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The impact of immersive virtual reality on art education: A study of flow state, cognitive load, brain state, and motivation

Xiaozhe Yang[1] · Pei-Yu Cheng[2] · Xin Liu[1] · Sheng-Pao Shih[2]

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Abstract

This paper presents a new art metaverse prototype, constructed using virtual reality technology to create an immersive scene with a specific artistic style and integrate virtual avatar technology to allow interaction with characters in the art painting. Ninety-six college students participated in the study, divided into two groups: the virtual reality group ($N=48$), who explored the art metaverse, and the computer group ($N=48$), who engaged in traditional art appreciation by viewing artworks on a screen. Both groups then participated in art painting activities. The results showed that the virtual reality group experienced a significantly more positive impact on their art attitude compared to the computer group. Furthermore, EEG attention monitoring revealed that during the art painting activity following the art appreciation activity, the virtual reality group demonstrated significantly higher attention levels than the computer group. This study highlights the potential of virtual reality technology to enhance art appreciation and provides valuable insights for the future development of virtual reality metaverses.

Keywords Metaverse · Virtual reality · EEG · Art experience · Flow · Cognitive load

1 Introduction

The impact of virtual reality on education has long been the focus of attention among researchers (Burdea & Coiffet, 2003). With the capability to immerse individuals in a different world, virtual spaces allow for free navigation and interaction with objects and characters within the virtual environment (Fox et al., 2009). The

✉ Pei-Yu Cheng
peiyu.cheng.tw@gmail.com

1 Institute of Curriculum and Instruction & Classroom Analysis Lab, East China Normal University, Shanghai, China

2 Department of Information Management, Tamkang University, Taipei, Taiwan

technology of virtual reality technology can simulate intricate scenarios, promote remote collaboration, and offer a unique perspective of the virtual world that may be difficult to attain in reality (Parsons et al., 2017). As the technology of virtual reality evolves, researchers have been exploring the concept of a metaverse, a virtual space that runs parallel to reality and exceeds it (Dionisio et al., 2013; Ondrejka, 2004). The potential of a metaverse has sparked excitement among researchers, offering an entirely new mode of the virtual world experience with immersive and interactive environments. In this space, people can participate in various activities, discover new possibilities, and experience a parallel world beyond reality. Researchers are continuously advancing virtual reality technology to bring the vision of the metaverse to fruition and unlock its full potential for education, entertainment, and beyond (Hwang & Chien, 2022).

Virtual reality has been explored in education as a tool for knowledge learning and skill training. Several studies have shown its potential in this regard (Huang & Han, 2014). Virtual reality technology is a valuable tool in art education, creating an interactive environment for artistic experiences and bringing new life to art (Simo, 2019). Participants engage in an enjoyable process, which leads to the creation of concrete visual expressions and novel artistic representations (Hacmun et al., 2018; Kaimal et al., 2020). While virtual reality technology has many benefits in improving learning outcomes, it is essential to carefully consider the amount of information being processed to ensure effective cognitive processing and creativity (Kassim et al., 2014). Additionally, objective monitoring of physiological responses, such as heart rate and brain activity, may provide insights into an individual's mental and psychological changes during the artistic experience (Xu & Zhong, 2018). In prior research, limited experiments have been conducted to explore the effects of virtual reality on the moods, emotions, and attitudes of individuals or groups (Atilola et al., 2016). This study aims to investigate the impact of virtual reality and the art metaverse created by it on subjects' art learning experience. It focuses specifically on the influence of the virtual environment on art attitude and the mechanism of change during the input process of art learning. Previous research has categorized art activities into two types: art appreciation activities, which concentrate on the input process of art learning, and artistic expression activities, which concentrate on the output process of art learning (Forseth, 1980; Venn et al., 1993) Through examining the effects of virtual reality on art appreciation activities, this study aspires to highlight the potential of virtual environments to shape art attitudes.

