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Research article

A study on how to improve users' perceived playfulness in and continuance intention with VR technology to paint in virtual natural landscapes

Jie Sun [a], Yanan Wang [b], Wei Miao [c], Wei Wei [c], Chun Yang [d], Jiangjie Chen [d], Fangfang Yang [e], Longfei Ren [e], Chao Gu [f,*]

[a] College of Arts and Design, Zhejiang A&F University, Hangzhou 311300, China
[b] Xia Qing Communication School, Handan University, Handan 056005, China
[c] School of Textile Garment and Design, Changshu Institute of Technology, Changshu 215500, China
[d] School of Design, Jiangnan University, Wuxi 214122, China
[e] Department of Sports Science, Honam University, Gwangju, 62399, South Korea
[f] Department of Culture and Arts Management, Honam University, Gwangju, 62399, South Korea

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ABSTRACT

COVID-19 has adversely affected public access to public green spaces. As a means of interacting with nature, parks and green spaces are an important aspect of residents' daily lives. In this study, the focus is on new digital solutions, such as the experience of painting in virtual natural settings through virtual reality technologies. This study examines factors that affect the user's perceived playfulness and continuance intention to paint in a virtual environment. A total of 732 valid samples were collected through a questionnaire survey, and a theoretical model was developed through structural equation model by analyzing attitude, perceived behavioral control, behavioral intention, continuance intention, and perceived playfulness. Results demonstrate that perceived novelty and perceived sustainability increase the positive attitude of users toward VR painting functions, whereas perceived interactivity and aesthetics have no impact on it within VR painting context. As users use VR painting, they are more concerned about time and money than equipment compatibility. This makes resource facilitating conditions a more influential factor for perceived behavior control than technology facilitating conditions.

1. Introduction

According to the United Nations, 56.1% of the world's population resides in urban areas in 2021. For urban residents, green space is an important part of their urban ecosystem and a place where they can connect with nature [1–3]. Numerous studies have demonstrated that exposure to urban green spaces benefits human mental health [4–6]. In spite of the fact that urban green spaces are beneficial in terms of soothing emotions, access to public spaces is restricted in order to reduce the danger of collective infection during the epidemic control process. As a result of the outbreak of the COVID-19 pandemic in 2020, epidemic prevention measures such as home isolation in order to prevent the spread of the epidemic have arouse negative feelings among the people [7,8]. It is therefore

* Corresponding author.
E-mail address: cguamoy@my.honam.ac.kr (C. Gu).

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imperative to provide the public with a new way to perceive nature during this difficult time.

According to previous studies, viewing green spaces at home can regulate one's moods in a similar manner as visiting natural areas [9]. However, simply viewing green plants in an indoor space is not sufficient to provide people with a full appreciation of the natural world. Virtual reality (VR) technology has been applied to studies of visual perception in psychology, and positive results have been observed [10]. Through the VR environment, users can have an immersive visual experience, providing a multi-sensory experience similar to visiting the virtual environment in person with 3D images, head motion tracking, hand motion tracking, stereo sound, etc. [11]. Moreover, there is evidence that creative cultural activities, such as painting, are beneficial to one's health and emotional well-being [12]. During painting, human beings need to mobilize their visual and other senses to participate in feeling objects, and describe objects. Art activities can enhance emotions related to vitality, causing people to feel alive, joyful, and powerful [13].

Presently, there is no study with the use of VR devices to paint in virtual natural environments. There are still some restrictions on access to parks or green spaces during the pandemic, as well as concerns about health issue. It is unfortunate that so many people lose contact with nature. Users' perception of nature in virtual space is a compensation for reduced outdoor gathering behaviors in the real world. Using digital media technology to simulate the real world is a valuable endeavor. To address these issues, the purpose of this study is to discuss the functional design strategy of virtual reality technology for painting experiences. Thus, from the perspective of user behavior analysis, it is imperative that users are provided with a more engaging experience when painting natural subjects in virtual environments through the use of a variety of sensory input modes [14,15]. As a result of optimizing the VR painting system, it provides additional opportunities for users to engage with natural landscapes.

This study aims to optimize the VR painting experience system. We will discuss ways in which design strategies can be implemented to enhance perceived playfulness and continuous painting intention when using VR technology. In order to promote painting education, provide design advice in developing the VR painting system. Another main contribution of this article is improving users' long-term use of VR systems for digital painting learning. People are unable to goto parks and green spaces during COVID-19. Virtual reality paintings offer a new way to appreciate nature. It is an interesting digital technology worth studying. At the same time, the results of this study also lay the foundation for the development of VR systems and theoretical construction in the field of education.

2. Literature review

2.1. The application of virtual reality to painting

VR (Virtual Reality) is a complex media system that simulates the real and imagined worlds [16]. Utilizing a computer-generated 3D virtual environment in which the user is able to interact with objects, creating a strong three-dimensional perception that makes it seem as if he or she is physically present [17]. Virtual Reality technology allows users to experience auditory, visual and other multi-sensory information, giving them a near-real sensory experience within a virtual environment [18]. The first prototype of VR was created by Jaron Lanier in 1980, who created the world's first head-mounted display (HMD) and the world's first VR control glove. Virtual reality technology can be divided into the following types: low-immersion desktop VR, which allows users to interact with 3D landscapes created by a computer using portable devices such as telephones and laptops; CAVE, which utilizes mobile devices in a confined space to provide a panoramic sensory experience; and head-mounted displays, which provide a more immersive experience. It has been demonstrated that multi-sensory VR technology improves the user experience [19,20]. Virtual reality painting involves the use of VR equipment to bring users closer to experiencing a natural scene in a virtual reality setting. As a result of this technology, people can connect with nature in a safer way during the COVID-19. It should be noted that different individuals experience VR differently, and that dizziness and other adverse effects may arise when VR technology is involved [19,20].

