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Research on the Elderly User Assisted Experience Based on Digital Twin Remote Collaboration System

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Abstract. With the deepening of digital technology, the role of smart home in improving people's life quality and safety is increasingly prominent. Also, the elderly participate in social interaction through new technologies also plays a positive role in maintaining mental health. However, the attitudes of elderly toward to the new technologies especially actual use experience may different from what researchers expect. The authors carried out the users-assisted experience research via the self- developed digital twin remote collaboration system. We invited 12 seniors who aged from 57 to 73 that to have experiments and interviews. During the experiment, the elderly was assisted by our system, and the experience was compared with the intelligent mobile devices which they familiar with. The interview investigated the users' feedback before, after and during the experiment, and according to the results to summarize the elderly's concerns about the remote collaboration. The results turn out that digital twin can be more effective in helping seniors, and they have a positive attitude toward smart technology, and don't want to been treated differently.

Keywords. Digital twin, Remote collaboration, older adults, Smart home, Mixed reality, Assisted experience

1. Introduction

With the improvement of social health conditions and welfare levels the life expectancy of the world's population has increased significantly. However, the ensuing problem is the increasing number and proportion of the elderly population. The population aging not only has an impact on the economic, social and culture in many aspects, but also profoundly affects the material life and spiritual needs of them. Most seniors who age at home face significant physical decline and are prone to health problems such as falls, sensory impairment, mobility problems and increased loneliness.

Since entering the Internet age, using technology to assist older adults has attracted the interest of many researchers. Many new devices and methods have been developed, such as: smart home systems, robotic assistive systems, augmented reality technologies, digital twin systems, and remote collaboration systems. This research can help seniors live better, but relatively little research has been done to improve their independent living and mental health.

In this research, the author builds a usage scenario based on a remote collaboration system for smart home (RCSSH) to have user studies. By comparing the remote

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collaboration approach with smart mobile devices which the user's familiarity, the author developed hypotheses about the effectiveness and acceptance of using intelligent devices.

(H1) The digital twin collaboration system can provide basic life assistance for elderly.

(H2) The digital twin collaboration system can enhance collaboration efficiency compared to traditional methods.

(H3) The digital immersive environment can bring psychological intimacy to elderly.

(H4) The digital twin collaboration system can meet the emotional value needs of elderly.

(H5) Elderly have a positive attitude towards to smart devices and new technologies.

The user experiment was designed based on the above hypotheses, and users were asked to use two different ways to complete the complex teaching tasks which had different levels of familiarity and learning costs.

User interviews were conducted both before and after the test experiments, and experimenters were asked to fill out evaluation forms for their experiences during the experiments. Finally, the concerns of the elderly during the experiment were analyzed, and several concerns of the elderly about the remote two-way collaboration approach were summarized with the experimental results.

The contribution of this paper are as follows.

- Contrasted the implications for elderly of two different approaches, digital twin remote collaboration and smart phone video call.
- Discussed recommendations for elderly to collaborate remotely on digital twin.
- Summarized the vision and perceptions of older adults for greater integration into an intelligent society.
- Proposed recommendations on how intelligent approaches can take care of the elderly on psychological layer.

2. Related works

2.1. Aging population and the emotional value needs of the elderly

Addressing the needs of the elderly in terms of pension, health, cultural life, and social participation is of practical significance to alleviate the social pressure of population aging, which not only enhances the sense of access, happiness and security of the majority of the elderly, but also taps the potential and stimulates the vitality of the aging society. The common phenomenon is that the mental health of the elderly has been neglected for a long time, the discomfort brought by physical aging, the psychological impact of the departure of family members, and the lack of companionship and communication by the absence of juniors, the loneliness caused by long-term empty nesting and living alone has become a vital factor troubling the mental health[1] .

While there are many reasons that contribute to the emotional and mental health problems of elderly people, the distance is one of the major factors. To address the problems, HCI researchers have increasingly focused on the use of technologies such as mobile web, mobile applications, and social networking services in care and assisted living for the elderly.[2] Lauriks et al. showed that smart home is used to reduce

loneliness, boredom, and social isolation and can assist older adults in remembering their daily tasks such as taking medication, drinking water, and brushing their teeth, and enable them to live independently.[3]

Smart home enhance communication by visual means of communication with family,which have a positive impact on the mental state of the elderly and can improve the life satisfaction. A study by Hensel et al. improves that video solutions is effective in improving mental satisfaction and well-being of the elderly[4] . Smart products can improve seniors' sense of separation from society, reduce degrees of loneliness and depression, and enable them to live healthy and safe independent lives[5].