Although attempts to build a fundamental art metaverse through virtual reality technology are still in their infancy (Nevelsteen, 2018). this study adapted a VR project, a scene experienced in a virtual reality environment, as the prototype of an art metaverse. The key to exploring its impacts on art learning is the identification of an effective assessment method to understand the subjects' art learning process in virtual reality. Csikszentmihalyi and Csikszentmihalyi (1992) proposed a mental state called "flow", where people are so completely immersed that they forget their existence. A state similar to flow often occurs in artistic creation (Csikszentmihalyi, 1997). Therefore, the level of the flow state is frequently used to indicate the psychological state during art activities (Jackson & Marsh, 1996). In addition, another psychological change worthy of consideration is whether virtual reality results in an increase in the cognitive load for subjects compared to traditional computer screen interfaces. While questionnaires and scales are useful tools, they may not be sufficient to reflect the subjects' overall changes fully. As such, complementary methods such as physiological measurements may be necessary to support the assessment. In addition, the use of traditional methods to assess learners' subjective feelings may lead to reduced accuracy due to the non-synchronicity between learning state and post-learning survey. EEG-based measurement is therefore a desirable method (Wan et al., 2021). Therefore, the research team has developed an integrated EEG brainwave system with the VR system to collect data on the subjects' attention in virtual reality. The effectiveness of this system has been demonstrated in previous research projects conducted by the team (Yang et al., 2018, 2019b). By using multimodal data, including flow status, cognitive load, and brainwave data, researchers can comprehensively understand the subjects' art learning experience in the virtual reality art metaverse.

Adopting an experimental research method, this study aims to examine the impact of the art metaverse prototype on an individual's art learning, including changes in art attitudes and the acquisition of art knowledge. The research delves into the internal mechanism of art learning and aims to understand the complete changes in the subjects' flow state, cognitive load, and brain state during the art learning process. The following are the research questions of this study:

- Compared with the computer interface, does the virtual reality metaverse cast a more significant impact on the subjects' art attitude?
- Compared with the computer interface, does the virtual reality metaverse cast a more significant impact on the subjects' art knowledge?
- In the art appreciation activities, what are the impacts of the virtual reality metaverse on the subjects' flow state and cognitive load?
- In the art appreciation and art drawing activities, what are the comprehensive influence of the virtual reality metaverse on the brain state of the subjects?

2 Literature review and related work

2.1 Research on virtual reality, metaverse, and education

Virtual reality is a three-dimensional simulated environment generated by a computer system (Witmer & Singer, 1998). Researchers proposed three basic characteristics of VR technology: immersion, interaction, and imagination (Steuer, 1992). A fully immersive virtual reality environment involves all five senses. However, most immersive VR now focuses on the senses of sight and sound (Riva et al., 2007). Head-Mounted Displays (HMD) have been challenging to use in the past because of the high price and limited system stability and imaging quality (Dionisio et al., 2013). Nowadays, with Virtual reality device products such as HTC VIVE and Oculus, it is relatively easier to build an immersive virtual reality environment.

With the development of VR technology, there have been constant trials to build a broader virtual world and realize the digital existence vision in the metaverse. In 1992, science fiction writer Neal Stephenson coined the concept of the metaverse (Ondrejka, 2004). The metaverse is a virtual world parallel to the real world (Dionisio et al., 2013). People can do anything in the metaverse, except sleeping and eating (Collins, 2008). Guided by this concept and through VR technology, people constantly try to build an immersive virtual world, where social interaction, work, learning, living can be realized in a maximum way. Meanwhile, there has been growing research interest in the construction of the metaverse prototype and its educational implications, even though the metaverse is still in its early stage of development (Díaz et al., 2020).

