes* towards telepresence robots mainly based on two reasons: they recognized both positive and negative aspects of the technology– and therefore had mixed feelings about it– and they had a sense of uncertainty towards robots in general (which influenced their attitudes towards telepresence robots).

In the future, feelings of uncertainty among older people could be diminished by greater exposure to telepresence robots. Older adults have shown an increasingly positive attitude towards telepresence robots as they become familiar with them and use them repeatedly [46].

### 6.2 Older Adults' Intentions To Use a Telepresence Robot

To answer RQ2, participants were classified into three groups based on their responses:

*Reluctant future users* ($n=12$) confirmed they would only use a telepresence robot if their life conditions changed in the future. Interestingly, most outlined scenarios were associated with worsening health conditions, frailty, and mobility issues. The use of a telepresence robot while being healthy and independent was not contemplated by these users. This could stem from the association of telepresence robots with stereotypical views of older adults as lonely and frail [9]. These negative associations should therefore be further explored and counteracted by future designs.

*Future non-users* ($n=10$) clearly stated that they had no interest in adopting a telepresence robot under any circumstances since they saw no significant benefits for themselves. As stated in previous research, for a telepresence robot to be adopted its design has to fit into the ecology of older people, support their values, and adapt to all the members of their social network [9]. These users considered their current social integration optimal and were not willing to add a new communication device to the ones they currently use. It is therefore important to consider that technological solutions are not one size fits all and the decisions of those unwilling to adopt them should be respected.

Finally, *enthusiastic future users* ($n=8$) said they would be willing to communicate via a telepresence robot if one was made available to them. They saw telepresence robots as helpful tools to stay in touch with loved ones and could easily imagine scenarios in which they would communicate via the robot. Their impressions were in line with studies that provided evidence showing that social robots can successfully enhance older adults' community engagement and social connectedness [24].

In general, those willing to try RMC gave reasons in line with technology acceptance constructs in the context of aging found in previous research [41]: attitude (general positive attitude towards robots), perceived usefulness (respondents believed the robot would be assistive), and perceived ease of use (respondents believed using the robot will be free of effort). The aforementioned constructs should be reinforced for telepresence robots to be accepted by a wider group of older adults.

### 6.3 Older Adults' Requirements for a Telepresence Robot

To answer RQ3, three groups of user requirements were obtained from the qualitative data: (a) *technology-related*

*requirements*, (b) *social integration requirements*, and (c) *successful aging requirements*.

The first group of requirements was connected to the *technological* aspects of the telepresence robot.

Older people wished for a robot of a manageable *size* that did not turn into an obstacle around the house. They feared that the robot "getting in the way" would be an annoyance and could deter them from using it. Similar concerns have been included in previous research [35, 61].Therefore, a robot for older adults should be designed based on their specific dwellings and taking into account their comfort level.

Users also brought up the topic of *anthropomorphism*, mainly to express that the form of the robot was not as important as its functions. This confirms that the functional value of robots can dominate anthropomorphism [62].

Although older adults understood that the remote communication partner was mainly in command of the robot, the ability to *control the robot* themselves– in a somehow simplified manner– was requested. A few buttons and an intuitive display were among the preferred characteristics. A proposed method to enhance older adults' experience with robot control is to provide training in navigating the interface and moving the robot [63, 64]. Said training, in addition to simplified control functions, would increase technology acceptance levels.

As expected, general *ease of use* was among the main technological requirements. Older adults requested a telepresence robot with a shallow learning curve, adequate for even the oldest old. However, it should be pointed out that older adults felt confident that they would be able to use a telepresence robot without any major complications. This perception should be considered a positive aspect since older adults' sense of empowerment and competence with emerging technologies have shown to be crucial for sustained adoption [65].

Another major concern was the capacity of the robot to *adapt* successfully to all types of living environments. Older adults feared that a telepresence robot would not be able to move freely in reduced spaces, between furniture, in houses with stairs, in multi-level apartments, etc. These implementation barriers have been shown to reduce technology adoption [35, 61] and should therefore be addressed by designers.

Finally, *privacy and data protection* emerged as an important requirement. The fear of being "observed" or even "spied on" by a third party (hackers, for example) was constantly brought up during the interviews. Older adults requested strong safety features fitting for a device that is designed to move freely around their home mostly without their intervention. Previous research has already pointed out that concerns about security and privacy, due in part to a perceived lack of control, should be addressed [36, 66].