In addition, technologies targeted to the elderly are becoming a proposition, they attempt to improve quality of life and extend their lifespan. These technologies are expected to satisfy specific abilities as well as the cognitive, social interaction and good health needs of older users.

2.2. Research on intelligent technology to assist the elderly

In the wave of smart home devices and online services for home care, the massive popularization and upgrade of smart home devices has made it inevitable for empty nesters to face the whirlpool of smart devices. Lack companionship and assistance from juniors and third-party service, the elderly's sense of loneliness and loss of control over smart home devices is increasingly prominent. Smart assistive devices are often designed to assisting with household tasks such as cooking, cleaning, monitoring, and health care, etc. Broekens et al. showed that smart robots can be companions to ease elderly's lives and enhance their lives by regulating positive emotions and reducing loneliness quality of life[6].

Providing smart home services is a major step toward improving the quality of life for seniors. Smart home services rely on home intelligence systems that contain many different types of sensors, electrical components, monitoring systems, and central control centers to support the creation of automated environments with autonomous user interaction.

While the benefits of smart home are numerous, they are not widely adopted in senior living scenarios. This can be attributed to the fact that the different technologies are still in the development stage or pending commercialization. Another reason could be that most of the research on smart home has focused on the underlying technologies, sensors, actuators, and the limited-service capabilities they can provide [7]. However, little is known about the user acceptance of these services, as well as the motivations for using such systems, and there is a lack of adequate empirical research on the intentions and behaviors of older adults using smart home services[8]. Age is a unique aspect that we consider in this work, as it can be a determinant of the receptivity to new technologies. Therefore, proposing a suitable framework to explain the intention and perception of the elderly on the use of various smart services.

Demiris et al. evaluated the elderly's perceptions of using smart home, including gait monitors, bed sensors, flame sensors, and motion sensors, which could monitor their health and increase security[9]. Yu et al. showed that the use of smart cameras can be used in a home environment to detect the elderly falls[10]. Fischinger et al. created a robot that can switch between different modes and includes features such as voice recognition, gesture recognition, etc. It can provide daily interaction to the elderly and assist them to live independently[11]. Rudzicz et al. developed a mobile robot designed to assist older adults with visual monitoring to provide voice alerts in assistance

situations[12]. These technologies involve remote assistance, virtual interaction, and emotional care, and are designed to support household tasks (e.g., cooking, cleaning, etc.) as well as assist in monitoring and maintaining health status.

It is clear that the published literature that more and more smart home is being developed. However, older adults do not necessarily see the benefits of smart home to change their perceptions of smart technology, which they perceive as being designed for those who are not as healthy as they are[13]. In two recent literature reviews, the authors concluded that there is a lack of investigation of the elderly's lived experiences with smart home technology. Lee et al. emphasized the importance of focusing on the mental health of older adults and Turjamaa et al. highlight that in many designs it is the designer's idea, but it lacks real elderly users participation.[14][15].These studies focus on the functional aspects of smart technologies to assist older adults, ignoring the receptiveness of them to new things and the cost of learning.

According to the analysis of on the literature of digital and smart technologies to assist older adults reveals that most studies conclude about the effectiveness of helping older adults live independently. Some studies document and analyz the status of the elderly access to smart home technologies or discuss their preferences for different technologies and the rationale for smart devices in home. But there has been a relative lack of research on improving their mental health (Figure 1).