Although not as often as they are applied for entertaining purposes, virtual reality and the metaverse are also applied in the educational field. The dominant multimedia educational resources are mainly in two-dimensional form, but 3D technology is becoming more common and educational content can be presented to students in 2D or 3D format (Bamatraf et al., 2016). The researchers used VR technology to build a virtual museum that was almost identical to reality, and children could pay a remote visit (Egger et al., 2017). Another group of studies, by simulating classical experimental scenarios such as physics, chemistry, and biology, allowed students to control the process of experiments in a virtual environment and try various combinations of experiments (Huang & Han, 2014). In the research, virtual reality has been proved to be helpful for the mastery of experimental skills and the acquisition of relevant content knowledge. Immersive virtual reality has also been applied to medical skills training (Jones et al., 2014). Research has shown that it helps medical beginners with sophisticated operation skills in complex spaces. Among the studies on virtual reality and education, most of them focused on the application of virtual reality to skills training, information acquisition, and remote assistance (Yu & Gong, 2012). Few focused on the effects of virtual reality on learners' emotions and attitudes. Fox et al. (2009) pointed out that the virtual world can be used as an important environment and tool for social science research and its impacts on individuals' cognition and emotion should not be ignored. One study showed that participants played a virtual role in a virtual reality environment who was taller (height) than the person in real life, which helped reduce negative views of themselves (Freeman et al., 2014). This research adopts the perspective of art learning, focusing on the influence of virtual reality and the metaverse on an individual's art attitude and knowledge acquisition, aiming to probe into the influence of virtual reality on learning motivation, learning mechanism, and learning attitude.

2.2 Virtual reality and art activities

Art activities are the main vehicle for art education and learning (Forseth, 1980). From learners' perspective, art activities can be divided into two major kinds: input activities and output activities (Venn et al., 1993). In the field of art education, art input activities often refer to activities such as observation, viewing, and appreciation. The art output activities are mainly painting, copying, design, and other activities (Duncum, 2002). The input and output of art activities contribute to art learning in different ways, and their use in combination is recommended rather than isolation.

Art appreciation activities often have a physical boundary between the subject and the object. Virtual reality technology provides another possibility, allowing learners to enter the three-dimensional world of art (Bellani et al., 2011). The three-dimensional environment of virtual reality tries to get rid of the one-way linear relationship of "artist-work-viewer" in art appreciation activities (Freeman et al., 2014). The learner is no longer outside the work of art, and rather, one could get into it. The complete immersion and the interactive perception of art come in line with the evolving trend of modern art. McLuhan and Zingrone (1997) believes that the medium is an extension of the human body, and virtual reality provides a reverse wrapping extension. The combination of virtual reality headsets, 3D digital objects and other displays can enhance the visual landscape of the object and convey narrative and concept in innovative ways (Cassidy et al., 2018). Although immersive virtual reality technology is deeply related to art learning, there is limited research on the application of virtual reality to art learning (Keefe et al., 2001). In previous study, this research team explored the impacts of virtual reality on an individual's creative design performance (Yang et al., 2018, 2019a). In this research, the comprehensive impact of virtual reality and art metaverse prototype on art learning is further studied, especially in art appreciation activities.

3 Methods

3.1 An art metaverse based on virtual reality

This study compared the different effects of virtual reality environment and computer environment on art appreciation activities. The group in the computer environment served as the control group. The art metaverse constructed by this study was adapted from the VR project, which embodied three VR characteristics, namely three-dimensional sense, interactive sense, and immersion sense.

First, the 3D environment of the art metaverse was recreated using several iconic works of Van Gogh such as "Night Cafe," "Starry Sky," "Sunflower," and "Self-Portrait." For instance, the interior design of the VR was modeled by Van Gogh's original piece, "Night Cafe." The appearance of 3D modeling was crafted to resemble the palette, brushstroke, and other artistic styles seen in Van Gogh's work and applied to different aspects of the 3D objects. This resulted in a virtual art scene with a 3D environment that strictly followed Van Gogh's painting style.

Next, virtual avatars were created to represent characters in the artworks to enhance the sense of interaction in the art metaverse. Characters from Van Gogh's paintings, including Van Gogh himself in his self-portrait, were selected and represented as 3D avatars in the metaverse (as shown in Fig. 1). Visitors to the art metaverse could get up close to the characters, providing a sense of intimacy and interaction.

