

## **Acceptance of gamified virtual reality environments by older adults**

The presence of advanced and affordable immersive technology has made available widespread applications of the virtual environment as a digital solution for different sectors, including entertainment, education, and healthcare. While the extant literature has addressed the acceptance of immersive technology by older adults, there is a dearth of research in the gamified context concerning its rehabilitative potential. This paper reports on a study that examined the technological acceptance of gamified virtual reality (VR) environments by older adults. A VR environment comprising six mini-games was specifically designed for the rehabilitative training, leisure and expressive experience of the participants, allowing them to freely engage in the VR gaming experience. Semi-structured interviews with older adults (N = 15) revealed a synergy between the stimulating effects of the video games and the realistic environment afforded by the immersive technology, the games' perceived usefulness in competency development and life skills training, the difficulties the adults encountered, and their feelings following their first experience with VR. External variables unique to older adults' acceptance of technology, or which could lead to digital exclusion, such as physical constraints, educational levels, and prior knowledge of technology, were identified. Suggestions were provided to the designers of the immersive technology that could better cater to the needs and characteristics of the older adults, in the process shedding light on design solutions for bridging the digital divide between the elderly and other, younger members of the population.

**Keywords:** technology acceptance, virtual reality, older adult, gerontechnology, gamification

## **Introduction**

The re-emergence of virtual reality (VR) has brought about revolutionary changes in the 21st century (Evans, 2018). It not only contributes to a more affordable and accessible immersive experience for the end users, but also makes available digital solutions that may not have been feasible before. Interdisciplinary efforts have been made to develop innovative VR applications in various sectors such as healthcare (Riva & Serino, 2020), vocational training (Chang & Lai, 2021), and education and the preservation of cultural heritage (Cheng & Leung, 2020). The gamified VR experience is of particular interest because of the synergy between the stimulating effects of video games and the realistic environment afforded by the immersive technology, both of which have resulted in growing research efforts and the development of serious games for the aforementioned purposes (e.g., Esfahlani et al., 2019; Pang et al., 2022). An increase in the use of VR games and other immersive technologies for broader applications means that bridging the digital divide in order to encourage acceptance by older adults needs to be addressed as part of the creation of a more inclusive future (Marimuthu et al., 2022).

This paper presents a qualitative study that examined the acceptance of gamified VR environments by older adults. A VR environment comprising six mini-games was specifically designed for their use, allowing them to freely engage in the gaming experience. With a dearth of research addressing older adults' acceptance of VR games, it is hoped that the findings of this study can inform the design of serious games and immersive environments for leisure and other practical purposes, including rehabilitative training and healthcare.

## **Conceptual framework**

The study is framed by the technology acceptance model (TAM), a prominent theory proposed by Davis (1986, 1989) that attempts to examine how users come to accept technology. The original version of TAM argues that the actual system use is predicted by the user's behavioural intention (BI), which in turn is influenced by his / her attitude (A), or impression, of the technology. BI and A contribute to the perceived usefulness (PU) and perceived ease of use (PEU) (Davis, Bagozzi & Warshaw, 1989), both of which refer to the belief that using a particular technology can improve task performance and that usage will be free from effort. PEU also has an impact on PU; together, they mediate the effects of other external variables on usage intention. Since the notion of TAM was first coined in the late 20th century, different versions and variations of the model have been developed to cater to users' needs in different contexts (e.g., Shih, 2004; Venkatesh & Davis, 2000).

Attempts to adapt TAM for older adults have also been made, along with the use of gerontechnology. Dogruel et al. (2015) expanded the TAM perspective by adding technophobia, self-efficacy, previous experience and expertise with technology as barriers to, and facilitators of, acceptance for elderly users. Tsai et al. (2019) proposed a learning and acceptance model that examined the learning process, from technology exploration to acceptance, for older adults. Wang & Sun (2015) constructed an extended technology acceptance model that was tailored to the characteristics of elderly users in an attempt to explore and examine the impact of potential factors on their gameplay intentions, while Chen & Chan (2014a) developed a senior technology acceptance model that took into consideration age, gender, education, and the gerontechnology self-efficacy of elderly Hong Kong Chinese, along with their anxiety, health, and ability characteristics. These variations of TAM for older adults, and the use of gerontechnology, constitute the conceptual underpinnings of this study.

