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ORIGINAL ARTICLE

The role of engagement in older adults' intention to use virtual reality for wellbeing

Hosam Al-Samarraie[1] · Ahmed Ibrahim Alzahrani[2] · Fahad Alblehai[2]

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Abstract
Immersive spaces of extended reality, including virtual reality (VR), have attracted significant attention from scholars seeking to shape the future of digital transformation across disciplines and practices. VR experiences for aging communities have been designed and developed to mitigate social isolation among older adults. However, evidence regarding their ability to provide sustained social stimulation or improve social interaction has been mixed. This study investigated how older adults' engagement with VR drives their use of it for wellbeing. A total of 135 older adults (aged 60 to 80 years) participated to validate a series of relationships between engagement factors and endurability, and ultimately, their intention to use VR. The results demonstrated distinct effects of aesthetics, novelty, felt involvement, and focused attention on users' endurability. The mediating effect of endurability on an individual's intention to use VR was found to be significant. The model explained 69% of the variance in endurability (R^2 = 0.690) and 60% of the variance in intention to use VR (R^2 = 0.597). Several other non-significant effects were identified, and these were thoroughly examined and discussed. These findings provide empirical evidence that older adults' willingness to adopt VR for wellbeing is driven primarily by endurability and the aesthetic qualities of the VR experience, thereby informing key design and intervention priorities for researchers and practitioners. The study also offers new perspectives on the previously unobserved impact of novelty, felt involvement, and focused attention on older adults' intention to use VR.

Keywords Virtual reality · VR and society · Wellbeing · Engagement · VR adoption

1 Introduction

Extensive work on extended reality by researchers, industries, and designers has introduced new ways for people to engage with technology across diverse contexts. Virtual reality (VR) is one example, offering fully three-dimensional environments designed to increase users' immersion in specific activities or tasks. The popularity of VR spaces has grown in recent years, attracting a wider range of users. VR adoption among older adults is a key area that researchers continue to explore, focusing on the antecedents that shape their experiences. The literature notes that older adults already represent a significant proportion of the global population, with 12.5% aged 60 years or older, according to a World Health Organization report (WHO) (WHO 2015). One reason for this increase is the decline in mortality rates, driven by investment in healthcare and wellbeing initiatives such as creating opportunities for social communication and participation (Afroj et al. 2025; Hu et al. 2024). As a result, governments and researchers have been motivated to examine the role of the metaverse in creating social spaces for older adults (Pillay et al. 2024). For example, Sohrabei et al. (2025) reported that VR technologies can provide dynamic platforms for exercise programmes, recreational activities, and personalised health interventions. Other studies like Mahmoud (2024) discussed public perceptions of VR as a tool to empower older adults through technology-enabled learning and adaptability, noting that VR can enhance social connections and quality of life by stimulating cognitive and physical engagement.

✉ Hosam Al-Samarraie
h.alsamarraie@leeds.ac.uk

✉ Ahmed Ibrahim Alzahrani
ahmed@ksu.edu.sa

[1] School of Design, University of Leeds, Leeds, UK

[2] Department of Computer Science and Engineering, College of Applied Studies, King Saud University, Riyadh 11495, Saudi Arabia

To add further context, our review of the literature on VR use for improving social participation among older adults revealed several dimensions. Most studies have examined the direct application of VR and its usefulness for wellbeing by reducing social isolation and providing open channels for communication (Corregidor-Sánchez et al. 2020; Hughes et al. 2017; Lee et al. 2019; Lin et al. 2018b; Shankar et al. 2025; Syed-Abdul et al. 2019), social engagement (Kalantari et al. 2023; Liang et al. 2023; Moreira Kares et al. 2025), safety and motor control training (De Bruin et al. 2010; Kamińska et al. 2018; Ren et al. 2023), cognitive and physical rehabilitation (Chatterjee et al. 2022; Juan et al. 2023; Mohamed Zein El-AbdeenMohamed et al. 2025; Tortora et al. 2024), and other pressing areas. Another stream of research has addressed environmental factors influencing VR use for social interaction among older adults. For example, Tuena et al. (2020) noted that most prior studies did not propose a model to explain how engagement attributes and intention to use VR could be predicted. The authors emphasised the need for research into how older adults perceive engagement with VR environments and how this perception influences their decision to adopt the technology. This gap has not been thoroughly explored in the literature, providing the rationale for the present study.

Perceived involvement, aesthetics, and related variables have consistently been used to conceptualise individual engagement across different contexts and situations (Donato 2025; Georgiou et al. 2019; Jo 2024; Li et al. 2024; Limerick et al. 2019). Previous research suggests that perceptions of aesthetic properties extend beyond entertainment or sensory stimulation, influencing people's feelings, beliefs, and understanding of their surroundings (Pizzolante et al. 2024; Świątek et al. 2024). These findings have led researchers to recognise the role of such variables in shaping engagement with an experience. O'Brien and Toms (2010) proposed that post-experience engagement can be examined by understanding how technological characteristics contribute to technology use. Their work validated this assumption by demonstrating that relationships among engagement-related variables can shape user behaviour. Building on this, we propose a conceptual framework for engagement to determine older adults' intention to use VR for wellbeing (e.g., establishing social interaction through immersive spaces). Precisely, this study addresses one key question: how does engagement influence older adults' intention to use VR environments for wellbeing? To explore this, a set of theoretically supported hypotheses was developed. Answering this question is expected to provide valuable insights for designers, practitioners, and policymakers on improving older adults' engagement with VR social spaces. Practitioners can use these findings to identify which engagement elements most strongly influence user interaction and behaviour, while health policymakers can assess older adults' intention to adopt VR for social interaction.

2 Aging and VR

The literature has reported the potential role of immersive technologies in improving social participation among individuals (Wei et al. 2022). This potential has been mainly linked to feelings of loneliness and diminished wellbeing, which are particularly pronounced among older adults living in conditions of spatial and social separation from wider communities (Thangavel et al. 2022). Limited opportunities for interaction may reduce the chances for these individuals to engage meaningfully with others. Evidence from previous studies (e.g., Hofer and Hargittai 2024; Yong et al. 2023) shows that a substantial proportion of older adults in low social interaction conditions develop symptoms of depression, cognitive decline, or other forms of psychosocial distress. In response, VR-based experiences have been designed and developed to mitigate social isolation among older adults (Clemente et al. 2024a, b). However, evidence regarding their ability to provide sustained social stimulation or improve social interaction has been mixed (Balki et al. 2022; Finnegan and Campbell 2023).

VR's experiential qualities have been associated with increased absorption and affective involvement, leading some researchers to propose that it may support behavioural change and enhance wellbeing among older users (Ng et al. 2024; Restout et al. 2023). Although research in this area remains relatively limited and often focuses on populations with specific clinical conditions, several studies (e.g., Afifi et al. 2023; Chan et al. 2023; Clemente et al. 2024a, b; Skurla et al. 2022) have reported benefits of VR use for older adults, including reductions in mental distress and improvements in cognitive functions such as memory and attention. Previous attempts to examine VR's role in improving quality of life and social participation among older adults have yielded encouraging findings. For example, Kenyon et al. (2023) reported that social VR can significantly reduce loneliness and social anxiety, particularly for users who regularly interact with familiar groups. The authors suggested that online group participation fosters belonging, positioning social VR as a promising intervention for enhanced social connection beyond the pandemic. In addition, Lin et al. (2018a) found that VR reduced social isolation and signs of depression among older adults, who also experienced positive affect more frequently. Seifert and Schlomann (2021) concluded that VR can facilitate positive social interactions when used for communication. Other studies, such as Healy et al. (2022) identified challenges including discomfort associated with current VR technologies, yet noted that VR platforms

allow older adults to access activities and environments more easily than in the real world, overcoming limitations caused by ageing. Despite these promising outcomes, comparatively little is known about how VR might support older adults' social and emotional wellbeing, particularly in relation to loneliness, connectedness, and motivation to engage. Furthermore, the mechanisms through which older adults perceive and interact with immersive environments remain insufficiently explored. This study addresses these gaps by examining how specific engagement-related factors influence older adults' intention to use VR for wellbeing.

3 Individual engagement and behaviour

Facilitating individual engagement with technology constitutes a significant mechanism for inducing changes in perceptions and behaviours (Baanqud et al. 2020; Eldenfria and Al-Samarraie 2019). Engagement emphasises the importance of conceptualising associations within the context of application and use (Kearsley and Shneiderman 1998). O'Brien and Toms (2008) described engagement as a multifaceted process encompassing points of engagement, sustained engagement periods, disengagement, and re-engagement, linking these stages to user attributes, system characteristics, and user–system interaction. Previous studies (e.g., Ichsan et al. 2025; Sriworapong et al. 2022; Yan et al. 2024) have widely employed these attributes to conceptualise users' engagement with VR. However, much of this work has focused on identifying situations or design features that enhance participation in specific tasks or activities (Kalender and Guzmán 2025; Tu and Lee 2025), rather than examining how engagement-related attributes translate into the adoption of immersive technologies. As a result, the literature offers limited insight into how environmental characteristics such as aesthetics, novelty, or focused attention could shape individuals' willingness to continue using or intentionally adopt immersive systems from a deeper theoretical perspective. This gap is especially evident in the context of VR, where the unique sensory, perceptual, and interactive properties of immersive environments introduce experiential demands that differ from those of non-immersive technologies (Lee and Ji 2025). Although these characteristics are central to VR experiences, their role in influencing behavioural intention, particularly among older adults, remains largely underexplored.