2.2. Perceived interactivity

The term "interactivity" refers to a set of actions resulting from human interaction with an environment, objects, or people [21]. Perceived interactivity (PI) is an important component of interactivity [22]. Perceived interactivity is believed to be an important factor in information exchange, either face-to-face or online [23]. In recent years, researchers have paid more attention to the interaction associated with new media devices [24]. The concept of perceived interactivity has been defined and operationalized differently by various studies included in McMilan and Hwang's review [25]. The perception of interactivity involves three dimensions: two-way communication, time required to load or find the message, and control of navigation. When these dimensions overlap, synchronous/asynchronous communication, active/passive participation, and engaging/complex activities are the results [25]. Literature research relevant to perceived interactivity at present focuses primarily on three aspects: technical characteristics, information processing processes, and user perceptions [26–28]. In our study, PI is defined as a psychological state experienced by a user during the interaction with the VR painting process.

2.3. Aesthetics

In the context of human computer interaction (HCI), there are two types of aesthetics: classical aesthetics and expressive aesthetics [29]. In classical aesthetics, the emphasis is on traditional ideas, emphasizing the originality of design. In expressive aesthetics, there are different quality dimensions such as: ergonomic、hedonic and instrumental and non-instrumental [30]. The importance of aesthetics in human-computer interaction has been demonstrated [31]. It is vital that the visual element of a virtual environment is properly implemented to enhance perceptual experience. With the high aesthetic value of the interface design, users are able to create a

more immersive experience when using the VR for painting.

2.4. Perceived novelty

Novelty is defined as the experience of something new or different from one's regular routine [32]. Perceived novelty (PN) refers to how users perceive technology, for instance, as something new, intriguing, and different from what they have previously encountered or understood [33]. Users' perceived novelty in new media is often considered a positive characteristic in the field of technology [34]. The perception of novelty by users of electronic devices, such as smartphones and tablets, can contribute to increased engagement and continued usage of those devices [35]. It has been shown that users' favorable evaluations of novelty are predictive of higher interest in the product [36]. Unfamiliar surroundings can spark interest in content [37]. However, users also weigh the risks and benefits of adopting a new technology [38], and ease of use [39]. The user will feel excited during the exploration process, which allows the user to enter a state of flow, also known as cognitive immersion [40]. In this study, the focus is on the PN generated when using VR equipment that provides a close experience to painting and the natural landscape.

2.5. Perceived sustainability

A growing body of research in recent years has addressed the possible benefits of perceived sustainability. With industrialization, mass production has increased, energy development has increased, and private consumption has increased, all of which have adverse effects on the environment [41]. The issue of environmental sustainability and the negative impact of human behavior on the environment became increasingly important as users began to contemplate the relationship between humans and nature [42–44]. This type of study involves observing how people reduce food waste by eating out and eating vegetarian foods on a regular basis [45], regulate the use of energy-saving and environmentally friendly means of transportation, such as shared bicycles [46], and raise awareness of environmental sustainability through sustainability education and implementation [47],etc. In this study, we investigate the effect of perceived sustainability on user behavior within the virtual natural environment created by VR systems.

2.6. Theory of planned behavior

Perceived Behavior Control (PBC) is a concept proposed in the Theory of Planned Behavior (TPB). Based on the Theory of Reasoned Action by Fisher and Ajzen [48], Icek Ajzen developed his theory of planned behavior [49,50]. TPB is used to describe the actions of a person under control. TPB suggests that human behavior is the result of careful plan and that all factors that influence behavior are indirect effects of behavior through behavior intention [50]. TPB proposes a new concept called Perceived Behavior Control. According to TPB, behavioral intention is influenced by three factors, which include personal attitude from the inner influence; subjective norm from the outer influence; and perceived behavioral control from both the internal and external influences [50]. In contrast to subjective norms, this research examines the users' feelings to optimize the design of virtual reality systems for painting in virtual natural environments. Therefore, the research model incorporates both attitudes and perceived behavioral control.

Attitude (AT) is the objective assessment of the psychology and emotions of an individual [51]. A person's attitude can reflect their emotional response to a particular behavior [52], whether they like or dislike the feeling of performing that activity [53]. The attitude of an individual is a psychological tendency, a state of the individual that cannot be directly observed, but can be derived from observable behaviors [54]. As part of this study, we examined the impact on attitudes of PI, AE, PN, and PS when users use VR to paint in a virtual natural environment.

The concept of perceived behavior control (PBC) is a reflection on behavior arising from internal or external constraints [50] that is used to indicate situations in which people lack complete volitional control over the behavior they desire [55]. According to Ref. [53]; the decomposed theory of planned behavior (DTPB) is a theory with good explanatory power. Hence, when exploring painting experiences with VR equipment, the perception is studied in reference to the PBC construct in DTPB. PBC may be influenced by facilitating conditions, which includes: their belief in the effectiveness of the system and the availability of the infrastructure [56]. Facilitating conditions in the field of information technology use can be divided into: resource facilitating conditions (RFC) and technology facilitating conditions (TFC). RFC refers to time and money resources, TFC refers to issues of technical compatibility that may affect users. A lack of facilitating conditions may hinder the use of technology or the formation of intentions in general. Nevertheless, the presence of facilitating conditions does not necessarily imply that users will take advantage of the service [53].

Behavioral intention refers to the motivational factors that influence a given behavior; the stronger the intention, the more likely it is that the behavior will be performed [50]. Intention is closely related to behavior [57], so to some extent that intention could be predicted, so could behavior. Accordingly, this study takes TPB and DTPB as the basis, incorporates AT, RFC, TFC, PBC, and BI into the model, and examines their relationship to VR painting behavior [50].