## **Literature review**

The acceptance of technology by older adults has long been an area of interest. Guner & Acarturk (2018) conducted a comparative study to explore the differences of technology acceptance between older and younger adults, the results showing that both groups of participants exhibited similar habits as framed by TAM, a finding consistent with the original model developed by Davis (1989). Another survey study by Wang et al. (2011) revealed that needs satisfaction, perceived usability, support availability, and public acceptance were the most important factors leading to the acceptance of technology by older adults. Putting TAM into the Hong Kong context, the study by Chen & Chan (2014b) revealed different attributes among older Hong Kong Chinese: in contrast to the original model by Davis (1989), no significant effects were found between usage behaviour and perceived usefulness, perceived ease of use, and attitude. Moreover, personal attributes, such as self-efficacy, anxiety, and facilitating conditions, were found to be more decisive than perceived benefits as predictors, indicating that for older Hong Kong adults, contributing factors for predicting technology acceptance are more personal and environmental in nature. This view is supported by Fong et al. (2022), who found that technical and social support could positively influence older adults' confidence in the future use of technology.

Previous studies investigating older adults' acceptance of particular types of technology have also been undertaken in order to inform the design and implementation of those tools for broader digital inclusion. Weck, Helander, & Meristö (2020) adopted a qualitative approach to explore the attitudes of ageing people towards assistive technology. They found that older adults' acceptance and willingness to use assistive technology was influenced by functional capacity, socio-demographic characteristics, digital literacy, educational background, and social

environmental support. Another qualitative study by Courtney et al. (2008) revealed more factors that influence older adults' willingness to adopt smart home technology, including physical condition, self-perceptions of health, and the influence of friends, family and healthcare professionals. The study by Yu-Huei et al. (2019) found that perceived usefulness was important to the acceptance of wearable devices by older adults, a result further confirmed and explored by Marston et al. (2016), who discovered that most older adults used technology for practical reasons, such as communication and online shopping, rather than for social networking.

The acceptance of immersive environments, one of the concerns of the current study, has also been previously explored. Huygelier et al. (2019) examined older adults' first exposure to head-mounted VR sets, the participants' feedback indicating a positive change of attitude towards the technology. Mascaret et al. (2020) surveyed older adults' acceptance of VR headsets designed to prevent falls. They found that the intention to use the headsets was positively predicted by perceived usefulness, perceived enjoyment, and perceived ease of use. Another study by Syed-Abdul et al. (2019) yielded similar results, with the experience of using VR as one of the additional, contributing factors. Perceived usefulness was further confirmed by Roberts et al. (2019), who provided some suggestions for increasing acceptance, such as improved interactivity, the facilitation of socialising with friends or family, and the desired simulation content.

The immersive gaming experience for the physical training of older adults have also been explored in previous studies. Xu et al. (2022) examined Chinese older adults' acceptance of VR exergames, revealing that perceived usefulness, perceived ease of use, and perceived enjoyment positively affected the intention to play. They also found that older adults who were younger, more educated, and with better socioeconomic status and health condition have a more positive

view of VR exergames. Chau et al. (2021) evaluated the feasibility, acceptance, and efficacy of VR training games among older adults and people disabilities. Positive results were yielded on participants' rehabilitation, cognitive function, and acceptance. In terms of their acceptance, negative feedback were sourced from the discomfort of the VR headset, complication of gaming tasks and the boredom of the training exercise. Shah et al. (2022) evaluated a social VR-based exergame for older adults based on their acceptance and gameplay experience. The participants found the VR gaming experience enjoyable and engaging socialising and exercising at the same time, which revealed the potential of social VR games to support older adults' participation in physical exercise. Apart of the aforesaid literature, no other studies have been identified that focus on older adults' VR gaming experience and acceptance for attributes other than physical training.

### **Aim and research questions**

This study examined the acceptance of gamified VR environments by older adults. The following three research questions guided the study:

- (1) How do the older adults find about the VR gaming experience?
- (2) What factors contribute to their acceptance of VR gaming?
- (3) What are the external variables that affect their acceptance of VR gaming?