Number	Literature	Purpose	Method	Physical	Psychological	Automatic	Collaboration
【11】	Senior residents perceived need of and preferences for smart home sensor technologies	Monitor their health and enhance their sense of security	Bed Transmitters, Gait Monitors, Cooktops and Motion Sensors	●		●	
【12】	A Posture Recognition-Based Fall Detection System for Monitoring an Elderly Person in a Smart Home Environment	Assistive system to detect falls in the elderly	digital video camera	●		●	
【13】	a care robot supporting independent living at home: First prototype and lessons learned	Support seniors to live independently	Multimodal interface, including voice recognition, gesture recognition, etc., can provide robots with daily interaction for the elderly	●		●	
【14】	Speech Interaction with Personal Assistive Robots Supporting Aging at Home for Individuals with Alzheimer' s Disease	Assist older adults with verbal cues in difficult situations	Visual Monitoring of Mobile Robots	●		●	
【15】	Older adults talk technology: Technology usage and attitudes	Explore older adults' acceptance of technology	focus groups, discussions		●		
【16】	A user study on mr remote collaboration using live 360 video	Enhance the remote collaboration experience	By adding visual perception and gesture recognition	●	●		●
【17】	Review of ICT-based services for identified unmet needs in people with dementia	Informal caregivers make caring for people with dementia easier	GPS technology and monitoring system	●			●
【18】	Videophone communication between residents and family: a case study[J]. Journal of the American Medical Directors Association	Videophone communication has psychological benefits for nursing home residents and family members	Videophone Communication vs. Voice Calls		●	●	
【19】	Technology to reduce social isolation and loneliness	Reducing loneliness among seniors at home	Interactive kinship photos		●	●	
【21】	A critical review of smart residential environments for older adults with a focus on pleasurable experience	Promote the physical and mental health of older adults	Application experiment of smart home environment		●	●	
【24】	Potential of Augmented Reality and Virtual Reality Technologies to Promote Wellbeing in Older Adults	Analyze older adults' perceptions of AR/VR use	AR/VR	●	●		●

Figure 1. Research literature on smart technologies to assist older adults.

2.3. Application of digital twin remote collaboration technology

Intelligent assistive technologies have the potential capability to maintain elderly's independence and improve their lives, such as staying in touch with family, allowing to remain socially active[16][17]. The digital twin immersive experience use creating familiar virtual content and supporting remote assistance that can provide a positive experience for users and facilitate communication between users. Existing immersive technology applications are provided for entertainment, education, or therapy purposes. They have limited application measures for family caregiving and home care for older adults.

Digital twin remote collaboration enables users who are far apart to be immersed in the same space. This tech involves the use of augmented reality (AR) and virtual reality (VR) to seamlessly blend physical and virtual spaces.

Similar to the interaction with physical objects, mixed reality users can assign value to virtual objects, experience a sense of virtual-reality association, and develop a sense of psychological belonging to these objects[18]. The collaborative system proposed by Kiyokawa et al. already allows users to easily switch between VR and AR views for a free interaction[19]. Piumsomboon et al. build a collaborative scenario in which the AR user's local environment is shared with remote collaborators via VR. The wearable device quickly captures spatial information around the local user and shares the reconstructed model with the remote collaborators in real time[20]. le Chénéchal et al. developed a mixed reality system in which expert users in VR share viewpoint and gestural cues with AR users to help them perform real-world tasks[21].

These studies suggest that the sharing of physical spatial information is fundamental to the formation of mixed reality spaces, and that adding avatars or gestures can improve collaborative experiences. This type of collaboration increases the social atmosphere, enables the use of natural nonverbal communication cues, and supports shared interaction with virtual content in space. Gauglitz et al. propose a system that supports an enhanced shared visual space, using for real-time remote collaboration for physical tasks. Remote users can explore the scene independently of the local user's camera and can communicate through spatial annotations that are visible to the local user in real-time in augmented reality[22]. AR and VR are generally considered to have a higher acceptance among the younger generation, older people are often excluded. However, many designers and researchers have recognized the potential of AR and VR technologies to enhance the social well-being, quality of care, social value, and independent living of older adults[23].

Nevertheless, most current research on AR and VR applications for older adults centers its attention on physical health. There are some researchers who have attempted to improve the elderly's mental health and have examined the enabling factors that stimulate interest and enhance engagement. Research on remote collaboration technologies for older adults remains limited, with a greater focus on enhancing innovative design and ease of use, and a greater tendency to ignore potential older users. This may be due to a lack of understanding of the capabilities, needs and preferences of the elderly.

Studies have shown that digital twin remote collaboration technologies and smart services have the potential to improve the mental health and quality of life of older adults and promote the value of them. Similarly, among participants who have tried smart home, acceptance among older users has increased significantly over time and with frequency of use.