A second group of requirements revolved around the topic of *social integration*.

Older adults were optimistic that a telepresence robot would give them a higher perception of *social presence* when talking to their loved ones. They were positive that communicating via a telepresence robot would "make them feel closer" to their communication partners by allowing them to better see facial expressions and gestures, among others. The increase in perceived social presence that results from using a telepresence robot [67, 68] should therefore be leveraged to achieve higher adoption rates among older adults.

The mere physical presence of a robot in the home was also stated by participants as a positive aspect, especially to guard older people against loneliness. Responses included feelings of "not feeling completely alone" if a robot was around or feeling like "someone else" was there. As previously researched by Noguchi et al. [69], this perception has been shown to have positive effects during robot-mediated communication by both encouraging self-disclosure towards the communication partner and reducing social isolation among older people.

Older adults believed that a telepresence robot could be a valuable tool to *maintain social contact* with others, which supports the findings of recent studies showing that older adults are growingly adopting new communication technologies and/or applications as a way to foster their own social integration [70].

Another important requirement for a telepresence robot was that it should facilitate participation in *social activities*. Because of past experiences during the COVID-19 pandemic– where technology was widely used to alleviate older adults' feelings of loneliness and social isolation [71]– interviewees were no longer strangers to online events and celebrations. Stories of virtual birthdays, dinners, cultural conferences, etc. were common among participants and have become part of their expectations for communication technologies.

The last group of requirements was related to *successful aging*, which according to Rowe and Kahn [72] includes high psychological and social functioning, among other constructs.

One of the main requirements for a telepresence robot is to allow the older user to maintain their *autonomy* which is supported by research that shows most older adults aim to age in place, in their environments and familiar surroundings [73].

Closely related to the topic of autonomy was the matter of *surveillance*. Participants were very clear that they were against the telepresence robot being used by family members or caretakers to "observe" or "spy" on them, especially if it was done against their will. Among the previously

proposed solutions for these concerns are the implementation of social rules for proper and polite use of the system and a recommendations guide about the use of the telepresence robot [29, 34].

Participants also brought up the topic of *trust* during the interviews. For older adults, the ability to trust that the robot was not "engaging in any wrongdoing" or "taking control from the user" was a recurrent theme. Given that trust towards telepresence robots increases when the system functions without errors [62], negative prejudices can be counteracted by optimizing the robot's operation.

Feelings of *anxiety* towards the telepresence robot were also to be expected, especially since it was considered a complex, innovative technology by participants. Older adults had some fears related to maintenance, software, and troubleshooting. They went back to experiences with their current devices and expected to face the same (or even more) challenges when using a telepresence robot. Since complex interfaces and the lack of experience manipulating them can cause fear among older adults [46] overcoming these obstacles is necessary to ensure proper technology adoption.

Directly related to aging was the requirement of a panic button or an open communication channel for *emergency/medical* personnel. However, this requirement was considered very important for "other older adults" who may need it, but not for the interviewees personally. As established by Neven [48] robot designers should always be cautious when interpreting these opinions, given that older study participants may typically believe that the "type" of users that would use a robot would be frailer and "not them."

*Social influence*, or the influence of those in their social circle, played an important role in participants' willingness to use a telepresence robot. Family members were constantly mentioned as older adults' "go-to persons" for tech support. Additionally, many older adults mentioned that loved ones had introduced them to certain technologies and had taught them how to use them. The importance of feeling that significant others would be happy if the older person adopts certain technology has been previously considered relevant for technology acceptance [41].

Finally, as older adults are usually on a fixed income, the issue of *cost* was constantly discussed during the interviews. There is evidence that suggests that older adults experience digital exclusion due to barriers like limited economic resources [5]. It is therefore relevant to take the economic factor into account when developing innovative technologies aimed at older users.

## 7 Limitations

Although the present study contributes valuable insights into older adults' attitudes, intentions of use, and requirements towards telepresence robots in the context of social integration, it is not without limitations.

Firstly, the sample for the study was constituted of active, older adults living in Germany, with an interest in and current experience with communication technologies. All participants had no cognitive impairments and lived independently. These characteristics limit the generalization of the results to other groups of older adults.