Afterward, the use of immersive VR equipment enhanced the sense of immersion of the entire art metaverse. The subjects wore an immersive virtual reality device (HTC VIVE) to enter the art metaverse. Different from simple-level virtual reality devices, immersive virtual reality devices constructed a three-dimensional scene in

Fig. 1 The art metaverse based on virtual reality

a much more thorough way. In addition, the subjects' movements in reality such as walking, jumping, squatting, etc., can all be fed back into the virtual world. The subjects wore EEG brain wave detection equipment throughout the process to record subjects' brain states in the art metaverse, especially their attention values during art activities. This approach has been proven feasible and effective in other studies by the research team.

3.2 The design of the experiment

To explore the impact of the immersive art experience in virtual reality on art learning, we took the approach of experimental research. The participants were all college students aged between 20 and 25 years old. The experiment was conducted at a virtual reality laboratory on the university campus. The sample consisted of 96 college students randomly divided into two groups, with 48 students in the experimental group (35 females and 13 males) and 48 in the control group (35 females and 13 males). During the experiment, the experimental group participated in art appreciation in a virtual reality environment, while the control group performed the same task in front of a computer screen. After completing the art appreciation activities, both groups participated in art painting while wearing brainwave detection equipment to measure their attention levels. Finally, all subjects completed relevant questionnaires. The total duration of the experiment was 30 min.

3.3 Experimental procedure

The experimental process is shown in Fig. 2. Before starting art activities, subjects were required to fill in demographic information and take a pre-test of art attitude assessment. After that, the experimental group entered the artistic metaverse prototype, a virtual reality environment constructed by virtual reality technology. This art metaverse was based on Van Gogh's classic paintings "Night Cafe," "Starry Night",