2.7. Perceived playfulness

Perceived playfulness (PP) is a subjective experience that exists between the user and IT, which is ephemeral and unconstrained [58,59]. It refers to a playful state in human-machine interaction, and its essence is focus, enjoyment and curiosity [60]. A single degree of emotional pleasure is commonly used to measure PP [61–64]. The hedonistic use of technology requires users to focus on self-fulfilling value rather than instrumental value, and experience happiness and enjoyment [65]. Therefore, PP may be closely associated with non-utilitarian intrinsic motivation. With the use of VR devices, one of the purposes of this study is to increase users' PP

when painting in a virtual natural environment.

2.8. Continuance intention

Continuance intention can be viewed as a way to assess the success of a product or service based on the behavior of consumers following the use of a product or the experience they have of a service [66,67]. Bhattacherjee was one of the first scholars to distinguish between technology acceptance and continuance behavior. He defines information system continuance intention as *an individual's intention to continue using an information system (unlike initial use or acceptance)* [68]. A number of research fields have applied continuance intention (CI) in recent years, including social networks [69–71], learning and education [72,73], mobile apps [74,75], business marketing [76,77], etc. VR painting provides a variety of benefits including the possibility to have long-term contact with nature in virtual space, which fosters skills development.

3. Method

This study was conducted according to the guidelines of the Declaration of Helsinki and received academic ethics review and approval from the review committee of the Ministry of Social Science, Changshu Institute of Technology. Our experiments informed consent was obtained from all participants and all methods were performed as per relevant guidelines and regulations.

In this study, we used a quantitative research method. The main methods used to construct a model of user behavior are exploratory factor analysis, confirmatory factor analysis, and structural equation modeling. In this section, we first present relevant hypotheses in 3.1 for AT, PBC, BI, and CI when users use VR to create natural scenes within virtual environments. A description of the subjects who participated in this survey study is provided in 3.2. Finally, in 3.3 we present our ideas regarding the design of questionnaires.

3.1. Hypothesis deduction

Fig. 1 shows the research hypothesis proposed in this study.

In order to improve the user's painting experience in virtual nature in the VR system, this study primarily investigates factors such as perceived interactivity, aesthetics, perceived novelty, and perceived sustainability, and examines their influence on the user's attitude. The majority of attitudes research focuses on the causes and effects [78]. According to previous research, the perceived interactivity of a website affects a user's attitude [79]. The more interactive the website is, the more likely users are to be positive about using it. Studies of online shopping malls indicate that the aesthetics of the web design directly impact consumers' attitudes toward the mall [80]. While this is a different type of media from virtual reality systems, the user experience is similar to media that incorporates the same interactive functions and interface features. According to Ref. [81] research on online Mukbang, perceived novelty has a significant impact on attitudes. The more novel the content is, the more likely it is to arouse participants' positive feelings. In a study of the relationship between consumers' environmental concerns and their dining choices, attitudes toward the environment showed an upward trend in terms of perceived environmental sustainability [45]. Therefore, perceived sustainability might also influence a user's attitude towards the interactive system. To sum up, we propose the following hypotheses:

H1: Perceived interactivity has a positive effect on attitude.

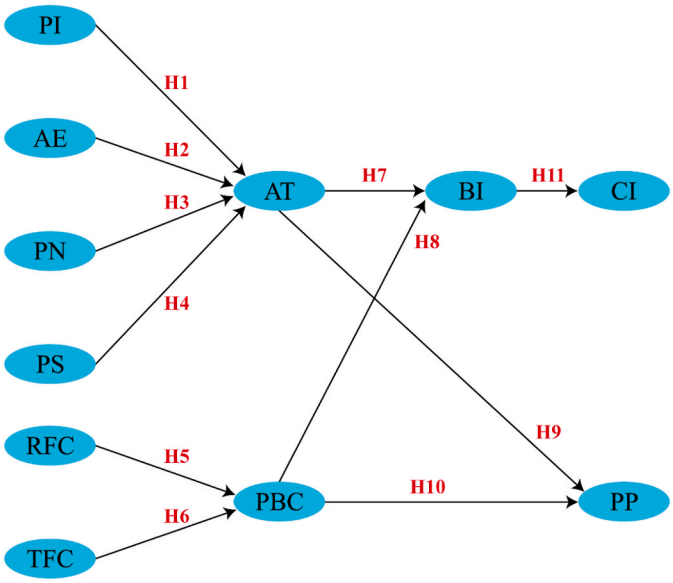

Fig. 1. Hypothetical model.

H2: Aesthetics has a positive effect on attitude.

H3: Perceived novelty has a positive effect on attitude.

H4: Perceived sustainability has a positive effect on attitude.

According to Taylor and Todd's decomposed theory of planned behavior [53], there is a close relationship between users' PBC, RFC, and TFC. Many previous studies have examined the relationship between users' PBC, RFC and TFC. In the original literature, RFC exhibited a significant effect; However, TFC had a negligible effect. When it comes to applying this theory in other fields, TFC is usually an important factor to consider. For example, a study of the intentions of working adults to participate in microlearning found that TFC was a significant predictor of PBC. Technical support and compatibility improvements make incumbents more willing to participate in microlearning [82]. Similarly, for community software adopters, TFC affects user behavior significantly [83]. The following assumptions are made in summary:

H5: RFC has a positive effect on perceived behavior control.

H6: TFC has a positive effect on perceived behavior control.

The majority of developmental and iterative research based on the TPB focuses on the relationship between attitude, perceived behavior control, and behavior intention [84]. investigated consumer behavior during social media use and concluded that perceived behavior control had a significant impact on behavior intentions. In the case of social media consumers, there may be an increased willingness to use due to perceived high levels of control or positive control effects. According to studies on live-streaming, user attitudes are significant predictors of behavioral intention. Furthermore, the results of the research on the intentions of users to use the self-driving car demonstrate that attitudes and perceived behavior control will have a positive impact on the behavioral intention of users [85]. To summarize, we make the following hypotheses:

H7: Attitude has a positive effect on behavioral intention.

