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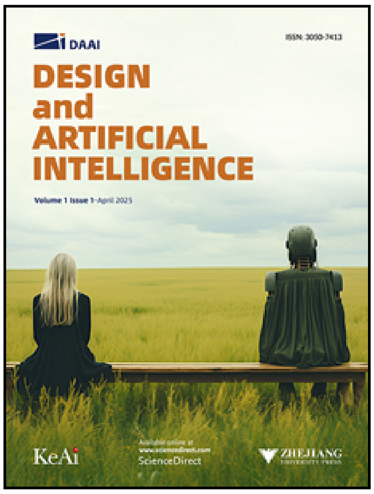

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Exploring user perception in mobile shopping: A comparison between augmented reality and virtual reality

Yilin Tang[a], Jiaxiang You[a], Liuqing Chen[a,b*]

[a]College of Computer Science and Technology, Zhejiang University, Hangzhou 310027, China, [b]Zhejiang-Singapore Innovation and AI Joint Research Lab

* Corresponding author. Address: No.866 Yuhangtang Rd., Hangzhou 310027, China; E-mail: chenlq@zju.edu.cn.

Despite the considerable potential that augmented reality (AR) and virtual reality (VR) hold for enhancing mobile shopping experiences, these technologies have often been misused or ineffective in practical applications. This study, focusing on the context of smartphone usage, investigates the distinct and shared impacts of AR and VR on user perceptions and responses. An extended technology acceptance model was proposed, including different features of AR and VR, namely immersion, interaction, and information. The theoretical model was tested in the actual mobile shopping applications with AR and non-immersive VR features, using survey-collected data from 274 participants and Partial Least Squares Structural Equation Modeling (PLS-SEM) analysis. The results demonstrate a common trend that immersion, interaction, and information can positively influence consumer perception and response in both AR and VR. However, AR and VR differed in how immersion and information have an impact on perceived enjoyment and perceived informativeness, highlighting the important role of information in AR and immersion in VR. This study provides practical insights for retailers in the user experience design of AR and VR-supported applications, as well as how to choose and integrate AR and VR for improved mobile shopping.

Keywords: augmented reality, non-immersive virtual reality, technology acceptance model, mobile shopping, smartphone, perception and response

Highlights:

·We compare augmented reality technology and virtual reality technology about their effects on customers' perceptions and responses in the context of mobile shopping.

·A new theoretical model is proposed to estimate customers' acceptance of AR and VR, in which different technical features between AR and VR are included.

·Information is outlined as an important factor in contributing to whether customers are willing to shop via AR, and immersion is the key factor for VR.

·Through a survey based on AR and non-immersive VR (interactive 360° panoramic view) functionalities in a commercial mobile shopping application, this study provides practical insights for retailers in their strategy of choosing or integrating AR and VR, as well as some recommendations in designing AR and VR supported applications.

1. Introduction

In recent years, retailers have shifted their focus to Augmented reality (AR) and Virtual reality (VR), which are projected to reach a market volume of over $571 billion by 2025 (Hilken et al., 2022), due to their potential to enhance customers' brand engagement (McLean, 2019), attitude (Anderson et al., 2022; Huang et al. 2023), usage intention (Yim et al., 2017; Oyman et al., 2022), and satisfaction (McLean et al., 2019). For example, Sephora and L'Oreal launched AR applications to help customers evaluate products by overlaying virtual makeup on their faces (Ameen et al., 2022). IKEA developed VR applications (Kim et al., 2023), in which users can try different fabrics, change wall colors, and configure room assets.

However, due to an insufficient understanding of how AR and VR differentially shape customers' perceptions and responses (Xi and Hamari, 2021), coupled with the fact that both smartphone-based AR and VR provide enhanced shopping experiences by processing 3D images, retailers often mistakenly use these two similar-sounding concepts interchangeably (Kim et al., 2023). Moreover, the current deployment of AR and VR is not tailored to the scenarios or shopping stages for which they are best suited, resulting in a waste of technological resources and a subpar user experience (Hilken et al., 2022; Farah et al., 2019). Retailers also miss the potential to create a hybrid shopping experience by leveraging the commonalities to combine both technologies (Hamari et al., 2019).

Previous research identified key features in each technology that enhance customers' experience, respectively, as shown in Table 1. For AR, these include novelty, interactivity, vividness, immersion, and aesthetic quality (Oyman et al., 2022; McLean et al., 2019; Pantano et al., 2017; Yim et al., 2017). While for VR, these contain escapism, interactivity, vividness, presence, and telepresence (Pleyers et al.,2020; Mkedder et al., 2024; Kim et al. 2021; Kim et al., 2022). However, without a rigorous comparative analysis between AR and VR (Suh, 2018), it is currently unclear which features drive the disparities in how AR and VR shape the smartphone-based shopping experience. To our knowledge, the only relevant study is that of Kim et al. (2023), which, based on the Stimulus-Organism-Response (S–O–R) framework, investigated two features, vividness and interactivity, and uncovered the distinct mechanisms through which they influence behavioral intention in AR and VR. However, other key features of VR and AR have yet to be explored. Moreover, the S–O–R framework, which focuses on users' reactions to specific stimuli, lacks direct guidance for optimizing technology design and user experience. Given the vital role of AR and VR and their unsatisfactory implementations, especially in the context of smartphone usage, more empirical research is needed to further explore their disparities and commonalities.

This study aims to enrich the literature by focusing on three novel features of smartphone-based AR and VR: immersion, interaction, and information, to provide a more comprehensive investigation of similarities and differences between AR and VR. By first conducting a rigorous comparative analysis using the TAM framework, we offer a more actionable and practical approach to optimizing user experience with these technologies. Specifically, through a survey of 274 participants based on the AR and non-immersive VR (interactive 360° panoramic view) functionalities in a commercial mobile shopping application, we examined similarities and differences in how these distinct features affect users' perceptions (usefulness, ease of use, enjoyment, and informativeness) and responses (attitude towards using and behavioral intention) in AR and VR. Our findings show that AR and VR differ in how immersion and information impact perceived enjoyment and informativeness, highlighting the key roles of information in AR and immersion in VR. The findings also provide practical insights for retailers in designing AR or VR shopping apps, as well as guidance on how to strategically choose or combine AR and VR for an improved mobile shopping experience.