From a theoretical perspective, previous studies have often construed engagement as a representation of individual interaction with tasks or activities. For example, Chapman (1997) investigated the role of cognitive and emotional attributes in driving users' engagement with multimedia system displays. These attributes have commonly been employed by scholars examining engagement with online tools such as games (Contreras-Espinosa and Gomez 2020; Sharek and Wiebe 2014), training/tutorials (Daher et al. 2021), and activities (Bonesso et al. 2018). The diverse approaches to assessing engagement in these studies complicate the generalisation of findings across contexts, users, and applications. Chapman (1997) established a link between engagement and the flow experience based on Czikszentmihalyi (1990). This understanding was later applied to computer-mediated environments, explicitly incorporating online elements into the structure of flow (Finneran and Zhang 2005). Beyond flow theory, other theoretical perspectives on engagement include crowdsourcing (De Vreede et al. 2013) and aesthetics (Adorno 1997). This amalgamation of theories inspired researchers like O'Brien and Toms (2010) to conceptualise engagement through attributes including usability, aesthetics, focused attention, involvement, novelty, and endurability. Subsequent attempts have sought to delineate user engagement across various technological contexts.

Immersive spaces of extended reality, including augmented reality, VR, and mixed reality, have attracted significant attention from scholars seeking to shape the future of digital transformation across disciplines and practices. These solutions are designed to facilitate interaction and immersion in specific activities and tasks. Feasibility studies have explored older adults' engagement with such experiences to elicit behavioural, cognitive, and emotional changes. In addition, the intention to use VR in wellbeing contexts represents one application that health organisations and researchers are actively investigating. However, our literature review highlights a lack of understanding regarding how older adults intend to use VR for wellbeing. This understanding is crucial for conceptualising engagement through established theories on aesthetics, flow, and play, which we employ to examine the impact of engagement on intention using the theory of reasoned action. The following section introduces the research model for this study.

4 Research model

The combination and arrangement of variables influencing individual engagement vary across studies. In this research, preceding theories on aesthetics, play, and flow were employed to characterise older adults' engagement with VR for wellbeing. This work examines how these theories based on specific environmental and individual attributes might contribute to the theory of reasoned action. The objective is to establish a conceptual framework outlining the relationship between engagement and the intention to use immersive technologies. O'Brien and Toms (2010) proposed a set of attributes of usability, aesthetics, focused attention,

involvement, novelty, and endurability to characterise individual engagement. This study deems these attributes suitable for its purpose, as they encompass a spectrum of users' needs, goals, emotions, actions, and thoughts concerning the visual presentation and organization of the experience. We also explored how these engagement attributes, viewed from a distinct perspective, may contribute to older adult's intention to use VR spaces in various wellbeing activities, such as establishing social interactions. However, the study posits that usability, while acknowledged in O'Brien and Toms' framework, does not necessarily constitute a central component of engagement. Rather, it asserts that individuals' attitudes play a key role in driving users' willingness to participate in the activity and, consequently, in forming the intention to use the technology. This rational is explained in the form of a research model.

From an endurability perspective, users' post-engagement experience has been used to reflect their desire to remember, revisit, or continue an experience perceived as valuable, enjoyable, or meaningful. This variable has been widely linked to individual attachment to the experience, in such a way that positive and memorable experiences are perceived to create lasting impressions that motivate individuals to engage again. According to Read et al. (2002), people are more likely to retain and recall positive experiences, thereby increasing the likelihood of re-engagement. In addition, the concept of endurability has been used by other studies to explain users' willingness to recommend an experience to others and to a sense of self-fulfilment a person attain when completing a task (Jung and Lee 2016). Other researchers like O'Brien and Toms (2008) treated endurability as an outcome of experiences in which users encountered novelty or received incentives. The authors reported that system interactivity plays a role in shaping one's perception of endurability. These insights are particularly relevant for VR, where immersive properties can amplify sensory, emotional, and cognitive involvement. In the context of the present study, endurability is considered a key mediator linking engagement-related attributes (such as aesthetics and involvement) to older adults' intention to use VR for wellbeing. This rationale stems from the assumption that VR experiences can evoke strong feelings of presence and emotional resonance; the extent to which these experiences are perceived as memorable, meaningful, and worth repeating is likely to influence whether older adults decide to adopt the technology beyond initial exposure. This understanding is further explained in the following subsections.

4.1 Individual engagement with VR

The relationship between individual engagement and intention to use VR is examined in this work from different angles in an attempt to provide a holistic understanding for future adaptation and development. According to Aldowah et al. (2025), individual engagement is shaped by the level of involvement a person experiences, which drives users' interests and interactions with tasks/activities. Zhang and Wang (2023) linked design aesthetics and perceptions of technology to cultural factors. In addition, Vazquez et al. (2021) reported that aesthetics influence relational experiences, which in turn drive flow and interactive behaviour. Aesthetics may also affect users' evaluation of the environment (Koranteng et al. 2021). The association between environmental aesthetics and social interaction has been widely explored in various contexts, including non-technological settings (Galindo and Rodríguez 2000). Based on this, we posit that aesthetic elements of the experience such as illustrations, storyline, lighting, and avatars can significantly contribute to older adults' perceived success in a task and their intention to use a service or system in the future. Therefore, this study proposes that:

H1 *Aesthetics influence older adults' endurability towards VR.*

H2 *Aesthetics influence older adults' intention to use VR.*

Novelty is the degree of newness (Miettinen 2006). Terms like curiosity, realism, immersion, and distinctiveness are commonly used in the literature to articulate this concept. Talukdar and Yu (2021) assert that the novelty of immersive VR can significantly enhance user satisfaction with the overall experience. Numerous studies have examined why online users perceive an experience as novel. Yim et al. (2017) for instance, attribute this perception to heightened vividness and interactivity when visualising an object. This leads us to assume that users experiencing lower levels of vividness and interactivity in VR may struggle to perceive novelty and excitement. Consequently, as the uniqueness of the experience diminishes, maintaining high levels of engagement becomes important to provide substantial variation within the environment (Haugtvedt et al. 1994). When the stimulus fails to offer such variation, attitudinal decay becomes likely, influencing the user's intention to use the technology in the future (Liu et al. 2023). This proposition has led scholars, including Hopp and Gangadharbatla (2016), to posit a link between novelty and willingness to continue a task. From a social perspective, it is anticipated that immersive VR stimuli can instigate positive changes in users' behaviour. Building upon research that associates novelty with behaviour, we hypothesise that:

H3 *Novelty influences older adults' endurability towards VR.*

H4 *Novelty influences older adults' intention to use VR.*

The literature also highlights the role of users' involvement when interacting with online platforms. O'Brien and Toms (2008) investigated felt involvement, considering the enjoyment users experienced during interaction and their level of immersion. From the perspective of flow theory, previous researchers have examined the connection between users' ability to overcome specific challenges and their engagement in the task. This conceptualisation has been adapted by prior studies to shape engagement in computer-mediated environments (Takatalo et al. 2015). We anticipate that an optimal state of flow occurs in VR due to the interplay of cognitions and emotions (Lazarus 1991) exhibited while navigating a virtual space. Users' flow experience has been assessed based on the quality of their interactions to overcome task challenges, the skills they possess to meet those challenges, and their perceptions of control (Hoffman and Novak 2009; O'Brien and Toms 2008). This experience is likely to shape perceptions of the virtual environment and, consequently, behaviour. Building on this understanding, we hypothesise that if an individual experiences felt involvement, it is likely to drive behaviour and perceived success in a task. Thus:

H5 *Felt involvement influences older adults' endurability towards VR.*

H6 *Felt involvement influences older adults' intention to use VR.*

Focused attention has been characterised as a key driver of individual engagement (Wang and Sun 2023). It is also used to describe users' state of flow, accompanied by a sense of pleasure (Khoshnoud et al. 2020), awareness, and sense of time (Nakamura and Csikszentmihalyi 2002). In a VR space, focused attention can contribute significantly to the interaction experience and actual behavioural outcomes (Alalwan et al. 2020). In an avatar-mediated environment, Vasalou et al. (2007) reported that avatars can influence users' self-focus and drive online behaviour. Based on these assertions, this study hypothesises the following:

H7 *Focused attention influences older adults' endurability towards VR.*

H8 *Focused attention influences older adults' intention to use VR.*

4.2 Intention to use VR

Behavioural intention to use technology has been extensively explored by scholars across various disciplines. Numerous conceptual frameworks and models have been proposed to enhance understanding of how specific technological characteristics shape individual attitudes towards technology (e.g., Al-Samarraie et al. 2018; Baanqud et al. 2020; Ghazal et al. 2018; Ma 2022). For example, Okoro et al. (2023) and Tsai et al. (2021) investigated how immersive experiences influence users' intention. In this study, we anticipate that the experience offered by VR can directly affect an individual's intention to use the technology for wellbeing. However, there is limited evidence on the role of engagement shaped by VR characteristics in influencing willingness to use it for various wellbeing activities. Previous studies have identified this willingness as an individual's sense of endurability, representing perceived success in a task and the intention to use an application in the future or recommend it to others. O'Brien and Toms (2010) described endurability as a factor combining elements of the experience that sustain engagement in the task. This assumption underpins our proposition of a direct relationship between perceived endurability and intention to use VR. Based on these considerations, the following hypotheses were developed:

H9 *Endurability influence older adults' intention to use VR.*

The above-mentioned relationships were consolidated into a single research model (see Fig. 1), in which endurability mediates the relationship between aesthetics, novelty, felt involvement, focused attention, and intention to use the technology. It is anticipated that this research model will pave the way for new avenues of inquiry, enhancing our understanding of VR's role in stimulating older adults' engagement and their intention to use immersive spaces for wellbeing.