3. User experiments

In our previous work, we built a remote collaboration system for smart home (RCSSH) to enable remote users and home users to finish assistive tasks such as interactive companionship and managing smart devices, and to validate the usability of the system. The system shared immersive perspectives and interactive collaboration elements, and collect data from the smart home environment through IoT hardware and overlaying on a digital twin model in real time. Using augmented reality and remote virtual interaction across physical space, the system can help seniors handle smart device management and assisted living issues through two-way remote collaboration, reduce the burden of learning and adapting to the smart home, expand access to remote companionship, and compensate for the lack of a sense of value for seniors. RCSSH is a system that provides multi-party remote collaboration to optimize the smart home experience and supports different levels of interactive functions. In basic interaction mode, local users can visualize data in their home using MR glasses (Microsoft Hololens 2), while remote users can use VR headsets (Oculus Quest 2) to remotely view and control smart devices in their physical space. Depending on the roles of the collaborating parties, there are two different modes of interaction and collaboration: remote user-led mode and home user-led mode.

Based on the proposed hypothesis, and based on the findings of previous work[24]. the experiment used a digital twin remote collaboration to compare with existing familiar collaboration approaches for users. The research work was conducted through two experimental tasks with 12 older adults aged 50 years and older, both had experiment and interviews.

3.1. Experiment design

To achieve the effect of simulating remote access, the experiment was implemented and tested in two separate room in an apartment: a kitchen provided to the elderly experimenter to simulate the environment of an elderly user at home, and a single bedroom used by the experimenter to simulate the general environment of a remote user. The kitchen was approximately 15 square meters in size and was equipped with the smart home required for the experiment, including a complete set of coffee machines, bean grinders, electronic scales, etc. and a vacuum cleaner. The bedroom was approximately 12 m^2 and was equipped with general living facilities.

- Experimental support systems and devices:

The experiment mainly used the remote collaboration part of the RCSSH system, and adapted and adjusted the system according to the requirements of this experiment. The hardware part included Microsoft Hololens2 for the elderly experimenter, which supported remote audio and video communication based on Web RTC and could capture audio and video and transmit them to the host. Prepared Oculus Quest 2 for the remote host, which supported immersive visualization, audio/video capture and gesture recognition. The software was a virtual space based on Unity 3D and a server for data exchange. The kitchen space and the appliances were modeled in Unity 3D in line with the physical space. The system also integrates the somatosensory interaction function developed based on XR Interaction Toolkit plug-in to support users to interact with virtual objects through the interaction handle, and to perform free movement operations such as forward, backward, left and right steering and destination transient using the

operation joystick. The remote host wear the Oculus Quest 2 in the bedroom, and the headset connected to a computer. The host was immersed in a virtual space with virtual kitchen and the coffee machine to demonstrate the process using a virtual model for an elderly user at home. The host could see what the elderly experimenter doing as the first-person perspective on the built-in screen. The elderly experimenter wearing Microsoft Hololens2 could see host's physical environment through transparent lenses, and could also see the host's demonstration screen on the built-in screen to simulate operation process. At the same time, the physical kitchen can be captured and transmitted to the remote collaborative host via the camera on Microsoft Hololens2.

- Subjects:

The authors recruited 12 older adults to participate, aged from 57 to 73 years (M=63.92), 5 of them were men and 7 of them were women. 12 participants did not have any visual or auditory impairment that could affect the results of our experiment.

- Experimental tasks:

The task was divided into two parts: making a cup of coffee using the coffee machine, and using the vacuum cleaner for sanitation and cleaning it. 12 subjects were randomly divided into two groups, A and B. Each group had to complete the two tasks, but they completed the experiments in a different order: group A used the coffee machine first to make coffee, and group B used the vacuum cleaner first. Two different collaboration methods were used, one representing the new future technology of digital twin remote collaboration system RCSSH, and the other representing the existing common method of smart phone video call (Figure 2).

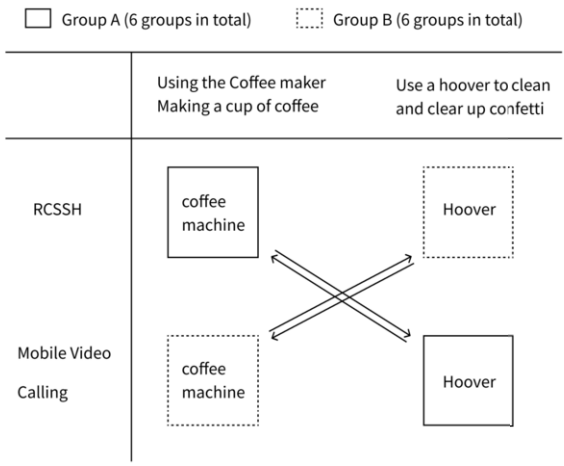

Figure 2. Method of assigning experimental subjects to groups and order of task completion.