H8: Perceived behavior control has a positive effect on behavioral intention.

In the existing educational research, researchers often examine the function that perceived playfulness of educational equipment or teaching methods can play in making students acquire a better learning attitude [86]. It is the same in the field of marketing, as consumer attitudes towards products are an important element that brands evaluate [87]. However, perceived playfulness is one of the most important reasons for users to engage with VR devices when they are painting in a virtual environment. Therefore, our study focuses on how to improve perceived playfulness by improving users' attitudes. Researchers have found a positive correlation between perceived playfulness and attitudes toward mobile instant messaging [88]. The attitude of the user can affect perceived playfulness. Muñoz Carril [89] discovered in their study of early childhood teachers who used blogs as an educational tool that the more positive their attitude towards blogs, the more interesting they found the medium to be. Furthermore, taking into account the close relationship between perceived behavior control and the user's attitude in the theory of planned behavior [90], this study attempts to explore the possible relationship between perceived behavior control and perceived playfulness. To sum up, we make the following hypotheses:

H9: Attitude has a positive effect on perceived playfulness.

H10: Perceived beDalvihavior control has a positive effect on perceived playfulness.

In terms of users' intentions to use smart-connected sports products, previous research has shown that attitude and perceived behavior control have significant impacts on continuance intentions [91]. As an example, the process of applying self-service technologies [92] and the continued intent to use mobile data services [93]. Both factors are important antecedents of the TPB. Thus, behavioral intention may have a positive impact on the user's intention to continue when painting into the VR system. As a result, the

Table 1
Demographic characteristics of the respondents.

Sample	Category	Number	Percentage (%)
Gender	Male	271	37.022
	Female	461	62.978
Age	18–25	171	23.361
	26–30	291	39.754
	31–40	229	31.284
	41–50	35	4.781
	Above 51	6	.820
Income	Under 4000	109	14.891
	4001–6000	221	30.191
	6001–12000	287	39.208
	12,001–18000	90	12.295
	Above 18,001	25	3.415
Education	Middle school and below	18	2.459
	High school or technical secondary school	149	20.355
	Undergraduate or junior college	493	67.350
	Graduate and above	72	9.836
Occupation	Public servant	71	9.699
	National-capital enterprise	171	23.361
	Private-owned enterprise	232	31.694
	Public service organization	122	16.667
	Foreign-capital enterprise	41	5.601
	Student	95	12.978

following hypothsis is proposed:

H11: Perceived behavior control has a positive effect on continuance intention.

3.2. Demographic characteristics

In this study, users who have experience with the VR system for painting, have been invited to participate in the research through the use of online questionnaires between October 2021 and April 2022. Participants scan the QR code and link to view the survey description. Participants in the survey answer the research questions voluntarily, and they may end the survey at any time. Thus, all the subjects were willing to complete the questionnaire under the principle of fully informed and voluntary participation. We received 1184 samples in total. With invalid samples removed (no actual experience, logical errors, or too many identical options), 732 samples were confirmed valid, resulting in an effective rate of 61.824%. There are 47 items in the questionnaire, and there are 732 valid samples that are satisfying the maximum likelihood method proposed by Jackson. The ratio of estimated parameters to samples (p:n) is greater than 1:10 [94]. Table 1 shows the variable distribution of subjects in this valid questionnaire.

3.3. Questionnaire design

In this study, questionnaires utilize a five-point Likert scale (1 is strongly disagree, and 5 is strongly agree). The questionnaire is based on validated items from previous research and has been translated into Chinese. Due to different research objectives, the subject of the questionnaire has been modified, without altering the questions. The questionnaires were read by five pre-testers who were randomly selected and fit the scope of this study. The candidates were asked to assess whether they completely understand each of the question items. The Chinese expressions of the items were polished following discussions with pre-testers to facilitate understanding. This study measures PI using 3 items proposed by Ref. [95]. Measured AE uses 3 items proposed by Ref. [87]. Measured PN uses 3 items suggested by Wells, J. D. et al. [96]. Measured PS uses 4 items was proposed by Ref. [97]. PS, TFC, AT, and BI were assessed using the items proposed by Taylor and Todd [53]. Except for AT, which is comprised of 4 items, all the other dimensions are composed of 3 items. Measured PBC with 4 items proposed by Wei [46]. Measured PP with 4 items proposed by Ref. [98]. CI is assessed through the use of 3 items proposed by Ref. [99]. Additionally, 2 reverse questions were added to the questionnaire to evaluate the validity of the answer, which are opposite to item 1 of AE and opposite to item 2 of AT.

4. Results

4.1. Preliminary data analysis and item deletion preliminary

The reliability and validity of items were analyzed prior to formal analysis in this study. After deleting items PS2, AT3, PBC2, PP2, all tests and model fitness indices met the standard. Therefore, the above items were deleted before formal data analysis. The descriptive tests on the remaining items show that all facets have skewness less than 3 and kurtosis less than 8 [100]. Therefore, it meets the normal distribution assumption and is suitable for further analysis. Table 2 provides a description of the test results.

4.2. Reliability analysis

A reliability test measures how consistent or stable the results of the scale are. This questionnaire uses Cronbach's alpha coefficient and Corrected Item-Total Correlation (CITC) to assess the reliability of the results. Cronbach's alpha coefficient could measure the degree of internal consistency. CITC ensures that correlation is unbiased. Table 3 illustrates the reliability analysis test results.

In the present study, the CITC values of each construct are greater than 0.4, and the reliability Cronbach's α coefficients of each measurement variable are greater than 0.7, indicating that no items should be deleted. The scale of this study has good reliability and can be used as a basis for further analysis [101–103].