5 Method

The objective of this study was to examine how older adults' engagement with VR technology can drive their intention to use it for various wellbeing activities. Specifically, we developed a research model (see Fig. 2) to understand the effect coefficients between the latent variables of individual engagement and usage behaviour. The exogenous latent variables in this study comprise aesthetics, novelty, felt involvement, and focused attention, while the endogenous latent variables include endurability and intention to use VR. Partial least squares structural equation modelling (PLS-SEM) was employed to validate the associations

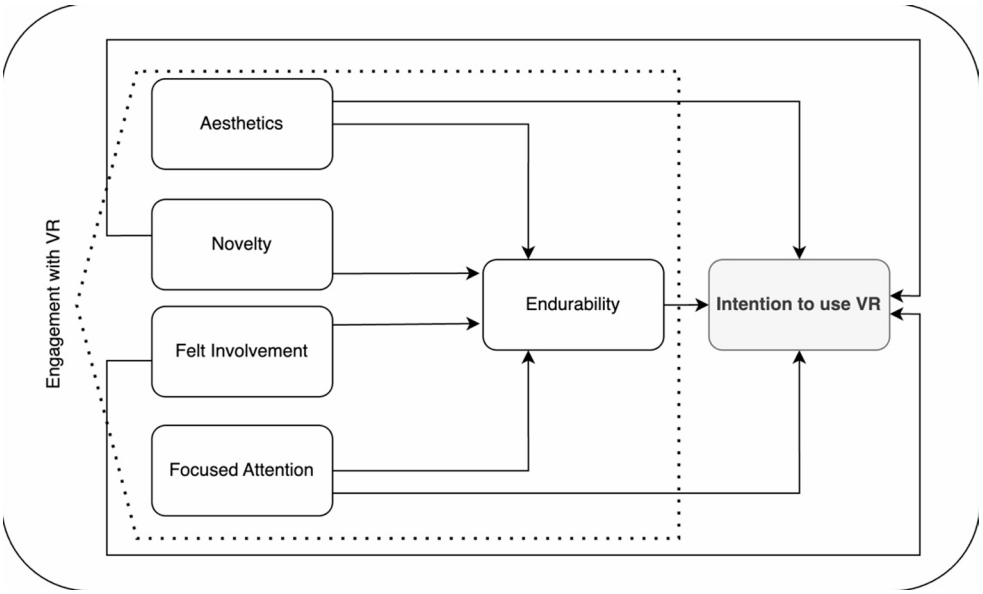

Fig. 1 Proposed research model

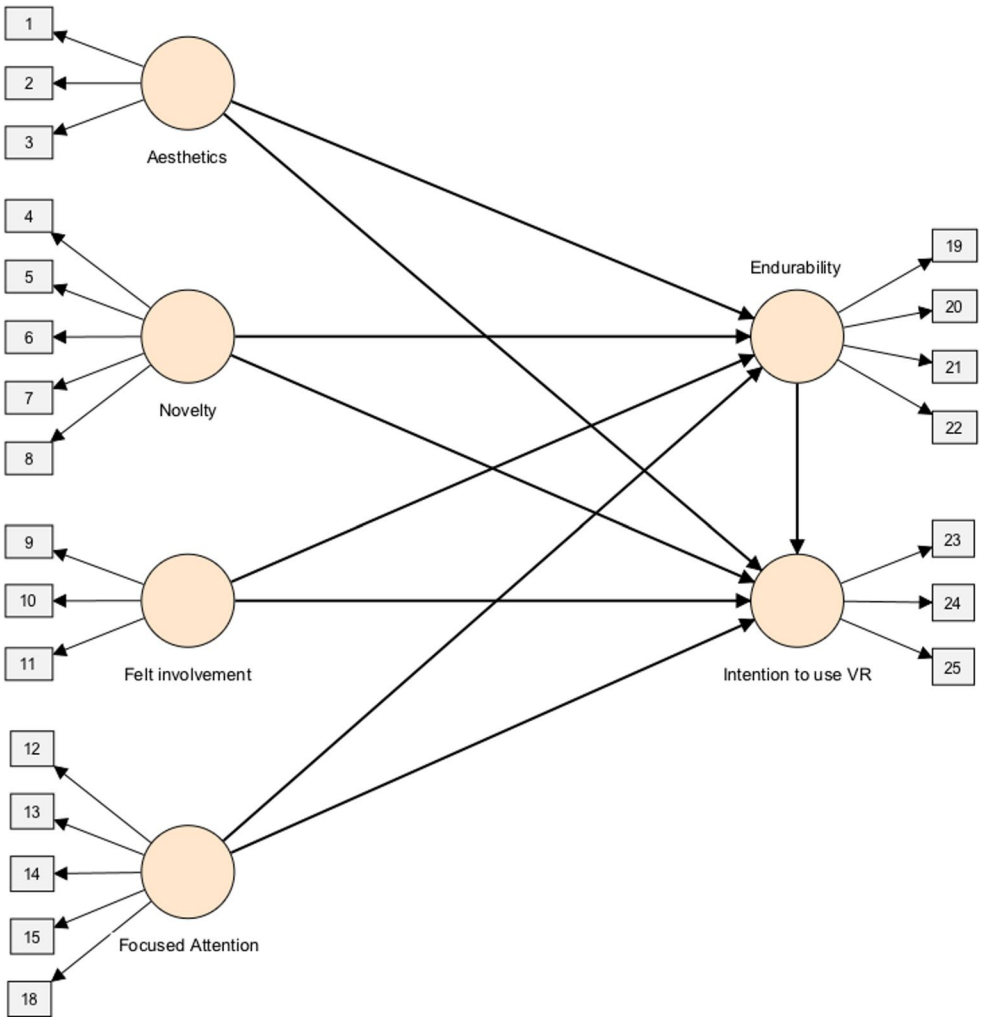

Fig. 2 The PLS-SEM model of this study

Table 1 Instrument used in this study

Construct	Items	Order	Source
Aesthetics	The design of the VR screen (e.g., color and menu) is attractive	Q1	Toufani et al. (2017)
	The content on the VR screen appears professionally designed	Q2	
	VR screen components (e.g., icons and compositions) are well-designed	Q3	
Novelty	VR makes me think about social interaction in a different way	Q4	Tokunaga (2012)
	Interacting with others in VR is new to me	Q5	
	VR introduce a novel perspective to my views about immersive social interaction	Q6	
	Interacting with others in VR satisfy my sense of curiosity	Q7	
	VR make me feel like I'm exploring new worlds	Q8	
Felt involvement	I become really drawn into VR communication with others	Q9	O'Brien and Toms (2010)
	I feel involved in the VR experience	Q10	
	The VR experience is fun	Q11	
Focused attention	I forget about my immediate surroundings while interacting with others in VR	Q12	O'Brien and Toms (2010)
	I become so involved in my VR experience that I ignore everything around me	Q13	
	I lose myself in the VR experience	Q14	
	My involvement in the VR experience makes me lose track of time	Q15	
	I block out things around me when I interact with others in VR	Q16	
	When I interact with others in VR, I lose track of this world around me	Q17	
	The time I spend interacting with others in VR slip away	Q18	
Endurability	Interacting with other in VR is worthwhile	Q19	O'Brien and Toms (2010)
	I consider my VR interaction experience a success	Q20	
	My interaction experience with others in VR work out the way I plan	Q21	
	My interaction experience in VR is rewarding	Q22	
Intention to use VR	I intend to continue using VR in the future	Q23	Davis (1989)
	I will always try to use VR spaces for my wellbeing	Q24	
	I plan to continue taking part in various wellbeing activities in VR	Q25	

between these latent variables. All latent variables in the proposed model were reflective.

5.1 Instrument

This study used an online questionnaire to collect older adults' perceptions of VR from engagement and usage behaviour perspectives. The questionnaire comprised three sections. The first section provided an information sheet outlining the study purpose and procedures, followed by a consent statement allowing the use of anonymous responses for analysis and publication. The second section contained demographic questions such as age, gender, prior VR experience, and wellbeing-related activities. The third section presented the questionnaire items, which were adapted from previous studies with minor wording adjustments. Table 1 lists the final items used to represent each latent variable in this study. All constructs were operationalised using a Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). To determine the content validity of the adapted items in terms of relevance, importance, and clarity for the context of older adults, we followed the recommendations of Polit and Beck (2006). This process involved calculating the proportion of experts (one from social sciences and two from psychology) who rated each item on a four-point Likert-type scale, divided by the total number of experts. The scale ranged from 1 (not relevant, clear, important, or appropriate) to 4 (highly relevant, clear, important, or appropriate). Experts were also invited to suggest alternative wording for any items that appeared unclear or open to multiple interpretations. Scale validity was assessed by averaging the item validity scores across all items, with values above 0.80 considered acceptable. Minor improvements and adaptations were suggested by the experts to ensure closer alignment with the study context. As all adapted items had previously been widely validated in various contexts, a pilot test was deemed unnecessary.