3.2. Experimental procedure

The author introduced basic information about RCSSH to the subjects before the experiment to reduce their concerns due to lack of understanding of relative technologies. The audio and completion times were recorded for analysis. Notably, only one user was pre-familiaried with the use of the coffee machine and vacuum cleaner, as she was

previously employed in the hotel and had been exposed to and learned about similar equipment. The remaining 11 users had not used either of these smart devices before the experiment. This situation is roughly in line with the reality of seniors in this age group, and is therefore conducive to restoring the true experimental conditions and results.

- Coffee making tasks：

The elderly experimenters were asked to follow the steps of the host's teaching instructions to complete the process of making a cup of coffee. The process includes: taking coffee beans - weighing and measuring - grinding coffee powder - loading the coffee machine handle - pressing the powder --installing the handle - extracting the coffee.

- Vacuum cleaner use tasks：

The elderly experimenter was asked to follow the steps of the host's instruction to complete the task of cleaning the confetti from the floor and desktop and cleaning the vacuum cleaner. The process includes: cleaning paper residue from the floor - replacing the vacuum cleaner head - cleaning paper residue from the desk - cleaning the vacuum cleaner cartridge.

Although there were some communications problems between the experiment, all the seniors' completed tasks and rated them. The scoring rules were based on four elements: usability, i.e., how strongly the elderly intended to use the experiment when two collaborative methods were available; ease of use, how tedious the experiment was to operate; satisfaction, how satisfied they were after the task was completed; and validity, whether they learned to use the coffee machine or vacuum cleaner.

3.3. Interviews for the experiment

Quantitative and qualitative data were collected before, during and after the experiment, and analyzed these data could indicate the effectiveness of the system in solving problems in the lives of older adults and their attitudes towards to smart technology. Each experimenter was invited to participate in two pre- and post-experimental interviews and completed a Richter scale at the end of the experiment. The audio of the entire experiment was recorded in its entirety to facilitate a later review.

The interviews consisted of pre-prepared generic questions and open-ended discussions by the experimenter in communication or based on questions that during the experiment. The pre-experimental questionnaire interviews focused on obtaining basic information about the elderly, their perceptions of the upcoming experiment and knowledge of new technologies such as the digital twin, and interpretation of the proper nouns that would appear during the experiment (Figure 3). Questions 1-4 were personal information, while question 5 was designed to find out whether the elderly lived with their children, a condition that would affect whether the elderly would need to collaborate remotely with their children in subsequent sessions. Question 6 was designed to infer the experimenter's acceptance of new things and technologies by knowing how often the experimenter used intelligent products such as a smart phone. Questions 7 and 8 were mainly used to find out how the elderly perceived with new technologies.

Pre-experimental interviews

1. Your age:

☐ Under 50 ☐ 50-60 ☐ 60-70 ☐ 70-80 ☐ Over 80

2. Your gender:

☐ Male ☐ Female

3. Your education level:

☐ High school and below ☐ Undergraduate ☐ Master degree and above

4. Your health status:

☐ Good ☐ Not good（☐ Limited mobility ☐ Poor eyesight ☐ Poor hearing ☐ Others）

5. Your current living accommodations.

☐ Living with children ☐ Not living with children

6. To what extent do you usually use smart devices (mobile phones)? (Multiple choice)

☐ Call ☐ Use of Alipay Health Code etc. ☐ Use of social networking software such as WeChat

☐ Take photos ☐ Make video calls ☐ Mobile Games

7. Do you know what a remote collaboration system is?

☐ I hadn't heard of it at all ☐ I know a little ☐ I know ☐ I know very well ☐ I have used

8. Do you know what virtual reality (AR/VR) technology is?

☐ I hadn't heard of it at all ☐ I know a little ☐ I know ☐ I know very well ☐ I have used

Figure 3. Question set for the pre-experimental questionnaire interview.