### **Methodology**

The study adopted a qualitative approach in order to examine the acceptance of gamified virtual reality environments by older adults, enabling researchers to go beyond pure description and deepen their understanding of participants' behaviour and other dynamics in their respective

contexts (Bryman, 1988). It also allowed the researchers to explore the ‘meanings’ that individuals attribute to their social situations (Hesse-Biber, 2016). A series of semi-structured interviews with fifteen older adults was conducted with the intention of discovering the acceptance, use, adoption and behavioural levels of older adults’ VR gaming experiences.

### *Gaming design*

Comprising six mini-games, the VR environment was designed by a research team dedicated to the rehabilitative training, leisure and expressive experiences of older adults. The player enters a big house, within which there are six doors. Each of these doors opens into a different location (a music room, a drawing room, a backyard, a kitchen, a toilet and a beach), each with its own, contextualised mini-game. Two of the mini-games (cleaning the kitchen and the toilet) are task-oriented, designed for the purpose of life-skills training; another two (swimming in the sea and gardening in the backyard) are designed for the player’s leisure and motor exercise development; the remaining two (the music room and the art room) are expressive in nature in that the player can paint or listen to music in each of the three-dimensional, ambisonic environments.

In addition to the simulated living environments and gaming content that were designed to correspond to the older adults’ real-life experiences and needs, careful consideration was taken in the design of the gaming controls. Instead of using a VR controller that worked like a traditional gamepad, this gaming design allowed ‘Tracker’ to be used as the input control. ‘Tracker’ is a type of controller available in the HTC Vive series of VR headsets; it has no buttons on it and only transfers the motion data for input control. Its lightweight design enables it to be attached to different parts of the human body, including participants’ hands (see Figure 1), which is suitable for those older adults who may not be able to control their finger movements fluently (Kruse et

al., 2021). The buttonless controller design allows older players to engage freely in the gaming experience, thereby improving the perceived ease of use for their acceptance in the gamified VR environment, while the gaming design facilitates the buttonless gaming experience by manipulating other input mechanisms. For example, the player can open the door by looking at it for two seconds (a timer is shown on the screen), a similar approach also being used for item collection, the controller being pointed at the targeted artefact for the same amount of time.



Figure 1. Participant engaging in the VR environment with the ‘Tracker’ controller

### *Participants*

Older adults in Hong Kong tend to favour rather basic health and home technology such as remote control, mobile phone, sphygmomanometer and glucometer, while self-efficacy, anxiety, and facilitating conditions characterise their use of gerontechnology (Chen & Chan, 2014b). Fifteen Hong Kong adults aged 65 and above without prior VR experience were invited to participate in this study. They were private residents either living independently or with their partner, and none of them lived in care home. The convenience sampling method was adopted because of the researcher-participant relationship, the sense of trust being built between them as a result serving to help minimise the effect of technophobia on the participants caused by a lack



of support from family or friends (Nimrod, 2018). Table 1 shows the participants' demographic information.

Table 1. Demographic information of the participants

Participant	Gender	Age	Educational level	Use of technology (excluding home appliances)
A	F	66	Primary	Smartphone
B	F	67	None	Smartphone
C	F	68	Primary	Smartphone, computer
D	F	78	Primary	Smartphone
E	F	79	None	Smartphone
F	F	81	None	Smartphone
G	F	82	None	Smartphone
H	M	65	Junior secondary	Smartphone, tablet, smartwatch
I	M	65	Primary	Smartphone, tablet
J	M	66	Primary	Smartphone, tablet, smartwatch

K	M	66	Primary	Smartphone, computer, tablet, smartwatch
L	M	67	Junior secondary	Smartphone, computer
M	M	70	Primary	Smartphone, computer
N	M	72	None	Smartphone
O	M	73	Primary	Smartphone, smartwatch