An additional limitation is that the hypothetical communication scenario was presented in the form of a storyboard, where not all of the telepresence robot's capabilities could be showcased. Furthermore, the older adult was only portrayed as the local user thus placing them in the more passive role. This may have influenced the evaluation of the telepresence robot and the communication scenario.

Future research can focus on different groups of older adults as well as their social circles and place older users in the role of the remote communication partner.

## 8 Design Recommendations for Future Robot Development

Based on the collected data, specific design recommendations for the development of a future telepresence robot for older adults were defined. These recommendations were validated with a robot designer from the CO-HUMANICS project for their potential usefulness and feasibility. The most suitable ones are presented here.

Following older adults' *technology related requirements*, a telepresence robot should allow for easy storage in reduced and/or crowded spaces. A *"foldable"* robot or the ability to *remove certain parts* of the robot when not in use, would be practical. Furthermore, although anthropomorphism was not always required, older users wanted the robot to have some human-like characteristics. Incorporating a *face on the robot's screen* that shows emotions could meet this need. Participants also mentioned that operating the robot should not be complicated. Ease of use could be positively influenced by the development of a *simplified user interface*, similar to those in which older adults already show proficiency (i.e., messaging applications, video conferencing applications, etc.). Similarly, the ability to *customize* the robot's hardware, such as the ability to switch between touch screen and regular buttons, would make the technology more appropriate for different aging conditions (i.e., tremors, reduced coordination, etc.). Additional features

such as *voice commands* could also be used to facilitate navigation and general operation of the robot.

To fulfill older adults' *social integration requirements*, a telepresence robot could be a *communication partner* and not just a communication mediator. By incorporating a *smart assistant* that provides information such as weather reports and latest news, answers questions, offers friendly greetings, plays requested music, etc., a telepresence robot can help combat loneliness. In addition, to facilitate the social integration of older adults, a *"speed dial"* function with profiles of the user's most frequent contacts could be added. Furthermore, by mediating *collaborative activities* between communication partners (i.e. playing digital board games, watching movies together, listening to music together, etc.), a telepresence robot could enhance perceived social presence.

Finally, *successful aging requirements* can be addressed with software modifications and external support. The perceived "one-sidedness" of RMC can be improved by giving older adults (the local users) access to more *control functions* that support autonomy. The ability to easily reject calls, turn off transmitted video, restrict access to rooms, and deactivate the robot would allow users to play a more active role in deciding when and how to engage in robot-mediated communication. In addition, anxiety levels could be reduced by providing a *simplified user manual* (digital and printed) and by creating a dedicated *technical support hotline* available 24/7. Furthermore, adding an easy to access *"emergency call"* button would allow older adults to contact a doctor or an emergency number at any time.

In conclusion, a telepresence robot aimed at the social integration of older adults should try to meet the needs of all requirement groups in order to adapt the preferences and lifestyles of older users and to be adopted for a longer period of time.

## 9 Conclusions

The present study explored older adults' attitudes, intentions to use, and requirements for telepresence robots and produced valuable insights for technology designers and developers. It was shown that older adults already possess technology-related skills that can be transferred to innovative technologies. By applying their existing skills, older adults' sense of autonomy and confidence can be reinforced which in turn could result in a higher probability of technology acceptance. Future innovative technologies could include functions that put this set of skills to good use.

Given that all participants had previous robot-related knowledge, older adults' prior exposure to robot imagery should be explored before designing innovative technologies. With this understanding, positive attitudes could be leveraged, and negative attitudes could be counteracted. Furthermore, reluctant future users' opinions should be probed further. By determining and fulfilling these users' requirements (technological, social, and age-related) technology adoption levels could rise among them. On the other hand, future non-users' opposition to telepresence robots should be respected and different technologies should be developed for their social integration.

Finally, it should be noted that participants of the present study were eager to share their views and showed great interest in playing a part in the design process. Future studies should therefore embrace co-design, human-centered design, and other participatory methodologies. In addition, viewing aging as a life stage to be supported rather than a problem to be solved could open up new avenues of research and innovative technologies better suited to older adults.

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## Declarations

**Competing interests** The authors have no competing interests to declare that are relevant to the content of this article.



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