Table 1. Studies on the acceptance of AR and VR technology in retailing

Reference	Technology	Application or System	Model	Investigated construct	Analysis methods
Oyman (2022)	AR	"YouCam" Makeup	TAM	Consumer novelty seeking, technology anxiety, PAR, PE, PEOU, PI, PU, BI	SEM (structural equation modeling)
McLean (2019)	AR	Amazon, ASOS, IKEA	TAM	Interactivity, vividness, novelty, PEOU, PU, PE, brand engagement, satisfaction with customer experience, brand usage intention	SEM
Pantano (2017)	AR	virtual mirror on Ray-Ban website	TAM	Aesthetic quality, interactivity, response time, quality of information, PEOU, PU, PE, AT, BI	PLS-SEM (partial least squares structural equation modeling)

Yim (2017)	AR vs. web	AR-based vs. web-based product presentations	-	Interactivity, immersion, vividness, previous media experience, media usefulness, enjoyment, media novelty, AT, purchase intention	SEM
Kim et al.(2021)	VR	IKEA VR store	TAM	Interactivity, vividness, telepresence, PU, PE, AT, BI	SEM
Pleyers et al. (2020)	Non-immersive VR	ANOMIZ 360° panoramic view	SOR	Presence, playfulness, AT, BI	GLM (Generalized Linear Model)
Altarteer and Charissis (2019)	VR	A system for online luxury product visualization and customization service	TAM	PU, PEOU, AT, perceived experience value, perceived presence, object customization	LRA (linear regression analysis)

2. The extended technology acceptance model development

2.1. Mobile augmented reality (MAR) and non-immersive virtual reality (NIVR) in shopping

Augmented reality (AR) is defined as "technology that enables users to engage with virtual information superimposed on the physical world (Suh, 2018). AR, when created and accessed through mobile devices, is referred to as Mobile Augmented Reality (MAR) (Olsson et al., 2013). MAR has gained popularity among users in the field of mobile shopping (Oyman, 2022) due to its high accessibility to end-users through smartphones. It makes user experience more attractive by enabling users to view and interact with virtual products in real environments and to evaluate products through virtual try-ons (Álvarez Márquez & Ziegler, 2023; Caboni & Hagberg, 2019). Due to its potential as the most likely form of AR shopping in the coming years (Dacko, 2017), MAR is the primary focus of this study.

Virtual reality (VR) is defined as "technology that generates an interactive virtual environment designed to simulate a real-life experience"(Suh, 2018). VR that is presented through computer or smartphone screens and involves interaction through controllers or mice is defined as non-immersive Virtual Reality (NIVR) (Yang et al., 2018). While NIVR cannot offer a fully immersive experience compared to VR based on headsets, it significantly reduces the entry barriers for users by eliminating the requirement for expensive equipment and motion sickness (Minocha et al., 2017). Consequently, most retailers such as JD.com and Alibaba adopted smartphone-based NIVR (360° panoramic view) as a cost-effective solution for VR shopping (Zeng & Richardson, 2016; Kim et al., 2022). In mobile shopping, NIVR benefits customers by simulating a sensory-rich in-store environment (Kim et al., 2023) and providing detailed visual-spatial product information (Kang et al., 2020). To obtain findings that are more representative and reflective of the current market conditions, this study conducted experiments using smartphone-based NIVR, which is currently the predominant form of VR shopping.

2.2. Technology acceptance model

Technology acceptance model (TAM) is a framework for modeling user acceptance of information systems and explaining the decisive factors of the technology acceptance process (Davis et al., 1989). As shown in Table 1, it has been widely used in empirical studies about the adoption of AR and VR in retailing, proving its robustness (Rese et al., 2017). The original TAM believed that perceived usefulness (PU) and perceived ease of use (PEOU) of the information system jointly affected users' attitude toward using (AT) and behavioral intention (BI), where PEOU represents the degree to which a person believes that using a particular system would be free of effort and PU represents the degree to which a person believes that using a particular system would enhance his job performance (Davis et al., 1989). AT represents the user's assessment of the specific system, and BI represents the degree to which a user intends to use the system (Kanchanatanee, 2014). The original TAM relationships have, for the most part, been confirmed for VR (Altarteer and Charissis 2019; Kim et al., 2021) and AR-based systems (Pantano, 2017; McLean, 2019; Oyman, 2022). Accordingly, it is hypothesized that:

H1. PU has a direct and positive effect on AT (a: AR, b: VR).

H2. PEOU has a direct and positive effect on AT (a: AR, b: VR).

H5. AT has a direct and positive effect on BI (a: AR, b: VR).

Considering that the unique visualization rendered by AR and VR can provide customers with additional product information (Billewar et al., 2022, p. 19) and an enjoyable shopping experience (Kim et al., 2023; Holdack et al., 2022), this study supplements the original TAM framework by introducing perceived enjoyment (PE) and perceived informativeness (PI) (Hausman and Siekpe, 2009; Ott et al., 2016). PE refers to the extent to which using a specific system is perceived to be enjoyable (Davis and Bagozzi, 1992). It has been proven to influence the use of mobile AR (Pantano, 2017; McLean, 2019; Oyman, 2022) and VR applications (Kim et al, 2021). PI refers to the adequate reliable information perceived in the system (Oyman, 2022). It has been identified as one of the main factors affecting AT in mobile commerce (Hausman and Siekpe, 2009; Ott, 2016.; Rese et al., 2017). Accordingly, it is hypothesized that:

H3. PE has a direct and positive effect on AT (a: AR, b: VR).

H4. PI has a direct and positive effect on AT (a: AR, b: VR).

2.3. Distinct features between AR and VR

The distinctive features of AR and VR could lead to differences in how they influence consumers' decision-making processes, beyond the factors previously identified by TAM. Building on the three key dimensions that differentiate AR from VR (Azuma, 1997; Parveau & Adda, 2018): the level of immersion, mode of interaction, and type of information, this study adopts immersion, interaction, and information as the distinctive features between the two technologies.

2.3.1 Immersion

When exploring immersive experience brought by AR or VR, presence (Kim et al., 2023; Sagnier et al., 2020) and immersion (Yim et al., 2017; Bafadhal & Hendrawan, 2019) are the two features that most commonly mentioned. Immersion (IM) is the extent to which a virtual system engrosses users, keeping them fully engaged from the real world (Yim et al., 2017). It represents the objective level of sensory fidelity provided by the system and can be enhanced by altering the system's technical properties (Slater,2003). Whereas presence refers to the degree to which a person feels present in a certain space (Sagnier et al., 2020), representing the user's subjective psychological response and may influenced by individual characteristics (Berkman & Akan, 2019). Our study adopts a technical property perspective, selecting immersion as one of the different features between AR and VR.