### *Procedure*

Research data was collected between July to September in 2022. The participants were contacted through the personal connections of a member of the research team, a local Hongkonger. Upon receiving their agreement to take part in the study, an appropriate date, time, and venue were arranged for the conducting of the participants' VR gaming experiences and the semi-structured interviews. During the interview sessions, which lasted for 60 minutes, participants were briefed on the purpose of the study and introduced to the VR technology. They were told of the potential hazards of the VR gaming experience, such as feeling dizzy and experiencing motion sickness, and reminded to speak up at any time if they felt unwell or if they wanted to stop. After being guided how to put on the VR head-mounted display and use the trackers for input control, the participants engaged with the VR environment and played the mini-games for approximately 20 minutes. While they were doing so, the researcher ensured that the participants spent enough time playing all six mini-games and monitored the safety measures of the VR experience. The

semi-structured interviews commenced after the VR experience, the participants being reminded to answer the questions honestly, while interviewer bias and minimisation of the Hawthorne effect (Adair, 1984) were catered for by stressing that they should not attempt to guess any desirable outcomes from the perspective of the researcher. With the agreement of the participants, the interviews were audio-recorded and then transcribed, after which the interviewees were contacted by phone for the purposes of double-checking and confirming the accuracy of the notations.

### *Semi-structured interviews*

Participants were invited to take part in semi-structured interviews on a one-to-one basis, which evaluated their VR gaming experience in relation to their technology acceptance. The following series of open-ended questions guided each interview.

1. What technologies do you use in your daily life?
2. Have you had similar experiences with immersive technologies in the past?
3. What kind of skills could be developed through playing the VR games?
4. How relevant are the mini-game tasks to your daily life?
5. What difficulties did you find when playing the VR games?
6. Did you find it difficult to control the hand and head movements?
7. If you were to play the VR games again, what kind of assistance would you need?
8. How do you feel about the VR games?
9. Would you like to play the VR games again?

### *Data analysis*

Theoretical coding was used to analyse the qualitative data (Thornberg & Charmaz, 2014).

Members of the research team individually read the transcripts line by line and code them based on the concepts in TAM. While coding, the researchers wrote a memo to capture the salience of different concepts and examine outliers in the data. Other than perceived usefulness, ease of use and attitude, which are TAM constructing variables, any other external variables were identified by the researchers as themes. Any coding discrepancies were reconciled through research team discussions; the resulting intercoder agreement served to ensure the reliability of the findings (Garrison et al., 2006).

## **Findings**

### *Perceived usefulness*

The participants commented that the VR games could help older adults to become more independent through competency development. These included memory and muscle training for improving their health and safety.

*It can definitely train up mindsets and muscles. Regarding the effectiveness, it really depends on the design of the games ... if the games are associated with muscle-strengthening activities, they could help players build stronger bodies. (Participant H)*

*I think they [the VR games] can help improve the efficiency of my daily life through the motor control, muscle and memory training that they offer. (Participant M)*

*They [the VR games] could make me less obtuse, and train my muscles by moving the hands around. (Participant O)*

Apart from the memory and muscle training, the regaining of life skills are achieved through the task-oriented gaming activities contextualised within the home environment.

*The soap should be placed in a soap dispenser; a new toilet roll should be placed in the holder; the toilet needs to be flushed after use ... these are daily activities that we have to cope with in everyday life. (Participant O)*

*The game encouraged me to remember where the household items should be placed.  
(Participant M)*

The training of life skills also comes with the development of cognitive skills, supporting the logic behind the mini-games.

*By repeatedly playing the games it reinforced my memory, while at the same time I have to think about how the games are played and where the items should be placed.  
(Participant K)*

*Apart from the muscle training, I think the games also help cognitive training by thinking logically - like putting the items in the right place or getting tasks done.  
(Participant J)*

#### *Perceived ease of use*

The perceived ease of use from the point of view of the participants manifested itself in two ways. On the one hand, some male participants mentioned that the VR technology was easy to use.

*It's quite easy to use when you have repeatedly played several times. (Participant J)*

*The first trial is always confusing for every piece of technology, but after that it becomes easy. (Participant I)*

*I followed your guidance step by step and made it work. It was easy and interactive. (Participant K)*

*It's quite easy to manipulate and easy for me to use, even without assistance. I don't really have difficulty using it, and the interface is quite understandable. (Participant H)*

On the other hand, some female participants insisted that assistance was needed when playing the VR games and that they could not handle them independently.