The post-experiment interview focused on whether the experimenters had new opinions about new technology, and other relevance issues. It included asking the users how they felt after using the two different modalities, the problems they encountered during the experiment, comparing the advantages and disadvantages of the two different modalities, as well as some suggestions for improving the system (Figure 4).

Post-experimental interviews

1. What is the difference between using the collaboration system and video calling from a mobile phone?
2. How difficult do you find the teaching guidance in using it?
3. Do you want your children to interact and collaborate with you in this way?
4. Do you feel more intimate? (Compare to mobile video calls)
5. What do you think works better in this way than a mobile phone? (What is not as good as a mobile phone?)
6. Are you interested in this type of operation (RCSSH)?
7. Would you still like to use it（RCSSH）?
8. What other features would you like to have?
9. What do you think could be improved when using the collaboration system?

Figure 4. Questions for the post-experimental interview with the subjects.

4. Analysis and Discussion

We conducted an experiment of simulated assisted living by using a digital twin remote collaboration system to assist older adults and evaluated the RCSSH system used in the experiment in comparison to their familiar smart phone. Interviews were then conducted to investigate the concerns and desired suggestions of the tested users before, during, and after use. In this section, we conducted quantitative analysis, qualitative analysis, and discussion based on the complete audio recordings of the user experiments, the Richter scale filled out after the experiments, and the results of the pre- and post-experiment interviews.

4.1. Quantitative analysis

We performed time statistics for each task. Based on the time spent data in Figure 5, it can be seen that all the ways using the RCSSH system took less time to complete than the ways using the cell phone, and the time difference between the two ways was smaller for the coffee machine experiment and larger for the vacuum cleaner experiment.

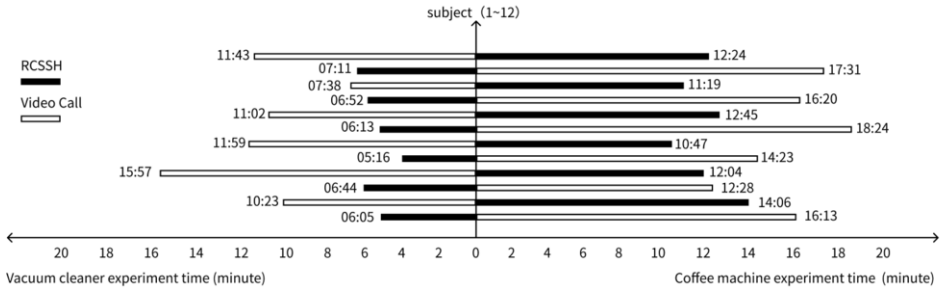

Figure 5. Time taken to complete the task for different subjects.

A questionnaire was set up after the experimental session to rate four specific evaluation indicators of the system, such as usability, ease of use, satisfaction, and effectiveness, and a total of 24 scoring sheets were obtained from the 12 experimenters who completed the task. The meanings of these indicator questions were as follows.

- Usability, i.e., the strength of intent to use the system when there are two options for collaboration.
- Ease of use, the tedium of operation during the task.
- satisfaction, the degree of user satisfaction with the process after completing the task.
- Validity, whether you learn to use the coffee machine or vacuum cleaner after the experiment is completed.

Based on the score of 12 elderly experimenters for the above four questions in different collaboration methods and task combinations, the mean and standard deviation were calculated as shown in Table 1. For the usability questions, the mean values of using the RCSSH method were all higher than using the cell phone, implying that more elderly were willing to use the RCSSH system rather than the cell phone video call when

there were two collaboration methods to choose from. The highest standard deviation value for the vacuum cleaner task using the mobile phone video call was due to one user scoring lower on this task because he could not find the vacuum cleaner rotation lock described by the host, thus resulting in an abnormal standard deviation. This feature was also reflected in the satisfaction indicator, where the remaining tasks scored a perfect 5 on the satisfaction scale, except for this task of completing the vacuum cleaner by means of a video call on a cell phone, which scored low. Among the effectiveness indicators, only the task of consulting on the use of the coffee maker via cell phone video call was not a perfect score, probably because the steps of using the coffee maker are more complicated than those of the vacuum cleaner, and the cell phone video instruction method has significant shortcomings in the instruction of detailed issues.

Table 1. Analysis of the results of the user evaluation of the RCSSH system after completing the task.