Table 2
Description of the test results.

Constructs	Mean	S.D.	Skewness	Kurtosis
PI	3.893	.599	−.889	2.379
AE	3.973	.578	−.983	2.346
PN	3.963	.550	−.846	1.692
PS	3.957	.607	−.781	1.074
RFC	3.940	.550	−.960	2.036
TFC	4.001	.549	−.747	.892
AT	3.991	.552	−.812	1.343
PBC	3.911	.603	−.771	.878
BI	3.928	.597	−1.014	2.049
PP	3.997	.553	−.721	1.569

Table 3
Results of reliability analysis.

Item	Corrected Item Total Correlation	Cronbach's Alpha If Item Deleted	Cronbach's Alpha	Item	Corrected Item Total Correlation	Cronbach's Alpha If Item Deleted	Cronbach's Alpha
PI1	.612	.629	.751	AT1	.565	.637	.733
PI2	.536	.717		AT2	.526	.682	
PI3	.591	.655		AT4	.579	.619	
AE1	.556	.560	.701	PBC1	.611	.532	.717
AE2	.487	.646		PBC3	.490	.681	
AE3	.509	.620		PBC4	.510	.659	
PN1	.590	.567	.718	BI1	.580	.653	.745
PN2	.490	.693		BI2	.530	.711	
PN3	.540	.628		BI3	.608	.617	
PS1	.555	.569	.703	PP1	.630	.530	.724
PS3	.516	.618		PP3	.526	.659	
PS4	.491	.649		PP4	.485	.709	
RFC1	.577	.606	.726	CI1	.600	.590	.732
RFC2	.515	.681		CI2	.520	.686	
RFC3	.554	.631		CI3	.546	.656	
TFC1	.636	.579	.743				
TFC2	.548	.683					
TFC3	.527	.710					

4.3. Exploratory factor analysis

SPSS 26.0 was used in this research to detect unidimensionality and perform exploratory factor analysis. In principal component analysis, each construct has a KMO value greater than 0.5 and the significance of Barlett's sphericity test is significantly less than 0.05. Therefore, an exploratory factor analysis can be conducted [104,105]. By using this method of analysis, data can be reduced to a limited number of summary variables and the underlying theoretical structure of phenomena can be explored. Only one new factor with an eigenvalue greater than 1 can be extracted from the items belonging to all constructs, suggesting that the construct has

Table 4
Exploratory factor analysis.

Construct	KMO	Bartlett's Sphere Test	Item	Commonality	Factor Loading	Eigenvalue	Total Variation Explained
PP	.684	.000	PI1	.706	.840	2.005	66.822%
			PI2	.616	.785		
			PI3	.683	.826		
AE	.667	.000	AE1	.672	.820	1.879	62.622%
			AE2	.589	.768		
			AE3	.617	.786		
PN	.666	.000	PN1	.701	.837	1.927	64.227%
			PN2	.577	.760		
			PN3	.649	.805		
PS	.669	.000	PS1	.669	.818	1.885	62.823%
			PS3	.625	.790		
			PS4	.591	.769		
RFC	.678	.000	RFC1	.681	.825	1.943	64.781%
			RFC2	.606	.778		
			RFC3	.657	.810		
TFC	.669	.000	TFC1	.735	.857	1.988	66.266%
			TFC2	.642	.801		
			TFC3	.611	.782		
AT	.682	.000	AT1	.662	.814	1.956	65.202%
			AT2	.616	.785		
			AT4	.679	.824		
PBC	.653	.000	PBC1	.723	.850	1.917	63.911%
			PBC3	.585	.765		
			PBC4	.610	.781		
BI	.682	.000	BI1	.675	.821	1.992	66.411%
			BI2	.611	.782		
			BI3	.706	.840		
PP	.647	.000	PP1	.739	.860	1.938	64.602
			PP3	.629	.793		
			PP4	.570	.755		
CI	.675	.000	CI1	.703	.838	1.954	65.132%
			CI2	.609	.781		
			CI3	.642	.801		

generally good validity [106,107]. Table 4 shows the results of the exploratory factor analysis.

4.4. Confirmatory factor analysis (CFA)

The variables in this study are correlated, which fulfills the premise of path analysis. Table 5 provides confirmation of the factor analysis results. As a result, all fitting values of the model are within the recommended range, and, therefore, the model is well fitted [108].

The term convergent validity refers to the similarity in the results when different methods of measurement are used to measure the same factor. According to the convergent validity results in Table 6, each item has a factor loading greater than 0.5. Furthermore, $t > 1.96$, $p < 0.05$, the ratio of the coefficient estimate to the standard error is significant, in accordance with the fitting index. Furthermore, the combined reliability (CR) value of each construct exceeds 0.6, which means the observed variables under each construct are well explained. And the AVE value is exceeds the base value of 0.36 [109,110], indicating that the scale has good convergent validity [109,110].

Table 7 shows the result of discriminant validity analysis, which refers to the degree to which different constructs are independent of one another. According to the research findings of Fornell and Larcker, if the square root of AVE of each construct is greater than the correlation coefficient between constructs, the model has discriminant validity [108]. All of the diagonal values in this study are greater than the values outside the diagonal, therefore all constructs of this study have good discriminant validity.

4.5. Results of the structural equation model

This study utilizes AMOS software to verify the relationship between variables and model hypotheses. Evaluation of structural model fit is performed by selecting MLχ2, DF, χ2/DF, RMSEA, SRMR, AGFI, CFI, NFI and GFI indicators. According to the researchers [111–113]; the research constructs are measured in terms of research hypotheses and models, as shown in Table 8. All standard models satisfy both the independent level and combination rule of recommended fitting. Therefore, the research model hypothesis is consistent with the actual survey results, and the structural model is well suited. Fig. 2 illustrates the path relationship between constructs.