*It wasn't easy the first time ... I didn't know how to use them and I think I will need help every time. The controller is difficult to use. (Participant E)*

*I was occasionally unsure what I should do when playing the games, particularly where to turn my head to and my current location. (Participant A)*

*It seems clearly understandable and easy to use, but I could not handle it myself. (Participant G)*

### *Attitude*

Participants shared both their positive and negative first impressions of the VR games. The positive ones reflected their curiosity about the VR games, and their eagerness to further explore the technology.

*I had never used VR before and only seen some kids playing it in the shopping mall. This was a fresh experience for me and I felt excited about it. (Participant J)*

*They [the VR games] look interesting. I think I need to try a few more times to tell whether I really like them or not. (Participant F)*

*I like to learn new things and I don't feel anything bad about it [the VR gaming experience], just that everyone needs to be familiar with the technology before enjoying it. (Participant K)*

The negative impressions tended to exhibit a preconceived attitude towards technology, rather than a more open mindset towards new experiences.

*I try my best to keep a distance from technology. (Participant L)*

*Is it necessary to use all the gears? I am too silly to handle all these things, unlike others who can use all kinds of technologies fluently. (Participant E)*

#### *Perceived enjoyment*

The participants felt excited about their first trial with the VR gaming experience. They were particularly stimulated by the sense of success they felt upon completion of the tasks and how closely these matched their daily living environment.

*I could sweep the floor by myself! After I had learnt the control mechanism, the interactivity provided by the games became interesting. (Participant A)*

*I like playing the mini-games in the kitchen and restroom most. It feels like I am at home. (Participant M)*

*I felt happy after completing the tasks by following the instructions. (Participant N)*

*I like swimming and the gardening tasks made me feel satisfied. The immersive environment is so beautiful as well. (Participant O)*

They were also intrigued by the immersive environments, especially those which simulated natural scenes that they might not be able to visit easily in real life.

*I would like to play the VR games again so that I can visit the beach. The virtual experiences make me feel as though I am travelling around. (Participant H)*

*There are many cute jellyfish in the swimming pool. I also enjoy playing in the kitchen and the restroom, which look so real. (Participant D)*

*I will run out of energy one day. When I'm not physically fit enough to continue my outdoor activities in the future, VR can help me to experience them virtually. (Participant H)*

#### *Education level and prior knowledge of technology*

The participants' responses revealed that an individual's educational background is an important factor which can affect their intentional behaviour. For example, the presentation of instructions, however simple, may not be understood by all the participants.

*I was not well educated and so I couldn't understand what the instructions were saying. (Participant E)*

*I rarely learn things easily. When it comes to new technology, it takes me a long time to get familiar with it. (Participant I)*



Prior technological knowledge and experience was also important from the participants' perspective.

*I have had some experiences with emerging technology before because of my work, so VR isn't too difficult for me. (Participant I)*

*I make use of technology a lot in my daily life and I am totally addicted to new tools. (Participant O)*

*Trying a few more times makes it easier to play around with the VR technology. Once I have this kind of background knowledge, I can easily operate it by myself. (Participant M)*

#### *Physical constraints*

Feedback reflected the degree to which the participants were constrained by their physical capacity.

*Sometimes the screen is so unclear; perhaps it's due to presbyopia. (Participant A)*

*The screen is clear, but I feel faint after playing for a while. (Participant G)*

*It's uncomfortable, I can't keep a consistent pace and feel quite dizzy after a while. (Participant L)*

#### **Discussion**

As reflected by the participants' responses, the findings of this study revealed different variations of technological acceptance of gamified virtual reality environments by older adults. They