	RCSSH + Coffee machine		Video Calls+Coffee machine		RCSSH+Vacuum cleaner		Video Calls+Vacuum cleaner	
	average value	standard deviation	average value	standard deviation	average value	standard deviation	average value	standard deviation
Usability	4.33	1.118	3.50	0.762	4.17	0.897	2.83	1.572
Ease of use	4.83	1.213	4.50	0.500	4.50	1.000	3.17	1.344
satisfaction	5.00	0	5.00	0	5.00	0	4.83	0.373
Validity	5.00	0	4.83	0.373	5.00	0	5.00	0

4.2. Qualitative analysis

In addition to the evaluation with the Richter scale, post-experimental interviews were conducted based on the status of the users to further discuss about the possibility of remote collaboration to address the concerns of the elderly extremely their attitudes toward this form of interaction (Figure 4).

In question 1, most of users mentioned that the RCSSH provided a way to free up their hands more than a cell phone, which usually requires one hand to hold the phone and point the camera at the object being displayed. However, one experimenter mentioned that "although the collaborative system frees up the hands when worn on the head, it can be uncomfortable for a long time", which is related to the limitations of current hardware technology. The positive rating for question 2 may be due to the subjective affective influence of the participants, which is similar to the Richter scale satisfaction score. Regarding question 3, most users were positive and looked forward to a technologically mature, intelligent and efficient approach. A few users indicated that although they gave high scores on the scale, they preferred to continue using smart phone collaboration given their current usage habits. For question 5, several users mentioned that the advantage of the RCSSH is that it is more intuitive to get the intention that the host wants to express, and you can see the host using the corresponding virtual model for demonstration, which is more like a hand-held teaching method, obviously better than the cell phone voice guidance. One of the seniors said, "When I was instructed to use the vacuum cleaner with my cell phone, I could never find where you said the rotary unlock was because there was no visual way to indicate it and I had to describe it through verbal language, so I never knew how to open it."

In response to questions 8 and 4, one user said, "I would like to see the other person's face in the guide, so that I can get more information through facial expressions and also have a more intimate feeling." Another user said, "If the device can be more portable, then she will be more willing to use it, after all, it seems that smart phones are more portable at present." And one user said, "I was not too interested in such new devices before using them, but after using them, I felt that technology is really progressing, and this experience made her feel amazing, just like what she saw in the movie, and I hope to have the opportunity to contact more new technologies in the future.

In addition, one of the test subjects had a particularly good time throughout the experiment because she already knew how to use the two smart appliances in the experiment beforehand. However, she said that she was equally happy to use new technology products with our teaching remote guidance method, and said that she herself is a person who is happy to learn and use new technology. Another user said that although she was aging at home and experiencing many inconveniences in her life, she did not want to be treated as someone who was frail or needed to be cared for, and this type of support for two-way remote collaboration made her feel that she could have more opportunities to bring her value into play.

4.3. Discussion

Most of the current studies aimed at elderly recruit a group of tested users who are typically frail, high care needs, or directly from places such as community or home care centers for retired seniors. These specific elderly users may hold some bias toward the practicality of new technologies. This study focused on the group of older adults suitable for remote collaboration, who are still healthy and live independently in their own homes, and this group of older adults whose perceptions of intelligent technology with real needs. In addition, the study compared older adults using RCSSH and using cell phone video calls to accomplish the same tasks. RCSSH technology is a new means of exploring the smart home experience, and studying those older adults recruited from the community to experience the digital twin and remote collaboration technology provides insight into their expectations and preferences. The purpose of this study is not to evaluate and define the RCSSH system itself. After all, the technology is still in the development and refinement stage.

To this end, a series of experiments and interviews were designed to assess older adults' perceptions and expectations of specific smart technologies, including the advantages and disadvantages of the system and the extent to their willing to use these technologies in their homes.

For the original hypotheses H1 and H2, comparing the time difference shows that all subjects took less time to complete the task using the RCSSH system than using a cell phone. Combined with the responses to the post-experiment interviews, "The RCSSH system provides a more hands-free approach than a cell phone, which usually requires one hand to hold the phone and point the camera at the displayed object," it is evident that the digital twin approach to remote collaboration can assist in solving many problems in the lives of older adults and can significantly improve the efficiency of collaboration. The digital twin approach to remote collaboration can help solve many problems in the lives of older adults and can significantly improve the efficiency of collaboration.