Additionally, based on the research results of Liao and Hu [114], this study uses $*p < 0.1, **p < 0.05, ***p < 0.001$ as the test criteria to test the path effect in the model. As shown in Table 9, when AT is used as the dependent variable, both PN and PS have a direct positive effect on AT, including PN ($p = 0.36$, $\beta = 0.500$), and PS ($p = 0.019$, $\beta = 0.479$). RFC has a direct positive effect on PBC when it is used as the dependent variable ($p = 0.010$, $\beta = 0.815$). When BI is the dependent variable, PN ($p = 0.019$, $\beta = 0.246$), PS ($p = 0.008$, $\beta = 0.236$), and RFC ($p = 0.011$, $\beta = 0.390$) possess indirect positive effects on BI, AT ($p = 0.002$, $\beta = 0.492$) and PBC ($p = 0.001$, $\beta = 0.479$) possess direct positive effects on BI. As PP is treated as the dependent variable, PN ($p = 0.026$, $\beta = 0.350$), PS ($p = 0.015$, $\beta = 0.336$), RFC ($p = 0.024$, $\beta = 0.206$) have indirect positive effects on PP, AT ($p = 0.003$, $\beta = 0.701$) and PBC ($p = 0.011$, $\beta = 0.253$) have direct positive effects on PP. When CI is the dependent variable, then PN ($p = 0.019$, $\beta = 0.227$), PS ($p = 0.009$, $\beta = 0.218$), RFC ($p = 0.010$, $\beta = 0.360$), AT ($p = 0.002$, $\beta = 0.454$), PBC ($p = 0.001$, $\beta = 0.441$) had an indirect positive effect on CI, and BI ($p = 0.001$, $\beta = 0.922$) had a direct positive effect on CI.

5. Discussion

The following discussion is based on the verification of the structural equation model and various verification results:

H1 is invalid, which means that the user's PI for painting in a virtual natural environment with VR equipment will not affect AT. Although PI is an important factor in information exchange [23], it had no significant effects on user attitudes in the current study. This differs from preconceived assumptions and contradicts previous studies [22,115]. There is a possibility that this may be since when users use VR equipment to paint in a virtual natural environment, they do not care whether it is able to generate perceived interactivity, and other factors such as the novelty created by using VR equipment are considered more important.

H2 is invalid. This means that AE has no effect on the user's AT when using VR equipment to paint in a virtual natural environment. Even though aesthetics play a critical role in both product design and marketing [116], unlike the pre-hypothesis of this study, high aesthetics do not directly influence users' attitude when they use VR equipment to paint in a virtual natural environment.

H3 is valid, indicating that PN positively affects the user's attitude when they use VR equipment to access a virtual reality environment, and the path coefficient is the highest, meaning that the impact on attitude is the most evident. Novelty is perceived as a positive technological characteristic [34]. Using VR equipment for painting could provide a unique visual experience, as well as a novel tactile experience associated with manipulating tools within a virtual environment, both of which may contribute to perceived novelty. Therefore, PN represents a key influence on consumer attitudes toward using VR devices to paint in a virtual natural environment.

H4 is valid, indicating that PS has a positive impact on the AT when paint in a virtual natural environment, and the path coefficient

Table 5
Adaptation indices of the CFA model.

Common indices	χ2	df	χ2/df	RMSEA	GFI	IFI	CFI	TLI	SRMR
Judgment criteria			<3	<0.08	>0.9	>0.9	>0.9	>0.9	<0.08
Value	1023.733	440	2.327	.043	.922	.941	.940	.928	.034

Table 6
CFA convergent validity.

	Items	Factor loading	t value	p value	SMC	AVE	CR
PI	PI1	.738	20.044	.001	.544	.505	.754
	PI2	.671	17.999	.002	.451		
	PI3	.722	19.574	.001	.522		
AE	AE1	.734	20.389	.001	.539	.443	.704
	AE2	.628	16.936	.001	.394		
	AE3	.630	16.999	.001	.397		
PN	PN1	.689	19.527	.001	.475	.464	.722
	PN2	.665	18.665	.001	.442		
	PN3	.690	19.569	.001	.477		
PS	PS1	.662	18.374	.001	.438	.443	.704
	PS3	.702	19.733	.001	.493		
	PS4	.630	17.290	.001	.396		
RFC	RFC1	.710	20.359	.001	.504	.473	.729
	RFC2	.668	18.869	.001	.446		
	RFC3	.685	19.485	.001	.470		
TFC	TFC1	.750	21.588	.001	.563	.500	.749
	TFC2	.714	20.287	.001	.510		
	TFC3	.653	18.118	.001	.426		
AT	AT1	.726	21.423	.001	.527	.477	.732
	AT2	.679	19.701	.001	.462		
	AT4	.665	19.177	.001	.442		
PBC	PBC1	.715	19.948	.001	.511	.462	.720
	PBC3	.677	18.686	.001	.459		
	PBC4	.646	17.622	.001	.417		
BI	BI1	.681	19.565	.001	.464	.498	.748
	BI2	.692	19.955	.002	.478		
	BI3	.742	21.852	.001	.551		
PP	PP1	.750	21.935	.001	.563	.479	.732
	PP3	.713	20.566	.001	.508		
	PP4	.604	16.710	.002	.365		
CI	CI1	.740	21.494	.001	.548	.480	.734
	CI2	.677	19.190	.002	.458		
	CI3	.659	18.569	.001	.434		

Table 7
Discriminant validity.