generally agreed with the usefulness of the VR games to develop skills and build capacity in certain areas, such as memory and muscle training, through task-oriented gaming achievements, a finding echoed in the existing literature that VR games can improve older adults' health conditions (Neri et al., 2017), physical functioning (Molina et al., 2014), memory development (Wais et al., 2021), and cognitive ability (Yen & Chiu, 2021). This is coupled with their perceived ease of use, which provided optimal conditions for the attitude and intention towards using the technology, and finally contributing to the acceptance of VR games. Nevertheless, some contrasting views were found among participants' responses about the perceived ease of use, in which some of them found it easy to use while some others did not. This can be explained by the external variables. TAM states that the predictive effects of external variables inform perceived usefulness and ease of use, both of which subsequently predict attitude. These relationships have been found to be valid in the Hong Kong context (Chen & Chan, 2014a), as well as being reflected in the participants' responses in this study. For example, as someone with lower education levels, Participant E and G were unable to understand the instructions and handle the technology fluently. This contributed not only to their negative perception of ease of use, but also the attitude, behavioural intention to use, and the overall acceptance of the technology. Perhaps a coincidence, all participants reported difficulties playing the VR games were female, while those who found it easy to handle were all male participants. Despite not aiming at generalising the qualitative findings, this observation echoed with the existing literature that educational level and gender have a moderating effect on older adults' perceived usefulness and ease of use on technology acceptance (Wang & Sun, 2015; Xu et al., 2022). More evidence in future studies is needed to substantiate this claim in older adults' VR gaming experience.

Apart from educational level and gender, findings of this study also revealed physical constraints, such as health conditions and functional disabilities, as another external variable affecting the acceptance by some of the study participants. These pre-conditions can contribute to the digital exclusion of older adults (Gallistl et al., 2020), who live in a world where digital technologies pervade all aspects of our lives, including social communication, access to governmental and public services, and physical well-being and self-care. While such pre-existing external variables do not lend themselves to easy intervention, there are nevertheless areas within the field of gerontechnology – including the application of design thinking principles, empathic understanding of older adults’ needs, characteristics and behaviours, tailor-made user interfaces, and greater involvement in user requirement analysis and evaluation processes – that can serve older adults’ technological needs more effectively. In terms of immersive design, Shah et al. (2022) advocated the consideration of design principles when developing VR games for older adults to ensure an engaging and enjoyable user experience. More efforts can be made towards this direction for a better VR gaming design suitable for older adults. A good VR gaming design allows old adults to better understand the game flow setting, as shown in this study that the participants were able to produce specific performance attainments and complete the mini-game tasks. This can further affect the perceived ease of use, perceived usefulness and other consequential factors contributing to their acceptance of the technology (Weck et al., 2020).

Positive attitudes and enjoyment were expressed by participants when first exposed to the VR games, which echoed with the study by Huygelier et al. (2019) indicating a positive change of attitude towards the VR technology after older adults’ first exposure. Combined with the stimulating effects of the emerging technology and the gaming experience that motivated the

elderly players (de Vries et al., 2018), VR games is of high potential in gamifying training exercises for older adults to overcome the boredom and engage in meaningful tasks, such as rehabilitative exercise, cognitive and muscle training, and life skills development.

## **Conclusions**

The study examined the technological acceptance of gamified VR environments by older adults. The findings revealed the perceptions of usefulness and ease of use felt by the participants following their first exposure to the VR games, along with detailing the external variables unique to the participants as older adults, including their prior knowledge, educational levels, and physical constraints. All of these factors had a moderating effect on the adults' acceptance of technology. In order to mitigate against the possibility of digital exclusion that prohibits older users from accessing VR and other immersive technology, while simultaneously enhancing their digital literacy and encouraging them to explore new technologies (Rasi, Vuojärvi & Rivinen, 2020), design solutions that cater to the characteristics and abilities of older adults need to be considered as part of the development process.

Several limitations were identified in this study that might inform future research. Participants were selected through convenient sampling. They may only represent a specific group of older adults with similar educational background, socioeconomic status, or health condition, which are contributing factors to the technology acceptance of older adults (Ma, 2016). This is coupled with the adoption of a qualitative approach meaning that the findings were limited to verbal responses from those participants. A large-scale quantitative study with randomly sampled participants that provides statistical evidence among the relationships within TAM, leading to further generalisation of the results, is therefore needed. A longitudinal study that looks into the

long-term effects and change of technology acceptance after regular VR gaming intervention is also anticipated. Similarly, while preliminary considerations have been proposed, a more in-depth studies that focuses on the different aspects of the developmental process, such as the interface design, user requirement analysis, and evaluation, would constitute an important step forward. Together, these conditions can serve to better inform design solutions for improving older adults' acceptance and willingness to use technology, in the process narrowing the digital divide between the elderly and other factions of society.

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