For hypothesis H3, we can see that the RCSSH system is not able to increase the sense of intimacy because the RCSSH system can only see the first view of the opponent,

but not the face, and cannot see each other's face. For hypothesis H4, since the experimental design recruit elderly people and the other party in the experiment is not a relative of the elderly, it cannot be verified for the time being whether the need to improve the emotional value of the elderly is achieved.

For hypothesis H5, all 12 users had a positive attitude toward the future use of intelligent technology and expressed a willingness to continue using it in the future as the technology matures. However, there were both similarities and differences in each experimental participant's understanding of new intelligent technologies. What was similar that they all had positive attitudes toward the new technologies and could sense that their acceptance increased as they used and experienced them. They generally said that smart products are inevitable in their future lives, and although they must sometimes pay a certain learning cost, they still want to accept and understand new things faster and fit into the changing trends of the times as much as possible. As one of them said, "The times are developing, the tools we use will definitely become more and more advanced, and this kind of research is particularly meaningful." For most older adults, they do not want to be deliberately treated differently, but rather want to be more freely to use new technologies. At this stage, there is inevitably room for optimization of the technology for remote collaboration, but as digital twin technology and smart home devices continue to evolve, and the products become lighter in size and more affordable, the quality of interaction and deployment costs of the system will become increasingly conducive to widespread adoption.

5. Conclusion and future work

The use of digital twin remote collaboration as a means to improve the quality of life of older adults was positively responded to by the subjects, and the previously proposed hypotheses were experimentally tested. Among them, hypotheses H1, H2, and H5 largely met expectations, and hypotheses H3, H4 and expectations had some differences. The reason may be that the user experiment ignored the rule that the real emotional needs of the subjects need to be generated among relatives and acquaintances. Overall, the digital twin approach to remote collaboration can assist older adults in solving problems in their lives in a more intuitive way and has significant collaborative efficiency advantages over the cell phone call approach. Also, participants had positive attitudes toward this new technology, and their acceptance increased significantly after using and experiencing it.

However, this research work still has several shortcomings as follows.

- The elderly experimenters were all recruited from the same economically developed city, and their living standards and perceptions are not representative of the entire elderly population. Further experiments need to consider enriching the diversity of the study sample, e.g., recruiting experimenters from different cities or rural areas may reveal very different views on smart technologies.
- This validation experiment is still relatively homogeneous and does not cover the full picture of a wide range of smart technologies, but what is certain is that older adults generally have a positive attitude toward mixed reality and digital twins and believe that remote collaboration can solve some of their basic life problems.

- There have been some device debugging flaws during the experiments, such as the device will incorrectly recognize the gesture and thus trigger the pop-up menu bar. These shortcomings have somewhat affected the usage experience and experimental results, and these technical flaws need to be eliminated in subsequent system upgrades.

As a follow-up to this project, it may be possible to recruit experimental subjects in juniors-senoirs combinations in order to verify whether digital twin remote collaboration can bring more intimacy, enhance family emotions and increase the sense of value of the elderly. It is also possible to provide the device to the subjects for a long time and let them use it in their own home environment for a longer period of time to obtain more realistic and reliable experimental data, which may help to identify more issues of concern.

6. Summary

This study compares the efficiency and perceptions of using the RCSSH and using smart phone video calls to guide seniors to learn new life tasks through experiments completed by 12 participants recruited from the community, discusses seniors' perceptions of applying smart technologies in their home lives, and proves the hypothesis that RCSSH can help solve the inconvenience of living with seniors in their homes. The user-based experiments and analysis can provide a reference for future intelligent product design for the elderly, and specific points of concern are summarized for exploring how to better improve the assistance of home remote collaboration for the elderly. Chief among these is that digital twin remote collaboration can be more efficient in assisting older adults, and that older adults have positive attitudes toward smart technology and do not want to be seen as a group that needs to be treated differently. Our findings illustrate the important role that remote collaboration plays in the lives of participants and the ways in which their use of digital twin remote collaboration can be more advantageous in supporting healthy living for older adults.

The results of the study will help to design and develop relevant intelligent technologies that are conducive to being accepted by elderly and can meet the needs of the elderly to a greater extent, providing more possibilities and convenience for the elderly to age in place while taking care of their psychological feelings.

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