	PI	AE	PN	PS	RFC	TFC	AT	PBC	BI	PP	CI
PI	.711										
AE	.370	.666									
PN	.376	.556	.681								
PS	.381	.503	.518	.666							
RFC	.389	.500	.568	.539	.688						
TFC	.345	.466	.565	.556	.586	.707					
AT	.376	.570	.640	.611	.629	.538	.691				
PBC	.423	.443	.439	.501	.512	.464	.535	.680			
BI	.388	.504	.504	.522	.573	.485	.600	.568	.706		
PP	.356	.503	.572	.555	.598	.526	.631	.519	.609	.692	
CI	.400	.421	.453	.529	.544	.494	.568	.555	.665	.556	.693

Table 8
Adaptability of SEM.

Common indices	χ2	df	χ2/df	RMSEA	GFI	IFI	CFI	TLI	SRMR
Judgment criteria			<3	<0.08	>0.9	>0.9	>0.9	>0.9	<0.08
Value	1133.315	469	2.416	.044	.914	.933	.932	.924	.038

is second only to PN. Studies have shown that PS (from an environmental and social standpoint) is related to consumers' AT [117,118]. One of the biggest challenges contemporary society faces is how to sustainably utilize Earth's resources in the face of increasing socio-economic populations [119]. The Sustainable Development Goals are at the heart of the UN 2030 agenda. Through using VR equipment, one can paint in a virtual natural environment without the need for chemical paints and experience the natural green space within the virtual environment. When individuals experience a virtual natural environment, they are more inclined to pay attention to sustainable development and environmental protection.

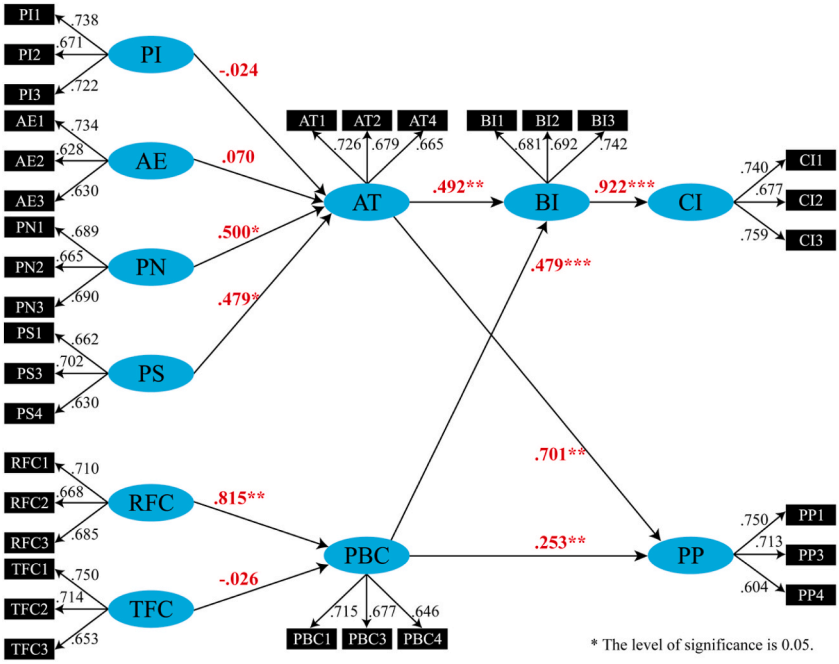

Fig. 2. Structural equation model.

Table 9
Direct and indirect effects.

Path	Direct effect		Indirect effect		Total effect	
	β	B–C Sig.	β	B–C Sig.	β	B–S Sig.
PI→AT	−.024	.711	/	/	−.024	.711
AE→AT	.070	.639	/	/	.070	.639
PN→AT	.500	.036	/	/	.500	.036
PS→AT	.479	.019	/	/	.479	.019
RFC→PBC	.815	.010	/	/	.815	.010
TFC→PBC	−.026	.993	/	/	−.026	.993
PI→BI	/	/	−.012	.662	−.012	.662
AE→BI	/	/	.034	.594	.034	.594
PN→BI	/	/	.246	.019	.246	.019
PS→BI	/	/	.236	.008	.236	.008
RFC→BI	/	/	.390	.011	.390	.011
TFC→BI	/	/	−.012	.991	−.012	.991
AT→BI	.492	.002	/	/	.492	.002
PBC→BI	.479	.001	/	/	.479	.001
PI→PP	/	/	−.016	.718	−.016	.718
AE→PP	/	/	.049	.627	.049	.627
PN→PP	/	/	.350	.026	.350	.026
PS→PP	/	/	.336	.015	.336	.015
RFC→PP	/	/	.206	.024	.206	.024
TFC→PP	/	/	−.007	.937	−.007	.937
AT→PP	.701	.003	/	/	.701	.003
PBC→PP	.253	.011	/	/	.253	.011
PI→CI	/	/	−.011	.658	−.011	.658
AE→CI	/	/	.032	.589	.032	.589
PN→CI	/	/	.227	.019	.227	.019
PS→CI	/	/	.218	.009	.218	.009
RFC→CI	/	/	.360	.010	.360	.010
TFC→CI	/	/	−.011	.993	−.011	.993
AT→CI	/	/	.454	.002	.454	.002
PBC→CI			.441	.001	.441	.001
BI→CI	.922	.001	/	/	.922	.001

H5 is valid, indicating that RFC has a positive impact on PBC when users use VR equipment to paint in a virtual natural environment. H6 is invalid, indicating that TFC does not have a significant impact on PBC of users who are using VR equipment in a virtual natural environment. In regards to the external factors impacting PBC, RFC is clearly more significant, which is consistent with the result of DTPB [120]. In utilizing VR devices, users place a higher value on the convenience of time and money than on technological elements such as compatibility. At present, VR technology is in its infancy and needs to become more mature in terms of battery life, visual image quality, wireless communication technology, etc. before it is widely adopted [121]. It will take some time for VR systems to become mainstream devices for interactive experiences. The creation of an API capable of handling various VR devices is crucial [122]. The maturity of VR technology can contribute to a reduction in device costs, thereby increasing user adoption [121].