The immersion experienced by users in AR and VR varies due to the distinct extent to which their direct sensory experience of the real environment is replaced by virtual stimuli and representations generated by AR or VR (Tang et al., 2004; Huang et al, 2018). AR allows users to have a more direct sensory experience of the physical environment while viewing virtual annotations. In contrast, VR completely substitutes the user's sensory experience of the physical environment with generated virtual stimuli and representations.

Sepasgozar et al. (2022) proved immersion has a positive impact on perceived usefulness in virtual teaching. Agarwal and Karahanna (2000) proposed that immersion means that all the attention resources of the individual are focused on specific tasks, which would reduce the cognitive burden. Peukert et al. (2019) found that immersion can increase users' enjoyment through a higher sense of presence. Shin et al. (2017) pointed out that users can experience a wide breadth of information with multi-sensory dimensions in an immersive environment. Therefore, it is hypothesized that:

H6. Immersion has a direct and positive effect on perceived usefulness (a: AR, b: VR).

H7. Immersion has a direct and positive effect on perceived ease of use (a: AR, b: VR).

H8. Immersion has a direct and positive effect on perceived enjoyment (a: AR, b: VR).

H9. Immersion has a direct and positive effect on perceived informativeness (a: AR, b: VR).

2.3.2 Interaction

Since AR and VR reshaped the mode people interact with the real and virtual worlds, the term interaction has become an important technical feature of both (Wu & Kim, 2022). Interaction (IT) is defined as "the extent to which users can participate in modifying the form and content of a mediated environment in real time" (Rauschnabel, 2022). The interaction in AR and VR may vary due to their distinct range (the number of possibilities for action at any given time) and mapping (the similarity of the control in the virtual world to the real world) (Steuer, 1992). The range of interaction in VR is mainly limited to the interactions with virtual objects, whereas in AR it includes intermediary interaction with both virtual and physical objects (Steffen et al. 2019). Control mechanisms in VR can be similar to or completely different from those in the real world, while in AR they are typically identical to the real world (Wu & Kim, 2022).

Shin et al. (2019) implied that the highly interactive system can improve users' ability to integrate, memory, understanding, and task performance. Klimmt et al. (2007) proved that the interaction of video games, such as the degree of control positively affects a player's enjoyment. Ott et al. (2016) found that the interaction of messages had a positive effect on advertisement effectiveness through the indirect pathway of perceived informativeness. Therefore, it is hypothesized that:

H10. Interaction has a direct and positive effect on perceived usefulness (a: AR, b: VR).

H11. Interaction has a direct and positive effect on perceived ease of use (a: AR, b: VR).

H12. Interaction has a direct and positive effect on perceived enjoyment (a: AR, b: VR).

H13. Interaction has a direct and positive effect on perceived informativeness (a: AR, b: VR).

2.3.3 Information

Previous research explored how AR or VR enables users to experience more dimensional information typically by examining features such as vividness (McLean et al., 2019; Yim et al. 2017; Kim et al.2021) and quality of information (Pantano, 2017). However, neither of these fundamentally indicates the differences in the types of information and data managed by AR and VR. This study adopts the general concept called "information", which is defined as "the data that can be obtained from a range of environmental stimuli and phenomena" (Madden, 2000).

From a perceptual perspective, users can obtain both virtual and real information in AR, while in VR they can only obtain virtual information. From a technical perspective, virtual objects in AR are positioned relative to the real environment, which leads to higher accuracy requirements for registration to ensure users perceive the existence and integrity of virtual objects in the real environment (Steffen et al., 2019). In contrast, VR can ease the strict requirement on system calculating capability by registering virtual objects relative to the virtual environment (Li et al., 2014).

Compared to traditional image-based online shopping, both AR and VR have the potential to enhance the presentation of products by providing clear and vivid information, allowing users to obtain richer product details (McLean, 2019). In addition, information that results in a vivid display of the real and virtual environments is likely to affect customers' perception of the ease of use of the technology (Kim et al., 2021). Childers et al. (2001) pointed out that rich, detailed information brought by interactive media leads to a higher degree of entertainment value. Therefore, it is hypothesized that:

H14. Information has a direct and positive effect on perceived usefulness (a: AR, b: VR).

H15. Information has a direct and positive effect on perceived ease of use (a: AR, b: VR).

H16. Information has a direct and positive effect on perceived enjoyment (a: AR, b: VR).

H17. Information has a direct and positive effect on perceived informativeness (a: AR, b: VR).

Following the above discussion, we constructed a hypothetical model as shown in Figure 1. We extend TAM with three different technical features between AR and VR (IM, IT, IF) to inspect how they affect user perception (PU, PEOU, PE, PI) and then users' attitudes and behaviors. In the following section, we aim to test whether these hypothetical relationships between the constructs are valid.

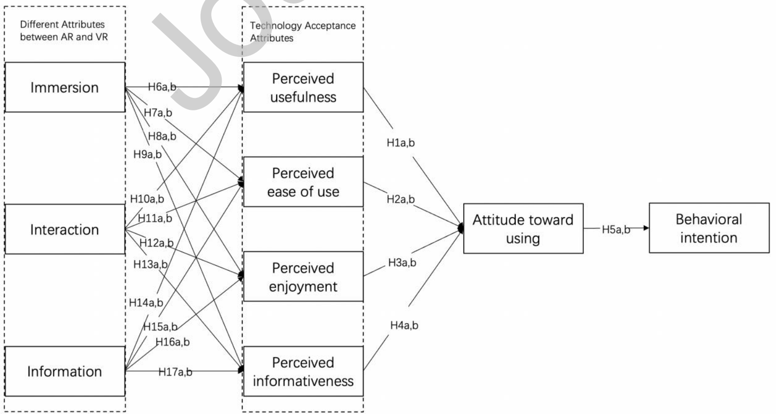

Figure 1. Hypothesized model with 17 hypotheses on the impact of three distinct technical features between AR and VR (IM, IT, IF) on user perceptions (PU, PEOU, PE, PI) and user responses (AT, BI).

3. Methodology

To test relationships in the hypothesized model, we conducted our study in the actual AR and VR commercial shopping environment. The mobile application from JD.com, featuring AR and VR (interactive 360° panoramic view) was chosen as our experimental platform. As one of the largest B2C e-retailing platforms in China, it is familiar to participants, reducing the uncertainty in the experiment. To ensure the practicality and guidance of our findings, we selected home appliances, which are representative products commonly used in AR and VR retailing (Riar et al., 2021), as the product category for our experimental task. Our experiment adopted the between-subjects design (Charness et al., 2012) and participants were randomly divided into two groups—AR or VR.