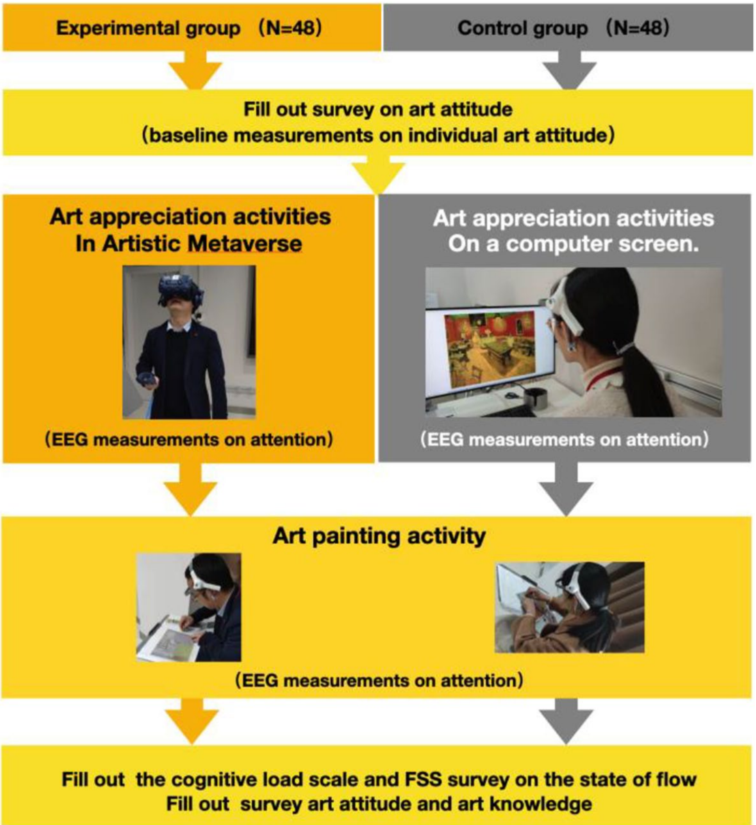

Fig. 2 The experimental process and measurements

"Sunflowers", "Self-Portrait" etc., and used Van Gogh's painting style to stylize three-dimensional scenes. In the virtual reality scene, several human characters in Van Gogh's paintings appeared, and the subjects could approach and observe those artistic characters. The subjects in the experimental group could walk, stand, squat, jump, etc. freely in virtual reality so that the subjects were able to choose different perspectives for art appreciation activities. Subjects in the control group watched electronic versions of Van Gogh's paintings on a computer screen. The subjects in the control group were able to zoom in and out of the electronic version of Van Gogh's artwork with a mouse to take a closer look. After a 5-min art appreciation activity, the subjects were asked to do an art painting activity. In this art painting activity, subjects in the experimental and control groups were asked to color up parts of van Gogh's painting that had been decolorized based on their perception of Van Gogh's artistic style and color characteristics. The decolorized painting was not among those appearing in the Art Appreciation event.

After that, the works of the subjects' painting activities were professionally graded to evaluate the subjects' understanding of Van Gogh's art according to a set of rules. Subjects of both groups wore simple brain wave equipment throughout the art appreciation and art painting activities. Finally, subjects filled out cognitive load scale, flow state scale, the Art Knowledge Test, and the post-test of Art Attitude Questionnaire.

3.4 Instruments and scale validations

The NeuroSky headset recorded EEG data through a single touch sensor on the forehead. The eSense algorithm is then applied to the remaining signal, resulting in explicated eSense meter values. Based on real-time EEG data, the headset could output the values namely attention. The attention value was between 0 and 100. Nowadays, the NeuroSky headset has been widely used in experimental research. Many researchers use this device to measure the brain waves of students as they learn (Sun & Yeh, 2017). Previous research has shown that the NeuroSky headsets provide effective, sufficient and reliable data (Chen & Huang, 2014).

Scales used in the experimental design include Art Attitude Questionnaire, Art Knowledge Test, Flow State Scale (FSS), and Cognitive Load Scale. The Art Attitude Questionnaire was based on the Attitude Scale Questionnaire proposed by Hwang et al. (Hwang et al., 2013). Huang's questionnaire is applied in the environment of educational games, and it has been used by a large number of researches related to attitude. According to the theme of art study, the questionnaire was adapted. It used a 5-point Likert scale ("5 means strongly agree", "1 means strongly disagree", a total of 7 items). The scale can reflect the subjects' attitudes towards the art theme before and after the experiment, including their interest, emotional experience, value recognition and behavior tendency of the art theme. Art Attitudes Scale can be used to assess the overall affective state for art in both the experimental and control groups before the experiment. At the same time, it was also used to evaluate the influence on art attitudes of the art activities. The Cronbach's alpha value of the scale was determined to be 0.79.

The Art Knowledge Test assessed the subjects' understanding of Van Gogh's works, including their recognition of brushstrokes, colors, and scenes. The test was based on the knowledge detection framework (Bloom et al., 1964) and consisted of 10 questions. The first five questions were about scene recognition, and the last five were about recognizing colors and brushstrokes. The test was administered after the art activities to evaluate the subjects' mastery of art knowledge.

The subjects participated in the experiment by filling out the Flow Status Scale and the Cognitive Load Scale. These scales are self-assessments designed to measure the subjects' state of flow and cognitive load during their activities (Bakker, 2005). The Flow Status Scale evaluates factors such as control and enjoyment. Examples are: "I felt in control of what I was doing during the learning activity" (*control*) and "I was completely immersed in this learning activity" (*enjoyment*). Previous work has proposed that these indicators can be used to provide an overall impression of flow during learning activity. Reliability analysis gave Cronbach's alpha of 0.79 for the control factor and 0.86 for the enjoyment factor.

"The Cognitive Load Scale, proposed by Sweller et al. (1998), comprises 8 items rated on a seven-point Likert scale. It measures both "mental load" and "mental effort" with 5 and 3 items, respectively. The scale captures the participants' subjective assessments of the overall load they experienced during the art appreciation and allows them to indicate their perceived level of difficulty or suitability of the learning material. The scale has been shown to be highly reliable, with Cronbach's alpha values of 0.86 and 0.85 for the two dimensions, respectively.