H7 is valid, revealing that the user's AT use of VR equipment to paint in a virtual natural environment has a positive impact on BI. H8 is valid, demonstrating that PBC of users using VR equipment to paint in a virtual environment has a positive impact on BI. Furthermore, when using VR equipment to paint in a virtual natural environment, the impact of the user's AT on BI is higher than that of the PBC, which is consistent with the theory of planned behavior [50]. There is evidence that AT plays a critical role in user-generated BI.

H9 is valid, indicating that the user's AT of utilizing VR equipment to paint in a virtual natural environment has a positive impact on PP. H10 is valid, indicating that PBC has a positive impact on PP. PP represents the intrinsic motivation associated with any new system [123–125]. Studies have shown that: concentration of attention during interaction, curiosity about the interaction process, enjoyment of the interaction process, interest in the interaction process, these three things have an impact on the individual's PP [126]. It is noteworthy that under this research topic, the positive effect of PN was confirmed, and perceived interactivity did not affect PP by affecting AT. Most of the literature focuses on the positive effects of PP on AT, and the effects of AT on BI. This study explores the impact of AT and PBC on PP and finds that AT has a greater positive effect on PP than PBC, showing that if users want to feel interesting from VR virtual natural environment paintings, they should focus on the attitude of the Users.

H11 is valid, indicating that the BI of the user who paints in a virtual natural environment with a VR device has a positive impact on CI. Using the Theory of Planned Behavior, AT affects BI and therefore affects behavior [50]. There is a strong link between behavior and intent. The stronger the BI, the more likely it is to execute that behavior [50,57]. VR equipment can provide users with an immersive experience, meaning they are more likely to achieve flow, i.e., to participate in this activity without regard to external interests, but for enjoyment and pleasure [126]. During the Flow experience, the user will not feel the passage of time and stimulating CI.

6. Theoretical implications

This study has important theoretical implications, in which we analyze the factors that influence users' PP and CI when they use VR equipment to paint in a virtual environment. In addition, the results of this study can be used to promote sustainable development and ecological protection and can also provide reference for relevant practitioners and software developers during COVID-19. The model constructs were validated by using SEM, and this study investigated the interrelationships between AT, PBC, BI, CI, and PP. This study has demonstrated the positive impact of PN and PS on AT when the user uses VR equipment to paint within a virtual natural environment, and the positive impact of RFC on PBC, whereas TFC has no impact on PBC. In addition, although PI and AE have been regarded as the key factors affecting AT in many studies, they did not affect AT in this context. The PI and AE are therefore not the top concern of users when using VR devices to paint in a virtual natural environment. In contrast, users are concerned that this process is novel, exciting, can save time and effort, and may contribute to sustainable development.

7. Practical implications

This study has important theoretical significance and examines the factors that affect users' PP and CI when they use VR devices to create virtual natural environments. According to the result of this study, the software R&D department should pay closer attention to the frequency of updating the content of the VR painting system. The addition of more novel features and interfaces, such as different styles of painting scenes, specific brush styles, and hidden special settings, will allow the users to continue to experience novelty even after a period of prolonged use and generate interest. Furthermore, in the VR painting system, add settings for natural environment-friendly scenes such as urban green space and natural landscapes, as well as settings for wild animal images. It is possible to use this function to get closer to nature, to perceive nature, and to promote the concept of protecting the environment as well as promoting sustainable development of the environment. Additionally, to facilitate the widespread use of VR equipment, it is necessary to support the development and research of VR equipment, or to reduce the manufacturing costs of non-functional hardware. Users can upgrade the configuration according to their own economic capacity.

8. Conclusion

Based on the findings, it is recommended to strengthen the development of new functions in the VR painting system development process, so users can adopt a positive attitude, appreciate the process, and be more likely to continue using it. Secondly, the use of VR for digital painting is still in its infancy. The present study extends its theoretical foundation by incorporating AT, PBC, BI, CI, and PP, and this construction is beneficial to related applications in the field of education. For the COVID-19 period, as part of the epidemic prevention measures and for the sake of safety, individuals could enter the virtual green space and interact with the virtual green space by painting. In addition, people who cannot go outside due to physical health problems or other reasons can take advantage of this type

of digital technology as a new method for communicating with nature, such as the elderly, the sick, and the disabled. In addition, the results of this study indicate that users attach great significance to perceived sustainability when using a VR painting system for their personal painting. Thus, it is possible to explore and apply this function from the perspective of cultivating ecological protection. There are still some limitations to our study that can be explored in future research:

1. The results of this study show that AT is not affected by PI or AE, but for what reason is unclear, it is worth further investigation.
2. In this study, quantitative research methods are used. Future studies may triangulate the data by measuring different variables and cross-checking to enhance the validity of the study. The research perspective can be further enhanced by adopting qualitative research methods.
3. In this study, we examine ways for people to feel close to nature during the COVID-19 period when it is inconvenient to go outside. However, it was unexpectedly found to have benefits for perceived sustainability as well. A future research initiative can start from this perspective and explore the value of VR-related applications.
4. Add new adjustments variables for further evaluation, based on different demographic characteristics

Author contribution statement

Jie Sun; Yanan Wang: Conceived and designed the experiments; Wrote the paper. Wei Miao; Wei Wei; Chun Yang; Jiangjie Chen: Performed the experiments; Contributed reagents, materials, analysis tools or data. Fangfang Yang; Longfei Ren: Performed the experiments; Analyzed and interpreted the data. Chao Gu: Analyzed and interpreted the data; Wrote the paper.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declaration of competing interest

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.heliyon.2023.e16201.

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