3.1. Participants

A total of 287 participants, who had experience with the JD.com mobile application, were recruited via voluntary sign-up on a local online shopping forum in an eastern Chinese city. After excluding incomplete questionnaires, we obtained 274 valid responses, with 144 from the AR group and 130 from the VR group. A prior G Power analysis indicated that a desired sample size of 85 would achieve an effect size of 0.15, a power of 0.80, with four predictors at an alpha level of 0.05. To ensure a more robust and consistent model, it is recommended to triple the G Power result (Henseler et al., 2016). Thus, the sample size of 274 in this study is well-suited. As shown in Table 2, the participants had a relatively even sex ratio, with 76% aged between 18 and 40. Nearly all participants (over 96%) reported shopping via mobile devices at least several times a month, and over 73% had previous experience with AR/VR in various forms.

Table 2. Characteristics of participants

	Category	**Participants in AR**	**Participants in VR**
Age	Under 20	11 (7.64%)	12 (9.23%)
	21-30	59 (40.97%)	60 (46.15%)
	31-40	48 (33.33%)	41 (31.54%)
	41-50	18 (12.50%)	15 (11.54%)
	Over than 51	8 (5.56%)	2 (1.54%)
Gender	Male	77 (53.47%)	59 (45.38%)
	Female	67 (46.53%)	71 (54.62%)
Education	Less than a high school diploma	17 (11.80%)	7 (5.38%)
	High school degree or equivalent	33 (22.92%)	23 (17.69%)
	Bachelor's degree	56 (38.89%)	64 (49.23%)
	Master’s degree	34 (23.61%)	26 (20.00%)
	Doctorate	4 (2.78%)	10 (7.70%)
Income (RMB/month)	Below 3000	6 (4.17%)	4 (3.08%)
	3,000-8,000	43 (29.86%)	33 (25.38%)
	8,000-15,000	71 (49.31%)	64 (49.23%)
	15,000-30,000	22 (15.28%)	29 (22.31%)
	Over 30,000	2 (1.38%)	0 (0.00%)
Mobile shopping frequency	Less than once a month	9 (6.25%)	0 (0.00%)
	Multiple times monthly	11 (7.64%)	13 (10.00%)
	Once weekly	21 (14.58%)	38 (29.23%)
	Multiple times weekly	65 (45.14%)	40 (30.77%)
	Once daily	13 (9.03%)	17 (13.08%)
	Multiple times daily	25 (17.36%)	22 (16.92%)
Knowing of AR/VR	Never heard of it	6 (4.17%)	0 (0.00%)
	Just heard about it	13 (9.03%)	15 (11.54%)
	Know the definition	26 (18.05%)	13 (10.00%)
	Used AR/VR application	70 (48.61%)	64 (49.23%)
	Used AR/VR HMD (Helmet Mounted Display)	29 (20.14%)	38 (29.23%)

3.2. Procedure

The whole experiment lasted about 15 minutes for each participant. Participants were required to familiarize themselves with the JD app on their phones in advance. Prior to the experiment, participants received instructions about the procedures of the experiment. Once all the settings were ready, participants were encouraged to experience AR or VR shopping for at least seven minutes to ensure that they could fully inspect, compare, and evaluate the products.

The entire experience process is divided into three sub-tasks and Figure 2 shows the differences in experimental conditions between AR and VR at three levels: immersion, interaction, and information. In the first step, participants had to assess how it fits within the environment by placing, moving, and rotating the virtual product. In the AR group, they could position the product within their actual surroundings and move the phone camera to gauge its compatibility with the real-world setting. In the VR group, participants placed the product in a virtual environment and inspected the virtual scenario by moving phones. Next, participants had to examine the features of the product. In the AR group, it more emphasis on the interaction between participants and the real environment. Participants need to use AR-based measurements to gauge the product’s dimensions and the available space in the real world to determine whether it can fit. In the VR group, it more focuses on the interaction between participants and virtual products. They can, for example, open the door of a microwave oven to inspect its internal structure. Finally, participants needed to inspect various parameters of the product. In VR mode, parameters such as capacity were presented in a virtual table. While in AR mode, this virtual information was labeled on the product model in a real environment. In both the AR and VR groups, participants had to examine more than three different product models for comparison to choose their favorite one. After the experience, participants were asked to fill out the questionnaire.

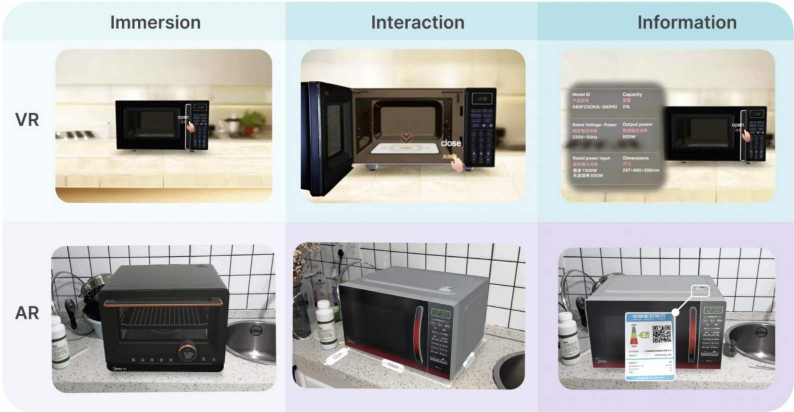

Figure 2. An example to show the differences in experimental conditions between AR and VR.

3.3. Questionnaire

The scales used in our questionnaire were drawn from previous literature and translated into Chinese to measure immersion (Agarwal & Karahanna, 2000; Jennett et al., 2008), interaction (Wu, 2005; Yim, 2017), information (Teo et al., 2008.), perceived usefulness (Davis et al., 1989), perceived ease of use (Davis et al., 1989), perceived enjoyment (F. Davis & Bagozzi, 1992), perceived informativeness (Rese et al., 2017), attitude toward using (Taylor & Todd, 1995) and behavioral intention (Venkatesh et al., 2008). All items in the scales for the study were measured on a 7-point Likert scale with a range from “Strongly Disagree (1)” to “Strongly Agree (7)”. Demographic questions were also included in the questionnaire including participants’ gender, age, education, income, the frequency of mobile shopping and the knowledge of AR or VR technology. Finally, to gain a deeper comprehension of the participants’ questionnaire responses, they were asked to provide their opinions about AR or VR shopping in an open-ended format. Table 3 illustrates the scales and items used in the questionnaire, and the results are introduced in the next section. Prior to the experiment, we conducted a pilot test on 40 participants who were not included in the main study, and the test results verified the validity and reliability of our questionnaire.