3.5 Data analysis

Statistical Product Service Solutions (SPSS), a social science statistics software, was used to process the data. One-way ANOVA was run to decide whether there was a significant difference in the art attitudes, art knowledge levels, flow state, cognitive load, and the mean of brainwave attention in art appreciation and art painting activities between the experimental group and the control group. In the art painting activity, the subjects were asked to paint on an adapted copy of Van Gogh's painting "Van Gogh's Bedroom in Arles". The work was processed in black and white, and eight areas were selected in it, as shown in the image below. For each area, if the subject's coloration and Van Gogh's coloration belong to the same color family, 1 point was awarded, otherwise 0 points. The color dimension had a total of 8 points (shown in Fig. 3). In the dimension of brushstrokes, according to the overall degree of correlation with Van Gogh's paintings, 2 points were awarded if they were very similar, and 0 points if they were completely different. Based on the scoring standard, three researchers scored all the painting works respectively, and the average value was taken as the final score of the painting works. Due to the varying perspectives of the researchers, there may be discrepancies in the scoring process. To assess the score reliability, the Kendall's Coefficient of Concordance can be used to determine the consistency of scores given by different subjects (Ma et al., 2022). The reliability of the researchers' scoring was analyzed by Kendall's Harmony Coefficient, and the calculated result was 0.533, indicating that the scoring had acceptable reliability.

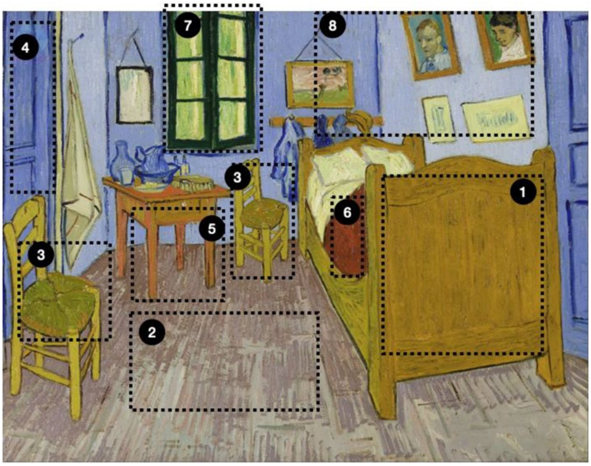

Fig. 3 The eight scoring areas of "Van Gogh's Bedroom in Arles"

4 Results

4.1 Analysis of art attitude

The first research question was addressed by comparing the impact of the virtual reality metaverse and the computer interface on the subjects' art attitude using ANOVA. The research question was phrased as: "Is the impact of the virtual reality metaverse on the subjects' art attitude significantly greater than that of the computer interface?". Before conducting the experiment, an independent t-test was performed to assess if there was a significant difference in the subjects' art attitudes between the two groups. The results showed that there was no significant difference ($p=0.147>0.05$). Then, a paired-sample t-test was used to examine the change in the subjects' art attitude after the experiment, by comparing their pre-and post-test scores. The results showed that both the virtual reality group and the computer group had a significant improvement in their art attitude after the experiment (see Table 1).

The results of the one-way ANOVA test are presented in Table 2, and they indicate a significant difference in the post-test art attitude performance scores between the Virtual Reality group and the computer group [$F(1,94)=18.379$; $p<0.01$]. These results suggest that the virtual reality metaverse had a more significant impact on the subjects' art attitude compared to the computer interface in this experiment.