Prior to beginning the questionnaire, all respondents were presented with an embedded consent statement explaining the purpose of the study, the voluntary nature of participation, and the anonymised handling of all responses. Only those who provided their consent were able to proceed to the survey page. Data were handled in accordance with institutional data protection requirements and GDPR principles, ensuring that all information was stored securely and used solely for the purposes of academic research.

5.2 Sample and procedure

The sample for this study comprised 135 older adults who had previously taken part in social experiments with VR. Respondents were recruited from various social gatherings,

events, and online channels hosting VR-related activities aimed at promoting wellbeing. The type of VR technology focused mainly on immersive VR, which refers to computer-generated, visually rich experiences delivered through a head-mounted display to create a powerful sense of immersion. Organisers of these events and organisations were approached to help distribute the questionnaire to older adults who had participated in their VR wellbeing activities. These activities included meeting people in a VR space using basic navigation and interaction elements, exploring heritage sites in a VR group, discussing documentaries in VR, taking part in social game scenarios, and engaging in health awareness activities. After obtaining permission from these organisations, an online questionnaire was distributed by the organisers to their participant pools. The questionnaire was designed to maintain respondent anonymity by excluding questions that could reveal personal identity. However, certain demographic details, such as age and gender, were collected to provide insights into the respondents' background. The collected data were processed and prepared for analysis using SmartPLS software.

The demographic characteristics, in terms of gender, indicated that the majority of respondents were male (68%), while the remaining 32% were female. Regarding VR usage, 72% of respondents reported using VR between one and five times in various community activities, while 28% reported using VR more than five times. VR engagement involved older adults taking part in single or multiple social activities, including social interaction experiments (37%), establishing communication with others (20%), mediating with other virtual members (18%), virtual hangouts (15%), and community or health-related collaborative activities (10%). These findings suggest that the intention to use VR varied among older adults, reflecting the diversity of community engagement initiatives and aligning with the study's objectives.

5.3 Common method bias

Concerns about potential bias were addressed in this study due to the use of a single data collection method (questionnaire) at a specific point in time (July 2022–Nov 2023). The variance inflation factor (VIF) was calculated for each item, and the maximum value was 3.31, well below the threshold of 10, indicating no multicollinearity issues. In addition, a marker variable procedure was conducted as a supplementary analysis. It was anticipated that the risk of common method bias in this study was minimal based on absence of multicollinearity and the results of the marker variable procedure.

6 Results

Based on the PLS-SEM analysis, Fig. 3 illustrates the relationships between the variables in the research model. Arrows from the independent latent variables to the dependent latent variables represent these relationships. The direct effects of the independent variables (aesthetics, novelty, felt involvement, and focused attention) on endurability and intention to use VR were examined, revealing a strong effect of aesthetics on both endurability (0.345) and intention to use VR (0.247). Moderate effects were observed in the structural model, with coefficients of 0.240 between felt involvement and endurability and 0.233 between novelty and endurability. The mediating effect of endurability on the relationship between aesthetics, novelty, felt involvement, and intention to use VR was significant, with a strong coefficient of 0.690. Focused attention's effect on endurability was significant (0.204), but not on intention to use VR. Meanwhile, the relationships of both novelty and felt involvement with older adults' intention to use VR were not statistically significant. The combined effect of VR aesthetics, novelty, felt involvement, and focused attention explained 69% of the variance in endurability ($R^2 = 0.690$). We also found that the combined effect of the independent variables and endurability explained 60% of the variance in older adults' intention to use VR ($R^2 = 0.597$). The evaluation of the measurement model, involving six structural equations, included assessing internal consistency, convergent validity, and discriminant validity. Internal consistency was measured using Cronbach's alpha and composite reliability, calculated with SmartPLS software.

We calculated the average variance extracted (AVE) to estimate the convergent validity of the structural model. Both the Fornell–Larcker criterion and the heterotrait–monotrait ratio (HTMT) were used to assess discriminant validity. Internal consistency and reliability of the proposed model were measured using Cronbach's alpha, along with the degree of correlation between the independent and dependent variables. Standard considerations for setting and reporting PLS-SEM results were based on the recommendations of Ringle et al. (2022). The Cronbach's alpha values for all variables exceeded the recommended threshold of 0.70 (e.g., aesthetics: 0.888; novelty: 0.937; felt involvement: 0.879; focused attention: 0.929; endurability: 0.886; intention to use VR: 0.927). Composite reliability values for all variables were also above the recommended threshold of 0.70. Spearman's rank correlation coefficient (rho) was used to examine correlations, with values ranging from −1 to +1 (closer to +1 indicating a perfect positive correlation). Based on the results in Table 2, all variables achieved positive correlations. Convergent validity was confirmed by

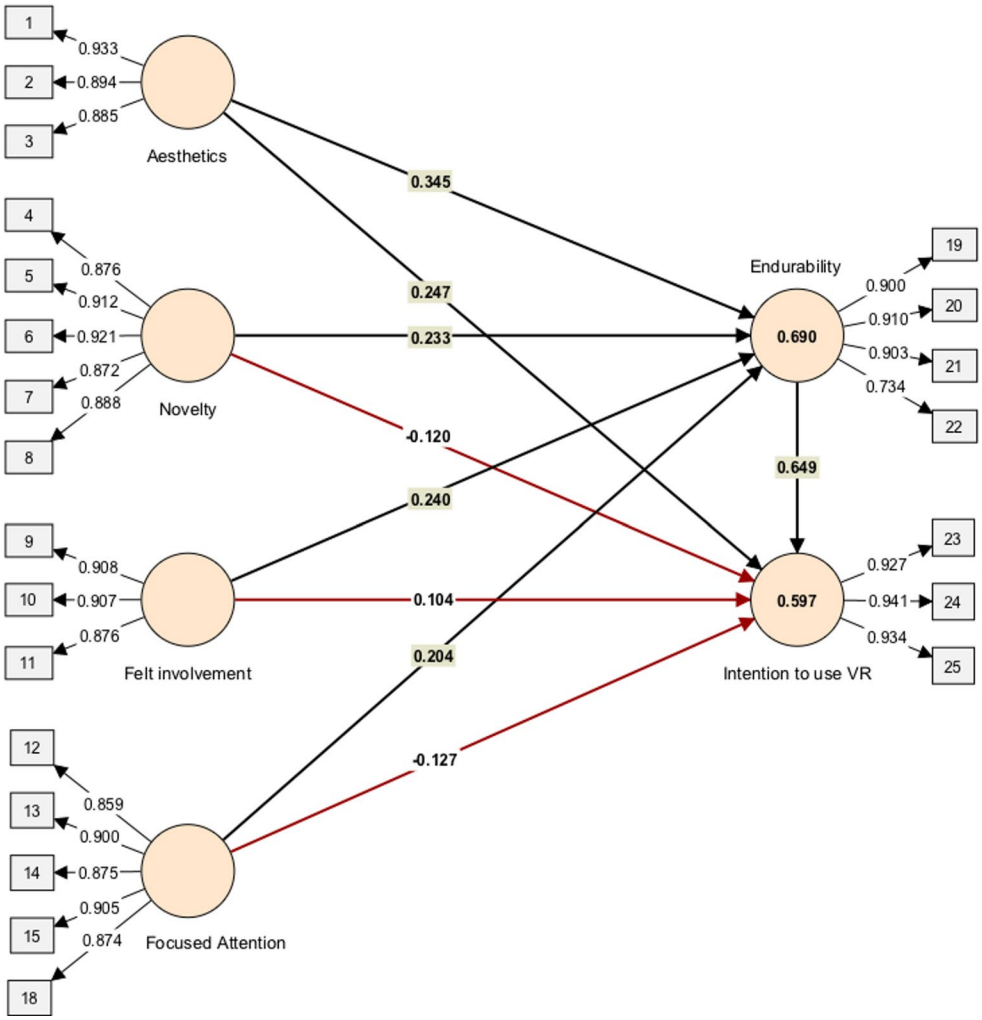

Fig. 3 PLS-SEM results of the conceptual model with coefficients and external loadings of variables

Table 2 Assessment of internal consistency and convergent validity within the evaluated model

Variables	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	AVE
Aesthetics	0.888	0.894	0.931	0.818
Endurability	0.886	0.905	0.922	0.748
Felt involvement	0.879	0.883	0.925	0.805
Focused attention	0.929	0.933	0.946	0.779
Intention to use VR	0.927	0.927	0.954	0.872
Novelty	0.937	0.943	0.952	0.799

AVE values exceeding the minimum threshold of 0.50, with all variables ranging from 0.748 to 0.872.