4. Data analysis and results

Partial Least Squares Structural Equation Modelling (PLS-SEM) was chosen to evaluate the proposed model in this study, since it is suitable for new models that have not been tested in the literature (Tam & Oliveira, 2016; Molinillo et al.,2024; Ye et al.,2023). The software SmartPLS 3.3.9 was used for data analysis.

4.1. Preliminary analysis

Reliability and validity tests were conducted prior to the assessment of the structural model. As shown in Table 3, the Cronbach's Alpha of all 9 constructs has exceeded the threshold of 0.7, which proves the internal consistency (Tavakol & Dennick, 2011). Almost all items loaded at least with a factor loading of 0.7, which confirmed that the items were firmly connected to associated constructs (Patak et al., 2016). Despite the slightly lower factor loadings for the "interaction" and "information" (ranging from 0.656 to 0.807), according to Hair et al. (2010), only construct with factor loadings below 0.5 should be removed; therefore, these items were retained.

As shown in Table 4 and Table 5, the scores of all constructs exceed the threshold of 0.7 for the composite reliability (CR) and 0.5 for the average variance extracted (AVE), which ensures the convergent validity of the model (Hair et al., 2011). Discriminant validity was confirmed due to the square root of AVE was greater than the correlations of the constructs (Fornell & Larcker, 1981). The above results indicate that the model has good internal consistency, indicator reliability, convergent validity and discriminant validity.

Table 4. Convergent and discriminant validity for AR

	CR	AVE	IM	IT	IF	PU	PEOU	PE	PI	AT	BI
Immersion (IM)	0.873	0.696	0.834								
Interaction (IT)	0.844	0.645	0.441	0.803							
Information (IF)	0.843	0.641	0.278	0.524	0.801						
Perceived usefulness (PU)	0.891	0.732	0.452	0.512	0.513	0.856					
Perceived ease of use (PEOU)	0.912	0.776	0.256	0.589	0.434	0.420	0.881				
Perceived enjoyment (PE)	0.968	0.884	0.471	0.684	0.511	0.619	0.698	0.940			
Perceived informativeness (PI)	0.896	0.743	0.379	0.611	0.698	0.640	0.558	0.663	0.862		
Attitude toward using (AT)	0.941	0.800	0.404	0.643	0.582	0.668	0.612	0.748	0.750	0.894	
Behavioral intention (BI)	0.939	0.793	0.384	0.419	0.451	0.655	0.469	0.549	0.589	0.752	0.891

Table 5. Convergent and discriminant validity for VR

	CR	AVE	IM	IT	IF	PU	PEOU	PE	PI	AT	BI
Immersion (IM)	0.908	0.768	0.876								
Interaction (IT)	0.874	0.699	0.423	0.836							
Information (IF)	0.870	0.691	0.346	0.530	0.831						
Perceived usefulness (PU)	0.932	0.820	0.534	0.594	0.545	0.905					
Perceived ease of use (PEOU)	0.888	0.726	0.370	0.640	0.406	0.498	0.852				
Perceived enjoyment (PE)	0.958	0.850	0.577	0.583	0.431	0.629	0.513	0.922			
Perceived informativeness (PI)	0.892	0.733	0.470	0.690	0.707	0.651	0.630	0.669	0.856		
Attitude toward using (AT)	0.933	0.776	0.524	0.556	0.555	0.702	0.390	0.715	0.720	0.881	
Behavioral intention (BI)	0.928	0.763	0.358	0.455	0.524	0.563	0.465	0.557	0.702	0.669	0.873

Table 3. Questionnaire scales and reliability measurement

Constructs	Scale Items	AR		VR	
		Loading	Cronbach's Alpha	Loading	Cronbach's Alpha
Immersion	· When shopping through AR (VR) technology, I am able to block out most other distractions.	0.757	0.786	0.764	0.850
	· I am immersed in the shopping environment provided by AR (VR) technology.	0.751		0.849	
	· When shopping through AR (VR) technology, my attention does not get diverted very easily.	0.839		0.802	
Interaction	· I am in control over the pace of my shopping through AR (VR) technology.	0.669	0.728	0.792	0.785
	· AR (VR) technology can respond to my specific needs effectively.	0.718		0.671	
	· I am able to interact with AR (VR) technology in order to get information tailored to my shopping.	0.754		0.752	
Information	· The product information provided by AR (VR) technology is accurate.	0.686	0.723	0.712	0.776
	· The product information provided by AR (VR) technology is detailed.	0.781		0.807	
	· I believe the product information provided by AR (VR) technology is reliable.	0.656		0.698	
Perceived usefulness	· Using the AR (VR) technology enhances my shopping effectiveness.	0.762	0.819	0.813	0.890
	· Using AR (VR) technology enhances my shopping performance.	0.856		0.873	
	· I find the AR (VR) technology to be useful for my shopping.	0.855		0.874	
Perceived ease of use	· I would find AR (VR) technology easy to use.	0.815	0.856	0.733	0.812
	· My interaction with the AR (VR) technology is clear and understandable.	0.814		0.835	
	· Learning to use AR (VR) technology in shopping would be easy for me.	0.77		0.732	
Perceived enjoyment	· I find using the AR (VR) technology in shopping is enjoyable	0.882	0.956	0.853	0.941
	· The process of using AR (VR) technology in shopping is pleasant.	0.935		0.939	
	· I have fun using AR (VR) technology in shopping.	0.911		0.889	
	· I think shopping through AR (VR) technology makes me happy.	0.906		0.900	
Perceived informativeness	· AR (VR) technology provides information that meets my need to inspect products in shopping.	0.754	0.826	0.789	0.818
	· AR (VR) technology provides information that helps me compare products.	0.771		0.757	
	· AR (VR) technology provides information that helps me in my decision.	0.813		0.773	
Attitude toward using	· Shopping through AR (VR) technology is a good idea.	0.853	0.916	0.850	0.904
	· I like the idea of shopping through AR (VR) technology.	0.845		0.849	
	· I am positive about shopping through AR (VR) technology.	0.832		0.840	
	· I think shopping through AR (VR) technology is attractive.	0.857		0.813	
Behavioral intention	· I am willing to use AR (VR) technology for shopping in the future.	0.847	0.913	0.837	0.896
	· In the future, I am more likely to use AR (VR) technology to buy some products.	0.896		0.904	
	· I will give priority to use AR (VR) technology to purchase products in the future.	0.754		0.700	
	· I intend to use AR (VR) technology for shopping in the future.	0.863		0.861	

4.2. Test for measurement invariance

The measurement invariance of composite models (MICOM), as a fundamental step before multi-group analysis (MGA), is used to ensure that differences in model estimation are not caused by different contents and meanings of latent structures across AR and VR groups (Henseler et al., 2016). We followed the three steps to implement the MICOM: (1) configural invariance, (2) compositional invariance and (3) scalar invariance (Cheah et al., 2020).

Since the indicators and constructs in the two groups (AR&VR) are the same, and data collection and treatment processes follow the same procedures, configural invariance has been confirmed (Henseler et al., 2016). Compositional invariance was established since the correlations (C value) of all composites are within the 95% confidence interval of the distribution of the correlation testing 5000 permutations. Finally, scalar invariance could not be established since the mean values of IM, PU, PEOU, PE and BI showed significant differences across the two groups (as shown in Table 6). The differences in the mean value of these indicators may indicate some differences between AR and VR, which will be explained in Section 5. Overall, the above results imply the partial measurement invariance of the model and the need for multigroup analyses (Henseler et al., 2016).

Table 6. MICOM results

Constructs	C value	5.0% confidence interval	Compositional invariance?	Difference of the composite's mean value	95% confidence interval	Equal mean values?	Difference of the composite's variances	95% confidence interval	Equal variances?
Immersion	0.99974	0.99113	yes	0.24684	-0.23657; 0.22254	no	-0.46165	-0.53175; 0.52305	yes
Interaction	0.99542	0.99436	yes	0.17403	-0.23117; 0.23128	yes	-0.36685	-0.31905; 0.32908	no
Information	0.99579	0.99019	yes	0.00318	-0.22786; 0.23124	yes	0.00650	-0.44018; 0.47820	yes
Perceived usefulness	0.99962	0.99825	yes	0.33053	-0.22186; 0.23645	no	-0.63017	-0.44310; 0.44067	no
Perceived ease of use	0.99884	0.99737	yes	-0.26309	-0.22786; 0.24435	no	0.40362	-0.42354; 0.44073	yes
Perceived enjoyment	0.99998	0.99974	yes	0.25496	-0.23263; 0.23521	no	-0.01778	-0.31417; 0.32423	yes
Perceived informativeness	0.99973	0.99835	yes	0.19399	-0.22694; 0.23677	yes	0.18542	-0.44310; 0.44067	yes
Attitude toward using	0.99985	0.99973	yes	0.13267	-0.22233; 0.23395	yes	0.09305	-0.46189; 0.45143	yes
Behavioral intention	0.99995	0.99906	yes	0.28645	-0.22665; 0.22475	no	-0.10954	-0.39759; 0.38556	yes

4.3. Hypotheses testing and multigroup analysis

As shown in Table 7, R^2 and adjusted R^2 for all constructs are in the range of 0.45-0.77 in this study, which indicates that the predictive power of the model can be described as moderate (Chin et al. 2020; Hair et al., 2021).

Table 7. Model fit results

Constructs	AR		VR	
	R^2	R^2 adjusted	R^2	R^2 adjusted
Perceived usefulness	0.500	0.482	0.501	0.484
Perceived ease of use	0.469	0.450	0.426	0.406
Perceived enjoyment	0.532	0.518	0.480	0.462
Perceived informativeness	0.579	0.566	0.656	0.644
Attitude toward using	0.705	0.684	0.670	0.642
Behavioral intention	0.614	0.577	0.776	0.751

A single path analysis was conducted to test the hypothesized relationships. As shown in Table 8 and Figure 3, 12 of 17 estimated paths are positive and significant with $p < 0.05$, which is consistent with our hypothesis. The remaining five paths include three that are not significant for both AR and VR groups (H7: Immersion → Perceived ease of use, H15: Information → Perceived ease of use, H2: Perceived ease of use → Attitude toward using), one that is not significant only for AR (H9: Immersion → Perceived informativeness) and one that is not significant only for VR (H16: Information → Perceived enjoyment). The result indicated that perceived usefulness was positively influenced by immersion, interaction and information, while perceived ease of use was only affected by interaction in both AR and VR.

Perceived enjoyment was shaped by immersion and interaction, and perceived informativeness was affected by interaction and information in both AR and VR. Moreover, in the AR and VR context, perceived usefulness, enjoyment and informativeness had a significant influence on attitude toward using and then on behavioral intention, while perceived ease of use did not. However, several differences were observed between AR and VR. Immersion enhanced perceived enjoyment for AR, but not for VR. Information enhanced perceived enjoyment for AR, but not for VR. Then, a multigroup analysis with types of immersive technology (AR vs VR) as a grouping construct was conducted. As shown in Table 8, the results implied that there are no statistical differences between AR and VR in relationships between constructs of the adoption of AR or VR shopping.

Table 8. Hypotheses testing including multigroup analysis

Hypothesis				AR			VR			Difference (AR-VR)	
				Path coef.	T statistics (p-value)	result	Path coef.	T statistics (p-value)	result	Path coef. differences	P-value
H6	Immersion	→	Perceived usefulness	0.262	3.024 (0.003)	supported	0.304	2.525 (0.012)	supported	-0.042	0.736
H7	Immersion	→	Perceived ease of use	-0.014	0.148 (0.882)	Not supported	0.110	1.039 (0.299)	Not supported	-0.124	0.386
H8	Immersion	→	Perceived enjoyment	0.199	2.812 (0.005)	supported	0.387	4.519 (0.000)	supported	-0.188	0.096
H9	Immersion	→	Perceived informativeness	0.107	1.354 (0.176)	Not supported	0.149	2.525 (0.012)	supported	-0.043	0.673
H10	Interaction	→	Perceived usefulness	0.228	2.012 (0.044)	supported	0.323	2.981 (0.003)	supported	-0.094	0.544
H11	Interaction	→	Perceived ease of use	0.504	5.220 (0.000)	supported	0.555	6.448 (0.000)	supported	-0.050	0.698
H12	Interaction	→	Perceived enjoyment	0.493	6.421 (0.000)	supported	0.364	4.147 (0.000)	supported	0.129	0.266
H13	Interaction	→	Perceived informativeness	0.295	3.863 (0.000)	supported	0.389	5.302 (0.000)	supported	-0.094	0.354
H14	Information	→	Perceived usefulness	0.321	3.224 (0.001)	supported	0.269	2.041 (0.041)	supported	0.052	0.759
H15	Information	→	Perceived ease of use	0.173	1.482 (0.138)	Not supported	0.074	0.649 (0.517)	Not supported	0.100	0.543
H16	Information	→	Perceived enjoyment	0.198	2.203 (0.028)	supported	0.104	1.114 (0.265)	Not supported	0.094	0.467
H17	Information	→	Perceived informativeness	0.514	6.209 (0.000)	supported	0.449	5.959 (0.000)	supported	0.065	0.564
H1	Perceived usefulness	→	Attitude toward using	0.197	2.430 (0.015)	supported	0.382 supported	2.166 (0.030)	supported supported	-0.085	0.552
H2 H16	Perceived ease of use Information	→ →	Attitude toward using Perceived enjoyment	0.096	1.142 (0.253) 2.203 (0.028)	Not supported	-0.064 supported	0.651 (0.515) 1.114 (0.265)	Not supported Not supported	0.160 0.094	0.215 0.467
H3	Perceived enjoyment	→	Attitude toward using	0.276	2.422 (0.015)	supported	0.320	3.173 (0.002)	supported supported	-0.044	0.759
H4 H17	Perceived informativeness Information	→ →	Attitude toward using Perceived informativeness	0.306	2.824 (0.005) 6.209 (0.000)	supported	0.309 supported	2.942 (0.003) 5.959 (0.000)	supported supported	-0.002 0.065	0.984 0.564
H5 H1	Attitude toward using Perceived usefulness	→ →	Behavioral intention Attitude toward using	0.752	9.531 (0.000) 2.430 (0.015)	supported	0.920 supported	14.622 (0.000) 2.166 (0.030)	supported supported	-0.167 -0.085	0.02 0.552
H2	Perceived ease of use	→	Attitude toward using	0.096	1.142 (0.253)	Not supported	-0.064	0.651 (0.515)	Not supported	0.160	0.215
H3	Perceived enjoyment	→	Attitude toward using	0.276	2.422 (0.015)	supported	0.320	3.173 (0.002)	supported	-0.044	0.759
H4	Perceived informativeness	→	Attitude toward using	0.306	2.824 (0.005)	supported	0.309	2.942 (0.003)	supported	-0.002	0.984
H5	Attitude toward using	→	Behavioral intention	0.752	9.531 (0.000)	supported	0.920	14.622 (0.000)	supported	-0.167	0.02