Table 3 presents the discriminant validity of the proposed model, calculated using the Fornell–Larcker criterion. This involves comparing the square root of the AVE with the correlations among latent variables, ensuring that the square root of each variable is greater than its correlations with other variables. The results indicate that Fornell–Larcker criterion values for each variable were higher than the correlations with other variables. Additionally, the HTMT correlation ratio was used for a comprehensive assessment of discriminant validity, where values closer to 1 suggest a

Table 3 Assment of discriminant validity (Fornell–Larcker criterion)ses

	Aesthetics	Endurability	Felt involvement	Focused attention	Intention	Novelty
Aesthetics	**0.904**					
Endurability	0.726	**0.865**				
Felt involvement	0.600	0.670	**0.897**			
Focused attention	0.492	0.612	0.504	**0.883**		
Intention	0.647	0.741	0.561	0.383	**0.934**	
Novelty	0.590	0.663	0.515	0.505	0.445	**0.894**

The bold values represent the greatest AVE value for each construct in correlation with other construct

Table 4 Application of the HTMT report to assess discriminant validity

	Aesthetics	Endurability	Felt involvement	Focused attention	Intention	Novelty
Aesthetics						
Endurability	0.811					
Felt involvement	0.677	0.761				
Focused attention	0.538	0.674	0.551			
Intention	0.711	0.802	0.619	0.408		
Novelty	0.644	0.728	0.567	0.535	0.474	

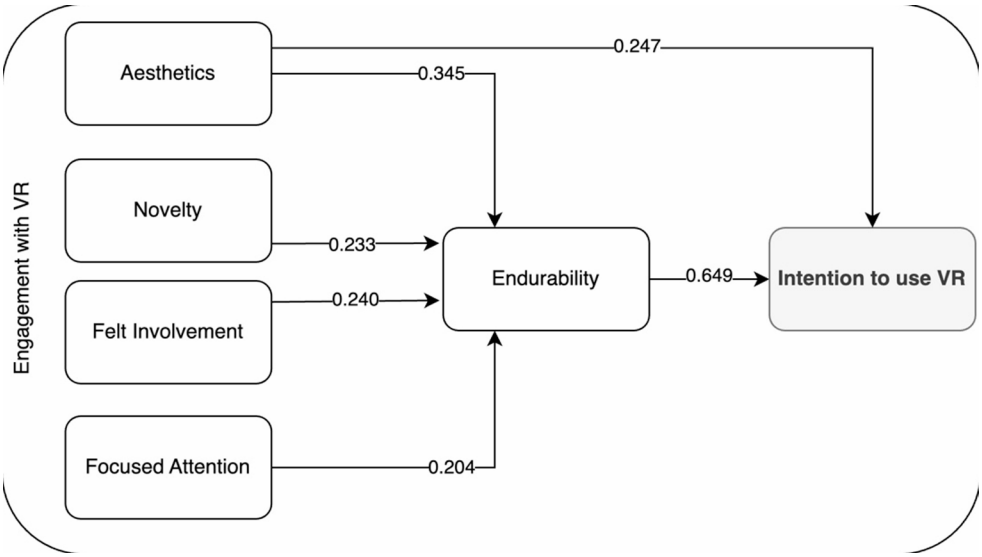

Fig. 4 Final validated model

lack of discriminant validity. The HTMT results, shown in Table 4, were below the maximum threshold of 0.90, ranging from 0.408 to 0.811. Both the Fornell–Larcker criterion and HTMT results confirm that the proposed model demonstrates acceptable discriminant validity.

We performed bootstrapping to assess the model assumptions, creating subsamples with observations randomly drawn from the original dataset (less than 500 samples) using PLS-SEM software. The estimates of parameters from the structural model in these subsamples were utilized for statistical reports, presenting t-test values and asymptotic significance (p-values). Among the nine hypotheses, six were validated ($p<0.05$): H1, H2, H3, H5, H7, and H9, all with asymptotic significance ($p<0.05$). The results confirmed the assumed mediating effect of endurability on the relationship between VR experience (aesthetics, novelty, felt involvement, and focused attention) and intention to use VR. Aesthetics showed significant effects on endurability (t-value = 4.627) and intention to use VR (t-value = 2.360) among senior communities. In addition, novelty, felt involvement, and focused attention exhibited direct impacts on endurability with t-values of 3.607, 3.335, and 2.711, respectively. These variables also mediated the relationship between endurability and intention to use VR, with a t-value of 5.919, the highest in the proposed model.

However, other hypotheses (e.g., H4, H6, and H8) were not significant, which lead us to suggest that variables like novelty, felt involvement, and focused attention had no direct influence on older adults' intention to use VR. This result, to some extent, contradicts some previous studies reporting a statistically insignificant relationship between focused attention and endurability and intention in other contexts. Figure 4 shows the final validated model with significant relationships (Table 5).

7 Discussion

In this study, six out of the nine hypotheses were statistically significant with correlations supporting H1 (effect coefficient of 0.345), H2 (0.247), H3 (0.233), H5 (0.240), H7 (0.204), and H9 (highest effect coefficient of 0.649). The results provide new insights on how older adults perceive the use of VR in wellbeing settings. The study also offers new theoretical and empirical perspectives on how VR characteristics/antecedents can drive individuals' engagement with the task, thus shaping their usage intention. The mediating effect of endurability on the relationship between VR antecedents and intention to use (H9) was significant. This finding provides new insight into the literature, as the association between VR engagement characteristics and older

Table 5 Values associated with the asymptotic significance p and t-test for the structural model hypotheses

Path coefficients	Original sample (O)	Sample mean (M)	STD	t statistics	*p*-value
Aesthetics -> Endurability	0.345	0.349	0.074	4.627	0.000
Aesthetics -> Intention	0.247	0.238	0.105	2.360	0.018
Endurability -> Intention	0.649	0.661	0.110	5.919	0.000
Felt involvement -> Endurability	0.240	0.240	0.072	3.335	0.001
Felt involvement -> Intention	0.104	0.100	0.087	1.200	0.230
Focused Attention -> Endurability	0.204	0.204	0.075	2.711	0.007
Focused Attention -> Intention	− 0.127	− 0.125	0.096	1.329	0.184
Novelty -> Endurability	0.233	0.229	0.065	3.607	0.000
Novelty -> Intention	− 0.120	− 0.120	0.076	1.581	0.114

adults' intention to use VR through perceived endurability has not been widely explored or reported.

The results also revealed that endurability is collectively influenced by VR aesthetics, novelty, felt involvement, and focused attention in a wellbeing setting (H1, H3, H5, and H7). This finding appears to have received comparatively less attention in previous studies, which can be possibly associated with the assumption that older adults are primarily motivated by the improvement of motor, cognitive, and perceptual experiences (Wang et al. 2020).

Our finding regarding the relationship between aesthetics and focused attention on endurability appears, to some extent, to both support and challenge previous studies. For example, Han et al. (2023) asserted that an improved perceived aesthetic appeal and focused attention facilitate older adults' engagement with online discussion platforms. It is conceivable that older adults' perception of aesthetics might influence their sense of endurability, which might encourage them to consider adopting VR for establishing social communication. In addition, the reported impact of VR aesthetics on users' intention to use the technology for wellbeing aligns with a variety of previous findings (e.g., Chaouali and Souiden 2023; Watfa and Akili 2023) exploring VR use in diverse contexts such as marketing, healthcare, entertainment, and education. Despite the direct and positive effect of aesthetics on endurability and intention to use VR, the impact of focused attention on older adults' intention to use VR was not documented in this study. This finding contrasts with previous research reporting significant relationships between the amount of attention a user spends on a task and their perceived intention to use VR (e.g., Katika et al. 2022; Masrek and Samadi 2017). From our perspective, it is possible that in a short and structured VR sessions, older adults may prioritise immediate enjoyment, comfort, and emotional resonance over cognitive attention to task detail. It can be also said that older adults with limited prior VR exposure may find the immersive environment inherently attention-demanding, which as a result might reduce variability in attentional responses and diminishing its predictive value. Our literature review revealed limited evidence regarding the relationship between focused attention and intention to use VR, thus demanding further research to confirm the results of this study. Meanwhile, our finding extends the work of O'Brien and Toms (2010), who mapped the relationships between aesthetics, felt involvement, novelty, focused attention, and endurability by demonstrating the mediating role of the latter in facilitating individuals' intention to use VR.

The results also indicate that both novelty and felt involvement had a significant effect on endurability (H3 and H5). In the context of VR, the literature reveals a lack of studies advancing our understanding of how both the novelty of VR and felt involvement can shape an individual's sense of endurability. The same can be said for their impact on users' intention to use VR. Some studies, such as O'Brien and Toms (2010), suggest that felt involvement has a direct impact on perceived endurability behaviour, potentially unlocking users' intention to use or accept technology. However, the results regarding the impact of VR novelty on endurability appear somewhat novel when compared to other applications and contexts. The findings of this study indicate that older adults' perceived novelty and felt involvement had no effect coefficient on the intention to use VR compared to perceived endurability. Meanwhile, this finding seems to contradict the conclusions of a few previous studies (e.g., Gonçalves et al. 2023; Jain and Yadav 2018; Pujiastuti 2020), which stated that novelty induces curiosity and presents individuals with a unique experience resulting in the final intention. A reason to this might be linked to those most prior studies examined novelty in consumer or entertainment settings, whereas older adults in wellbeing programmes may evaluate VR less in terms of novelty and more in terms of comfort, ease, and emotional connection. In addition, first-time VR users may experience a form of novelty saturation, where the immersive nature of the environment is already overwhelming enough to reduce differentiation in novelty perception. For example Cox and Yetter (2022) asserted that new users with different experience or exposure from those who are familiar with the technology are less likely to become immediately immersed, and therefore, persuaded. This lead us to suggest the importance of developing context-specific models of engagement for older

adult populations rather than importing assumptions from younger or general users. In our opinion, the variation in the type of technology and usage settings weakens support for these relations in VR settings. Therefore, this result should be further validated by future studies.