Coef. – coefficient

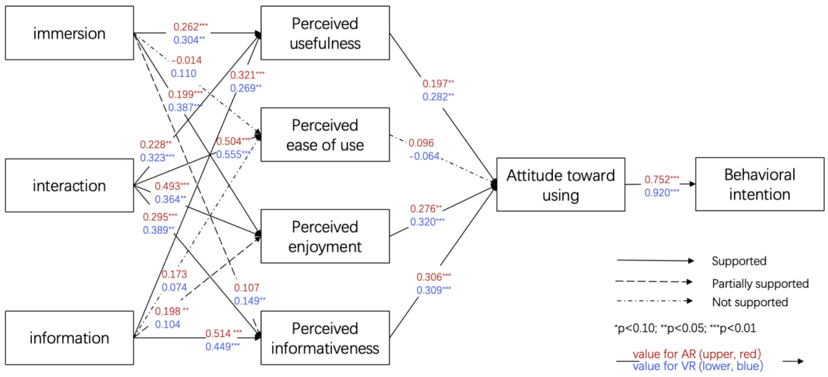

Figure 3. Hypothesis testing results of the research model—12 significant paths and 3 non-significant paths for both AR and VR groups, 1 non-significant path exclusive to AR, and one non-significant path exclusive to VR

5. Discussion and implications

5.1. Discussion

5.1.1. Similarities between AR and VR

The non-significant results of the multi-group analysis indicate that, despite the technical differences offered by AR and VR, how these factors shape user perceptions and responses is similar in general. This similarity is further substantiated by the results of hypothesis testing, where 12 out of 17 relationships were found to be positive in both AR and VR contexts, indicating a common trend that both technologies provide users with immersive experience, effective interaction modes, and unique information to enhance user perceptions and responses.

There are still three paths that are not significant for both AR and VR. Immersion and information were found to not be a predictor for perceived ease of use, consistent with the findings of Huang et al. (2016). This may suggest that in low-immersion AR or VR systems, interaction is more important in determining whether AR or VR app is easy to use rather than immersion and information. The results also indicated a lack of significant effect of perceived ease of use on user attitudes towards using, which is consistent with previous literature (Henderson & Divett, 2003; Sagnier et al., 2020). This can be explained that most participants are familiar with these technologies (almost 40% had prior experience with mobile AR or VR applications), thus PEOU is no longer a constraint or a major concern for their attitude toward AR or VR (Indarsin & Ali, 2017). Furthermore, only interaction can enhance attitudes toward using through increasing both perceived usefulness, enjoyment, and informativeness in the context of AR and VR, highlighting its significant role.

The above results revealed that users may have similar perceptions and responses when using AR and VR. This implies the possibility of integrating these two technologies to create a more comprehensive shopping experience. The practical recommendations are detailed in Section 6.2.

5.1.2. Differences between AR and VR

In VR, immersion had a positive impact on perceived informativeness, which was not found in AR. One possible explanation is that the higher level of immersion in AR (the mean value of immersion in AR is statistically higher than VR, as shown in Table 6) may act as seductive details, hindering participants from cognitively assimilating new information to existing schemas (Makransky et al., 2019). On the other hand, information enhanced perceived enjoyment for AR, but not for VR. This may be because the 2D-delivered information disrupts the users' coherent 3D virtual experience in VR, causing a sense of disconnection and interfering with perceived enjoyment. While AR can increase user enjoyment by providing user-related information such as virtual try-ons, which is believed to trigger users' positive affect (Smink et al., 2019). This means that, unlike VR, information in AR can also enhance attitude toward using by eliciting users' enjoyment. The above results emphasize the imperative role of immersion in VR and information in AR for enhancing user perceptions and responses.

The scale score (as shown in Table 6) indicated that, despite its crucial role in VR, the mean value of immersion in VR was significantly lower than that in AR, suggesting that participants perceived AR to be more immersive. It may be due to that AR provides more sensory clues about users' physical situations, enhancing their sense of participation and immersion. However, the lack of avatars in first-person VR scenes weakens the user's self-perception in the virtual space and leads to a lower immersion (Tang et al., 2004). Perceived ease of use in VR is significantly higher than that in AR, which means participants spend more effort on shopping with AR. This probably occurs as participants expend more cognitive resources to process physical and augmented information simultaneously in AR, while in VR they solely process the virtual information (Xi et al., 2022). An alternative explanation is that the unique interaction of AR is not natural enough (for instance, users need to scan a plane in the real world through a camera to place a virtual product). Moreover, as shown in Table 6, AR has significantly higher mean values for perceived usefulness, perceived enjoyment, and behavioral intention compared to VR, indicating that participants believe AR is more useful, enjoyable, and preferable for future use than VR.