Regarding the impact of endurability on the intention to use VR, the result was very strong (0.649), according to respondents' experience. This finding appears to be unique, as the association between endurability and the intention to use VR is rarely explored. However, one study validated our result and explained it by providing a rewarding and successful experience to the user, which serves as a predictor of intention (Jain and Yadav 2019). This finding needs more thorough research in the future. Few studies have investigated the association between engagement variables and the intention to use VR in a wellbeing context. Hence, it is advised that cross-cultural and longitudinal studies could be conducted to potentially offer new insights into VR use among older adults for wellbeing.

8 Theoretical and practical implications

The findings of this study aim to provide new insights into the application of VR by proposing a research model that examines the relationships between users' engagement and intention to use in a wellbeing context. For the first time, this study explores the role of VR engagement antecedents of aesthetics, novelty, felt involvement, focused attention, and endurability in promoting older adults' use of VR. The theoretical contributions include highlighting the mediating effect of endurability on the under-examined relationship between aesthetics, novelty, felt involvement, focused attention, and intention to use VR in wellbeing settings. One distinctive aspect of the study is the influence of aesthetics and endurability on older adults' intention to use VR. Another is the strong impact of endurability on users' intention to use VR. These findings add to the current body of knowledge on individuals' interaction with VR (e.g., Carroll et al. 2021; Deighan et al. 2023; Pretsch et al. 2020) and how it can shape their sense of engagement and future use of the technology. The study also offers new perspectives on the previously unobserved impact of novelty, felt involvement, and focused attention on older adults' intention to use VR.

In addition to the theoretical aspects of this study, the findings provide practical implications for decision-makers, VR practitioners, wellbeing specialists, researchers, and wellbeing communities and organisations worldwide. Supporting the wellbeing of older adults must remain an ongoing concern for both decision-makers and technologists. According to the results, particular attention should be paid to balancing the aesthetic appeal of VR environments with the endurability of older adults when completing immersive tasks. It is also recommended that VR designers and developers prioritise aesthetic elements in relation to knowledge, skill base, and users' abilities to establish effective social interactions. The importance of endurability in this line of research can be further strengthened by offering a rewarding experience that encourages effective use of VR technology. Less emphasis may be placed on novelty, felt involvement, and focused attention when facilitating older adults' interaction with others in VR. There is a strong need to ensure that effective design measures are in place when engaging older adults in immersive experiences. These measures should be aligned with the direct needs of the older adult population, taking into account the nature of the activity and the interaction settings.

9 Limitations and future works

This study has several limitations that future research could address. First, the sample was drawn from various wellbeing and social communities without considering the cultural background of older adults or differences in their prior experience with immersive VR environments. These activities included social VR interactions, group exploration tasks, virtual discussions, and recreational VR scenarios. While this heterogeneity reflected real-world usage patterns and was appropriate for the exploratory nature of the study, variability in VR familiarity may still influence perceptions of engagement and intention to use the technology. Second, the study focused exclusively on VR applications and did not include other technologies such as augmented or mixed reality, which differ in functionality and usage scenarios and may therefore influence the results. Third, the research relied on quantitative measures to estimate older adults' engagement with VR and its impact on their intention to use the technology in a wellbeing setting. Although a quantitative design was suitable for modelling relationships between variables, alternative methods of data collection could have provided deeper insights into why older adults perceived novelty, felt involvement, and focused attention as having no impact on their intention to use VR. Fourth, the absence of attention-check or instructed-response items within the questionnaire is another limitation worth exploring. Although data-quality screening was used to mitigate the risk of inattentive responding, future research should incorporate explicit attention checks to ensure greater consistency and reliability in self-report data. In addition, the absence of a formal measure of social desirability bias might have influenced older adults to provide favourable or socially acceptable responses, and despite the use of anonymity and self-completion procedures to minimise

this risk, it is suggested that future studies should consider incorporating validated social desirability scales to assess and control for this potential source of bias. Fifth, the study did not examine the moderating effect of demographic characteristics (e.g., gender and type of use) on the relationships between the latent variables in the proposed model. Sixth, although the specific VR engagement antecedents used in this study were sufficient to explain older adults' engagement with VR, other aspects of users' engagement, such as emotional, behavioural, and cognitive, were not fully considered in this work. In addition, using only three items to measure the aesthetics of VR represents a limitation, as it may not fully capture the multidimensional nature of aesthetic experience.

Based on these limitations, it is suggested that future studies pay special attention to widening the sample selection pool to further confirm and validate the results of this study. In addition, future studies might also consider the moderating effect of immersive technologies on users' engagement and usage intention among the older adult population. This includes employing qualitative methods to further understand how specific technological characteristics drive older adults' use of the technology in wellbeing settings. It is also recommended that future work concentrate on the moderating effect of certain cultural and demographic variables in influencing older adults' intention to adopt and use immersive technologies. Furthermore, the examination of individuals' engagement with technology can be approached from other cognitive, emotional, and behavioural angles, which might shed new insights into the role of VR in facilitating older adults' wellbeing and social interaction.

10 Conclusion

This study proposes a novel model to explain older adults' engagement with VR based on aesthetics, novelty, felt involvement, focused attention, and endurability. Users' intention to use VR, rooted in their engagement, was examined and contextualised within the sphere of wellbeing. The results reveal that endurability significantly mediates the relationship between the independent variables and the intention of older adults to use VR. The robust impact of endurability on users' intention to use VR underscores its pivotal role in influencing an individual's decision. These findings present various theoretical implications relevant to promoting VR use among older adults for wellbeing. The study also offers practical insights into the essential engagement antecedents for maintaining positive endurability among VR users.

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Data availability Data from this study can be shared upon request from the corresponding author.

Declarations

Conflict of interest The authors declare no competing interests.

Consent to participate A consent form was distributed and obtained from all respondents.

References

Adorno TW (1997) Aesthetic theory. A&C Black

Afifi T, Collins N, Rand K, Otmar C, Mazur A, Dunbar NE, Fujiwara K, Harrison K, Logsdon R (2023) Using virtual reality to improve the quality of life of older adults with cognitive impairments and their family members who live at a distance. Health Commun 38(9):1904–1915

Afroj S, Bashir T, Vishnu P, Khan KA (2025) Digital inclusion and economic participation of the elderly: challenges and strategies. Perspectives on the economics of aging. IGI Global Scientific Publishing, pp 49–78

Al-Samarraie H, Teng BK, Alzahrani AI, Alalwan N (2018) E-learning continuance satisfaction in higher education: a unified perspective from instructors and students. Stud High Educ 43(11):2003–2019

Alalwan N, Cheng L, Al-Samarraie H, Yousef R, Alzahrani AI, Sarsam SM (2020) Challenges and prospects of virtual reality and augmented reality utilization among primary school teachers: A developing country perspective. Stud Edu Eva 66:100876

Aldowah HA, Al-Samarraie H, Noman F (2025) Students' online engagement in higher education: a DEMATEL study. J Computers Educ 13:31–86

Baanqud NS, Al-Samarraie H, Alzahrani AI, Alfarraj O (2020) Engagement in cloud-supported collaborative learning and student knowledge construction: a modeling study. Int J Educational Technol High Educ 17(1):1–23

Balki E, Hayes N, Holland C (2022) Effectiveness of technology interventions in addressing social isolation, connectedness, and

loneliness in older adults: systematic umbrella review. JMIR Aging 5(4):e40125
Bonesso S, Gerli F, Pizzi C, Cortellazzo L (2018) Students' entrepreneurial intentions: the role of prior learning experiences and emotional, social, and cognitive competencies. J Small Bus Manage 56:215–242
Carroll J, Hopper L, Farrelly AM, Lombard-Vance R, Bamidis PD, Konstantinidis EI (2021) A scoping review of augmented/virtual reality health and wellbeing interventions for older adults: redefining immersive virtual reality. Front Virtual Real 2:655338
Chan SHM, Qiu L, Esposito G, Mai KP, Tam K-P, Cui J (2023) Nature in virtual reality improves mood and reduces stress: evidence from young adults and senior citizens. Virtual Reality 27(4):3285–3300
Chaouali W, Souiden N (2023) Design aesthetics in predominantly-utilitarian versus predominantly-hedonic services: the what is beautiful is good and Ulysses effects. J Mark Theory Pract 31(4):502–515
Chapman PM (1997) Models of engagement: intrinsically motivated interaction with multimedia learning software. University of Waterloo]
Chatterjee K, Buchanan A, Cottrell K, Hughes S, Day TW, John NW (2022) Immersive virtual reality for the cognitive rehabilitation of stroke survivors. IEEE Trans Neural Syst Rehabil Eng 30:719–728
Clemente D, Romano L, Russo C, Carrus G, Panno A (2024a) 3D built virtual Arctic environment increase Vigor through connectedness in older people. Sci Rep 14(1):23432
Clemente D, Romano L, Zamboni E, Carrus G, Panno A (2024b) Forest therapy using virtual reality in the older population: a systematic review. Front Psychol 14:1323758
Contreras-Espinosa RS, Gomez JLE (2020) How could the use of game elements help students' affective and cognitive engagement during game play? J Inform Technol Res (JITR) 13(1):17–29
Corregidor-Sánchez A-I, Segura-Fragoso A, Criado-Álvarez J-J, Rodríguez-Hernández M, Mohedano-Moriano A, Polonio-López B (2020) Effectiveness of virtual reality systems to improve the activities of daily life in older people. Int J Environ Res Public Health 17(17):6283
Cox M, Yetter C (2022) This is so cool: A phenomenological study on virtual reality novelty. J Commun Technol 5(1):84–103
Czikszentmihalyi M (1990) Flow: the psychology of optimal experience. Harper & Row, In: New York
Daher W, Sabbah K, Abuzant M (2021) Affective engagement of higher education students in an online course. Emerg Sci J 5(4):545–558
Davis FD (1989) Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly 13:319–340
De Bruin ED, Schoene D, Pichierri G, Smith ST (2010) Use of virtual reality technique for the training of motor control in the elderly: some theoretical considerations. Zeitschrift für Gerontologie Und Geriatrie 43(4):229–234
De Vreede T, Nguyen C, De Vreede G-J, Boughzala I, Oh O, Reiter-Palmon R (2013) A theoretical model of user engagement in crowdsourcing. In: Collaboration and technology: 19th International conference, CRIWG 2013, Wellington, New Zealand, October 30–November 1, 2013, Proceedings 19
Deighan MT, Ayobi A, O'Kane AA (2023) Social virtual reality as a mental health tool: how people use VRChat to support social connectedness and wellbeing. Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems
Donato C (2025) Aesthetic influence on consumer behavior. Eco-Label visual design and sustainability: the impact on consumer perceptions and market trends. Springer, pp 39–73
El-AbdeenMohamed MZ, Noshy Abd D, Mohamed EL-A, H., Hassan A, Elhameed S (2025) Effect of a home-based physical rehabilitation program via virtual reality on the functional outcomes of frail older adults: a quasi-experimental study. Sci Rep 15(1):4180
Eldenfria A, Al-Samarraie H (2019) Towards an online continuous adaptation mechanism (OCAM) for enhanced engagement: an EEG study. Int J Human–Computer Interact 35(20):1960–1974
Finnegan DJ, Campbell S (2023) Tackling loneliness and isolation in older adults with virtual reality: how do we move forward? Gerontol Geriatric Med 9:23337214231186204
Finneran CM, Zhang P (2005) Flow in computer-mediated environments: promises and challenges. Commun Association Inform Syst 15(1):4
Galindo MPG, Rodríguez JC (2000) Environmental aesthetics and psychological wellbeing: relationships between preference judgements for urban landscapes and other relevant affective responses. Psychol Spain 4(1):13–27
Georgiou Y, Ioannou A, Ioannou M (2019) Investigating immersion and learning in a low-embodied versus high-embodied digital educational game: lessons learned from an implementation in an authentic school classroom. Multimodal Technol Interact 3(4):68
Ghazal S, Al-Samarraie H, Aldowah H (2018) I am still learning: modeling LMS critical success factors for promoting students' experience and satisfaction in a blended learning environment. IEEE Access 6:77179–77201
Gonçalves G, Meirinhos G, Melo M, Bessa M (2023) Correlational study on novelty factor, immersive tendencies, purchase intention and memory in immersive VR e-commerce applications. Sci Rep 13(1):11407
Han S, Teng AK, Lin S-Y, Demiris G, Zaslavsky O, Chen AT (2023) Examining engagement and usability in an online discussion platform for older adults: findings from pilot studies. CIN: Computers Inf Nurs 41(9):665–672.
Haugtvedt CP, Schumann DW, Schneier WL, Warren WL (1994) Advertising repetition and variation strategies: implications for Understanding attitude strength. J Consum Res 21(1):176–189
Healy D, Flynn A, Conlan O, McSharry J, Walsh J (2022) Older adults' experiences and perceptions of immersive virtual reality: systematic review and thematic synthesis. JMIR Serious Games 10(4):e35802
Hofer M, Hargittai E (2024) Online social engagement, depression, and anxiety among older adults. New Media Soc 26(1):113–130
Hoffman DL, Novak TP (2009) Flow online: lessons learned and future prospects. J Interact Mark 23(1):23–34
Hopp T, Gangadharbatla H (2016) Novelty effects in augmented reality advertising environments: the influence of exposure time and self-efficacy. J Curr Issues Res Advertising 37(2):113–130
Hu M, Han S, Ghorbany S, Zhang K (2024) Healthy aging in place with the aid of smart technologies: A systematic review. Encyclopedia 4(4):1918–1932
Hughes S, Warren-Norton K, Spadafora P, Tsotsos LE (2017) Supporting optimal aging through the innovative use of virtual reality technology. Multimodal Technol Interact 1(4):23
Ichsan MHH, Sik-Lanyi C, Guzsvinecz T (2025) Virtual reality in skill development through user experience and technology advancements. Discover Comput 28(1):1–30
Jain K, Yadav D (2018) The role of website personality and website user engagement on individual's purchase intention. System performance and management analytics. Springer, pp. 347–360
Jain K, Yadav D (2019) The role of website personality and website user engagement on individual's purchase intention. System performance and management analytics. Springer, pp. 347–360
Jo H (2024) Determinants of word-of-mouth in the virtual reality market: A focus on aesthetic attributes and perceived value. Int J Human–Computer Interact 40(24):8590–8606