The above results revealed the distinctions between AR and VR, suggesting potential areas for optimization in each technology. This also highlights opportunities for harnessing the unique strengths of both AR and VR to create a seamless shopping experience.

5.2. Implications

5.2.1. Integrating AR and VR

The similarity between AR and VR opens up the possibility of integrating both to create a mixed shopping experience. Given the parallels in how immersion, interaction, and information shape user perceptions and responses in AR and VR, applying similar design strategies related to these three factors in both technologies may yield comparable effects. Therefore, when retailers integrate AR and VR, they should adhere to similar principles, such as using resembling interaction patterns and information layouts, to achieve a seamless transition and ensure a continuous user experience. Additionally, the successful strategies applied in AR for creating immersive environments, effective interaction, and novel content are likely to be applicable to VR as well. Therefore, we recommend that retailers should contemplate cross-technology transfer in their design strategies to accelerate the development of new technology applications and broaden their user base.

The differences between AR and VR indicate that retailers can effectively harness the distinct strengths of each technology by considering key factors such as temporal dynamics and consumer motivation. VR excels in immersion, enhancing user attitudes through enjoyment, while AR stands out in delivering information, improving user attitudes by increasing perceived information. Thus, adjusting the temporal sequence of these technologies can better support customers' needs at different shopping stages. For example, when designing an online shopping journey, UX designers can first create an immersive VR environment, such as a brand experience center, to stimulate enjoyment and attract customers, then leverage AR to display product information, assisting customers in making purchase decisions and enhancing shopping efficiency.

Additionally, tailoring the application of these technologies to consumer motivation is essential. For instance, when designing spaces where low-motivation consumers are likely to congregate, such as digital marketing hubs or recommendation pages, VR can be employed to introduce impactful and immersive visual elements such as virtual brand mascots or promotional videos, serving as heuristic clues to inspire shopping. Conversely, when customers have clear shopping goals, AR should be utilized to display product specifications and allow users to overlay the target products in their real usage environment, guiding consumers to make more informed purchase decisions.

5.2.2. Choosing between AR and VR

Considering the imperative role of immersion in VR and information in AR for enhancing user perceptions and responses, retailers can choose suitable technology for showcasing different categories of products to increase purchase intent. For services or products with a strong sense of immersion, such as hotels and restaurants, retailers should consider using VR to provide free exploration to enhance customers' enjoyment and understanding of the products. And for fashion products that include rich information, we recommend retailers utilize AR, which provides users with product details by combining virtual information with the real world.

5.2.3. Designing AR and VR Shopping Applications

Our finding highlights the significant role of interaction in enhancing attitudes toward using in both AR and VR. Thus, designers should be aware that if the goal is to encourage more people to use AR or VR apps, they should prioritize the adoption of a user-friendly interaction mode over concerns about the immersion of the environment and the presentation of information. For example, employing simple gesture controls or voice commands enables users to navigate and select products effortlessly, while avoiding overly immersive environments, excessive entertaining features, such as gamification marketing, and overly intricate information, all of which can overwhelm users.

In addition, VR exhibited lower levels of immersion in our experiment, which could be attributed to the absence of user self-perception. Considering the advantage of immersion in enhancing users' attitudes and intentions toward VR, designers may contemplate incorporating a first-person perspective avatar in representing customers when designing the digital shopping market, thereby enhancing their immersion. As for AR, our results indicated lower perceived ease of use, likely due to the cognitive load of processing both physical and virtual information simultaneously. This suggests that designers need to optimize the presentation of information in AR, such as by offering layered information displays that allow users to access additional details progressively as needed.

5.3. *Limitations and future research*

With few previous studies on the effects of differences between AR and VR on user perception, the present study is exploratory. However, some limitations might be addressed by further studies.

First, the experiment in this study is conducted in the context of home appliances. Given that consumers' attitudes and behaviors toward technologies may vary depending on the type of product, our findings should be generalized with caution. Specifically, the complexity of home appliances and the need for them to match existing home environments mean that consumers are more likely to seek detailed information and virtual demonstrations when using AR and VR. Compared to other product categories, consumers may have higher expectations for the level of information and immersion in this context. Future studies could compare the present findings across a wider range of product categories, such as fashion, electronics, and automobiles. Cross-category research could elucidate the differences in AR and VR across these categories, determine which types of products are more suited to VR and which to AR, and identify potential product-specific barriers to adoption.

Second, given the infancy of immersive technology in mobile shopping, this study focuses on smartphone-based AR and VR applications, particularly mobile AR and non-immersive VR, which are considered to be the most likely form to be implemented in the next five years. However, focusing on NIVR may limit the comprehensiveness and broader applicability of our findings, as it could not provide a fully immersive user experience. In the future, devices such as HoloLens or Oculus are expected to be integrated into mobile shopping, harnessing the full potential of AR and VR to deliver a more engaging experience. Therefore, it will be meaningful to examÅine the application of AR and VR across various devices and diverse media environments to revalidate the proposed model.

6. Conclusion

This study, based on a survey of 274 participants using the AR and non-immersive VR (interactive 360° panoramic view) functionalities in a commercial mobile shopping application, is the first to rigorously compare how AR and VR utilize immersion, interaction, and information to influence consumer perceptions and responses, grounded in the Technology Acceptance Model. The result indicates a common trend that immersion, interaction, and information can positively influence consumer perception and response through similar mechanisms in both AR and VR. However, in both AR and VR, only interaction affected perceived ease of use, and perceived ease of use did not have a positive impact on attitude towards using. This study also revealed some differences in how AR and VR shape users' perceptions and responses. In VR, immersion plays a critical role in enhancing attitude towards use by increasing perceived informativeness, whereas this effect is not observed in AR. Conversely, in AR, information can enhance attitudes toward use by increasing perceived enjoyment, while this effect is not observed in VR. Moreover, AR is superior to VR in creating immersive environments, while VR is easier to use.

By studying their differences and similarities, we established a connection between VR and AR, suggesting that they are not independent but can supplement each other in mobile shopping. Based on their similarities, we provided some suggestions for retailers on integrating both to create a blended shopping experience. In light of their differences, we proposed recommendations for retailers to leverage the respective strengths of AR and VR at various stages of the user shopping journey or choose the appropriate technology based on the characteristics of different products. This study also revealed the shortcomings of AR and VR and provided some insights for designers to improve user experience in future mobile shopping app designs.

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Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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CRediT author statement

Yilin Tang: Conceptualization, Methodology, Investigation, Data curation, Writing - Original draft. Jiaxiang You: Investigation, Data curation, Writing - Review & Editing. Liuqing Chen: Supervision, Writing- Reviewing and Editing, Funding acquisition.