Juan M-C, Elexpuru J, Dias P, Santos BS, Amorim P (2023) Immersive virtual reality for upper limb rehabilitation: comparing hand and controller interaction. Virtual Reality 27(2):1157–1171
Jung S, Lee S (2016) Developing a model for continuous user engagement in social media. In: Proceedings of the 10th International Conference on Ubiquitous Information Management and Communication
Kalantari S, Xu TB, Mostafavi A, Kim B, Dilanchian A, Lee A, Boot WR, Czaja SJ (2023) Using immersive virtual reality to enhance social interaction among older adults: A cross-site investigation. Innov Aging 7(4):igad031
Kalender Y, Guzmán F (2025) What drives consumers to engage in immersive technologies? A consumer metaverse engagement motivation model. Psychol Mark 42(3):921–950
Kamińska MS, Miller A, Rotter I, Szylińska A, Grochans E (2018) The effectiveness of virtual reality training in reducing the risk of falls among elderly people. Clin Interv Aging 13:2329–2338
Katika T, Karaseitanidis I, Tsiakou D, Makropoulos C, Amditis A (2022) Augmented reality (AR) supporting citizen engagement in circular economy. Circular Econ Sustain 2(3):1077–1104
Kearsley G, Shneiderman B (1998) Engagement theory: A framework for technology-based teaching and learning. Edu Technol 38(5):20–23
Kenyon K, Kinakh V, Harrison J (2023) Social virtual reality helps to reduce feelings of loneliness and social anxiety during the Covid-19 pandemic. Sci Rep 13(1):19282
Khoshnoud S, Igarzábal FA, Wittmann M (2020) Peripheral-physiological and neural correlates of the flow experience while playing video games: A comprehensive review. PeerJ 8:e10520
Koranteng FN, Ham J, Wiafe I (2021) Investigating user perceptions of persuasive design elements that influence perceived credibility. In: International conference on persuasive technology
Lazarus RS (1991) Progress on a cognitive-motivational-relational theory of emotion. Am Psychol 46(8):819
Lee YJ, Ji YG (2025) Effects of visual realism on avatar perception in immersive and non-immersive virtual environments. Int J Human–Comput Interact 41(7):4362–4375
Lee LN, Kim MJ, Hwang WJ (2019) Potential of augmented reality and virtual reality technologies to promote wellbeing in older adults. Appl Sci 9(17):3556
Li Y, Chen D, Deng X (2024) The impact of digital educational games on student's motivation for learning: the mediating effect of learning engagement and the moderating effect of the digital environment. PLoS ONE 19(1):e0294350
Liang H, Li J, Wang Y, Pan J, Zhang Y, Dong X (2023) Metaverse virtual social center for elderly communication in time of social distancing. Virtual Real Intell Hardw 5(1):68–80
Limerick H, Hayden R, Beattie D, Georgiou O, Müller J (2019) User engagement for mid-air haptic interactions with digital signage. In: Proceedings of the 8th ACM international symposium on pervasive displays
Lin CX, Lee C, Lally D, Coughlin JF (2018a) Impact of virtual reality (VR) experience on older adults' well-being. In: International conference on human aspects of it for the aged population
Lin CX, Lee C, Lally D, Coughlin JF (2018b) Impact of virtual reality (VR) experience on older adults' well-being. Human aspects of IT for the aged population. Applications in health, assistance, and entertainment: 4th international conference, ITAP 2018, held as part of HCI international 2018, Las Vegas, NV, USA, July 15–20, 2018, Proceedings, Part II 4
Liu J, Liu Q, Yu S, Ma J, Liu M, Wu L (2023) How do autonomy and learner characteristics combine to influence learners' learning outcomes and cognitive load in virtual reality learning environments? A fuzzy-set qualitative comparative analysis approach. Educ Inform Technol 29(1):77–101
Ma Z (2022) The use of immersive stories to influence college students' attitudes and intentions related to drinking and driving. J Am Coll Health 70(7):2042–2049
Mahmoud AB (2024) Aging in the digital age: public beliefs about the potential of virtual reality (VR) for the aging population. J Macromarketing 45(4):632–647
Masrek MN, Samadi I (2017) User engagement in academic web digital library. Int J Civil Eng Technol 8(9):789–799
Miettinen R (2006) The sources of novelty: A cultural and systemic view of distributed creativity. Creativity Innov Manage 15(2):173–181
Moreira Kares E, Tuomi A, Caiola V, Pillan M, Spallazzo D (2025) Social presence in shared virtual reality experience among older adults. Virtual Reality 29(1):1–14
Nakamura J, Csikszentmihalyi M (2002) The concept of flow. Handb Posit Psychol 89:105
Ng WHD, Ang WHD, Fukahori H, Goh YS, Lim WS, Siah CJR, Seah B, Liaw SY (2024) Virtual reality-based reminiscence therapy for older adults to improve psychological well-being and cognition: a systematic review. J Clin Nurs. https://doi.org/10.1111/jocn.17375
O'Brien HL, Toms EG (2008) What is user engagement? A conceptual framework for defining user engagement with technology. J Am Soc Inform Sci Technol 59(6):938–955
O'Brien HL, Toms EG (2010) The development and evaluation of a survey to measure user engagement. J Am Soc Inform Sci Technol 61(1):50–69
Okoro CS, Nnaji C, Adediran A (2023) Determinants of immersive technology acceptance in the construction industry: management perspective. Eng Constr Architectural Manage 30(7):2645–2668
Pillay SS, Candela P, Croghan IT, Hurt RT, Bonnes SL, Ganesh R, Bauer BA (2024) Leveraging the metaverse for enhanced longevity as a component of health 4.0. Mayo Clinic Proceedings: Digital Health 2(1):139–151
Pizzolante M, Pelowski M, Demmer TR, Bartolotta S, Sarcinella ED, Gaggioli A, Chirico A (2024) Aesthetic experiences and their transformative power: a systematic review. Front Psychol 15:1328449
Polit DF, Beck CT (2006) The content validity index: are you sure you know what's being reported? Critique and recommendations. Res Nurs Health 29(5):489–497
Pretsch J, Pretsch E, Saretzki J, Kraus H, Grossmann G (2020) Improving employee well-being by means of virtual reality–REALEX: an empirical case study. Eur J Econ Bus Stud 6(1):95–105
Pujiastuti EE (2020) Novelty seeking to predict behavior intention in rural destination. J Bisnis Dan Manajemen. https://doi.org/10.26905/jbm.v7i2.4067
Read JC, MacFarlane S, Casey C (2002) Endurability, engagement and expectations: measuring children's fun. Interaction design and children. Shaker Publishing, Eindhoven, vol. 2, pp. 1–23
Ren Y, Lin C, Zhou Q, Yingyuan Z, Wang G, Lu A (2023) Effectiveness of virtual reality games in improving physical function, balance and reducing falls in balance-impaired older adults: A systematic review and meta-analysis. Arch Gerontol Geriatr 108:104924
Restout J, Bernache-Assollant I, Morizio C, Boujut A, Angelini L, Tchalla A, Perrochon A (2023) Fully immersive virtual reality using 360 videos to manage well-being in older adults: A scoping review. J Am Med Dir Assoc 24(4):564–572
Ringle CM, Wende S, Becker J-M (2022) SmartPLS 4. Oststeinbek: SmartPLS gmbh. J Appl Struct Equ Model
Seifert A, Schlomann A (2021) The use of virtual and augmented reality by older adults: potentials and challenges. Front Virtual Real 2:639718
Shankar R, Devi F, Xu Q (2025) Virtual reality interventions to reduce social isolation in older adults: a protocol for systematic review. BMJ Open 15(10):e100830

Sharek D, Wiebe E (2014) Measuring video game engagement through the cognitive and affective dimensions. Simul Gaming 45(4–5):569–592

Skurla MD, Rahman AT, Salcone S, Mathias L, Shah B, Forester BP, Vahia IV (2022) Virtual reality and mental health in older adults: a systematic review. Int Psychogeriatr 34(2):143–155

Sohrabei S, Zolfaghari V, Ehsanzadeh SJ (2025) The Effect of Immersion Technology on the Quality of Life in Older Adults: A Systematic Review. Aging Med 8(4):324–346

Sriworapong S, Pyae A, Thirasawasd A, Keereewan W (2022) Investigating students' engagement, enjoyment, and sociability in virtual reality-based systems: a comparative usability study of spatial. io, Gather. town, and Zoom. In: International conference on well-being in the information society

Świątek AH, Szcześniak M, Borkowska H, Stempień M, Wojtkowiak K, Diessner R (2024) The unexplored territory of aesthetic needs and the development of the aesthetic needs scale. PLoS ONE, 19(3):e0299326

Syed-Abdul S, Malwade S, Nursetyo AA, Sood M, Bhatia M, Barsasella D, Liu MF, Chang C-C, Srinivasan K, Li Y-CJ (2019) Virtual reality among the elderly: a usefulness and acceptance study from Taiwan. BMC Geriatr 19(1):1–10

Takatalo J, Häkkinen J, Nyman G (2015) Understanding presence, involvement, and flow in digital games. Game user experience evaluation, Springer, Cham, pp. 87–111

Talukdar N, Yu S (2021) Breaking the psychological distance: the effect of immersive virtual reality on perceived novelty and user satisfaction. J Strategic Mark 32(8):1147–1171

Thangavel G, Memedi M, Hedström K (2022) Customized information and communication technology for reducing social isolation and loneliness among older adults: scoping review. JMIR Mental Health 9(3):e34221

Tokunaga RS (2012) Engagement with novel internet technologies: the role of perceived novelty in the development of the deficient self-regulation of internet use and media habits. The University of Arizona

Tortora C, Di Crosta A, La Malva P, Prete G, Ceccato I, Mammarella N, Di Domenico A, Palumbo R (2024) Virtual reality and cognitive rehabilitation for older adults with mild cognitive impairment: A systematic review. Ageing Res Rev 93:102146

Toufani S, Stanton JP, Chikweche T (2017) The importance of aesthetics on customers' intentions to purchase smartphones. Mark Intell Plann 35(3):316–338

Tsai J-C, Chen LY, Peng H-Y (2021) Exploring the factors influencing consumer's attitude toward using and use intention of virtual reality games. Int J Org Innov (Online) 13(4):160–175

Tu H-Y, Lee SW-Y (2025) Curiosity, interest, and engagement: unpacking their roles in students' learning within a virtual game environment. J Edu Comput Res 62(8):1775–1799

Tuena C, Pedroli E, Trimarchi PD, Gallucci A, Chiappini M, Goulene K, Gaggioli A, Riva G, Lattanzio F, Giunco F (2020) Usability issues of clinical and research applications of virtual reality in older people: a systematic review. Front Hum Neurosci 14:93

Vasalou A, Joinson AN, Pitt J (2007) Constructing my online self: avatars that increase self-focused attention. In: Proceedings of the SIGCHI conference on Human factors in computing systems

Vazquez D, Cheung J, Nguyen B, Dennis C, Kent A (2021) Examining the influence of user-generated content on the fashion consumer online experience. J Fashion Mark Manage Int J 25(3):528–547

Wang H-Y, Sun JC-Y (2023) Real-time virtual reality co-creation: collective intelligence and consciousness for student engagement and focused attention within online communities. Interact Learn Environ 31(6):3422–3435

Wang Y-L, Hou H-T, Tsai C-C (2020) A systematic literature review of the impacts of digital games designed for older adults. Educ Gerontol 46(1):1–17

Watfa MK, Akili A (2023) Factors influencing elders' intention to use a housing community: a virtual reality approach extending the theory of planned behaviour. Int J Constr Manage 23(5):799–813

Wei X, Jin X, Fan M (2022) Communication in immersive social virtual reality: A systematic review of 10 years' studies. In: Proceedings of the tenth international symposium of Chinese CHI

WHO (2015) Population division. World ageing population 2015. https://www.un.org/en/development/desa/population/publications/pdf/ageing/WPA2015_Report.pdf

Yan Z, Lv C, Chen Q, Shang D (2024) Impact of user engagement on virtual reality behavioral response from the human–computer interaction perspective toward a service context: a hybrid statistics and machine learning approach. Expert Syst Appl 247:123243

Yim MY-C, Chu S-C, Sauer PL (2017) Is augmented reality technology an effective tool for e-commerce? An interactivity and vividness perspective. J Interact Mark 39(1):89–103

Yong S, Hung M-W, Yuan CW, Chiu C-C, Huang M-C, You C-W (2023) Mind and body: the complex role of social resources in Understanding and managing depression in older adults. Proc ACM Hum Comput Interact 7(CSCW1):1–25

Zhang X, Wang L (2023) The influence of design aesthetics on the purchase intention of AI-generated products: taking cultural and creative products as an example. International conference on human-computer interaction