4.2 Analysis of art knowledge

ANOVA was used to answer the second question, which is, "Compared with the computer interface, does the virtual reality metaverse cast a more significant impact on the subjects' art knowledge?" The subjects of the two groups took the art

Table 1 Paired -sample t-test results of pre-tests and post-tests for art attitude performance

Group	Art attitude performance	N	Mean	SD	t
Virtual reality group	Pretest	48	3.726	0.52	0.000**
	Posttest	48	4.186	0.63	
Computer group	Pretest	48	3.407	0.72	0.013*
	Posttest	48	3.550	0.81	

*$p<0.05$ **$p<0.01$

Table 2 The result of one-way ANOVA test for art attitude performance

	Sum of squares	sd	Mean of squares	F	P
Between Groups	9.722	1	9.722	18.379	0.00**
Within Groups	49.723	94	0.529		
Total	59.445	95			

*$p<0.05$ **$p<0.01$

Table 3 Mean score and standard deviation for art knowledge performance

Group	N	Mean	SD
Virtual reality group	48	7.979	1.509
computer group	48	7.938	1.261

Table 4 The result of one-way ANOVA test for art knowledge performance

	Sum of squares	sd	Mean of squares	F	P
Between Groups	0.042	1	0.042	0.022	0.884
Within Groups	181.792	94	1.934		
Total	181.833	95			

$*p<0.05$ $**p<0.01$

knowledge performance test after the art appreciation activities. The results of one-way ANOVA test are shown in Tables 3 and 4.

According to Tables 3 and 4, there was no significant difference in art knowledge performance score between the Virtual reality group and the Computer group [$F(1,94)=0.022$; $p>0.05$], although both groups did well in Van Gogh's art knowledge performance test.

4.3 Analysis of flow and cognitive load

ANOVA was used to answer the third question, which is, "In the art appreciation activities, what are the impacts of the virtual reality metaverse on the subjects' flow state and cognitive load?" The results of one-way ANOVA test are shown in Tables 5 and 6.

According to the analysis results, there was no significant difference in flow state score between the Virtual reality group and the Computer group [$F(1,94)=2.420$; $p>0.05$]. At the same time, there was no significant difference in cognitive load score between the virtual reality group and the computer group [$F(1,94)=0.017$; $p>0.05$].

Table 5 Mean score and standard deviation for flow state and cognitive loads score

Scale	Group	N	Mean	SD
Flow state	Virtual reality group	48	4.247	0.560
	computer group	48	4.416	0.506
Cognitive load	Virtual reality group	48	2.612	0.145
	computer group	48	2.640	0.164

Table 6 The result of one-way ANOVA test for flow state and cognitive loads score

Scale		Sum of squares	sd	Mean of squares	F	P
Flow State	Between Groups	0.690	1	0.690	2.420	0. 123
	Within Groups	26.812	94	0.285		
	Total	27.503	95			
Cognitive Loads	Between Groups	0.020	1	0.020	0.017	0.897
	Within Groups	108.602	94	1.155		
	Total	108.622	95			

$*p<0.05$ $**p<0.01$

4.4 Analysis of attention measured by EEG

The results of one-way ANOVA were used to address the final research question, "What is the comprehensive influence of the virtual reality metaverse on the subjects' brain state during art appreciation and art drawing activities?" The results of the ANOVA test are presented in Table 7. It was found that during the art appreciation activity, the subjects in the virtual reality group had a significantly lower level of attention (Mean = 48.11) compared to those in the computer group (Mean = 53.69), and there was a significant difference in attention between the two groups [F (1,94) = 8.776; $p<0.01$]. After the art appreciation activity, the subjects performed the same art drawing activity, and the attention level of those in the virtual reality group (Mean = 52.25) was significantly higher than that of the computer group (Mean = 47.75). There was a significant difference in attention between the two groups during the art drawing activity [F (1,94) = 5.577; $p<0.01$]. This suggests that students who performed the art appreciation activity in virtual reality maintained a higher level of attention during the art drawing activity.

Table 7 The result for attention in Art Appreciation Activities and Art painting Activities

Activities	Group	Mean	SD	ANOVA	
				F	p
Art Appreciation	virtual reality group	48.11	7.76	8.776	0.004**
	computer group	53.59	1 0.20		
Art painting	virtual reality group	52.25	8.91	5.577	0.020**
	computer group	47.75	9.75		

$*p<0.05$ $**p<0.01$

5 Discussion

This study explored the comprehensive impacts of an art metaverse prototype constructed by immersive virtual reality technology on art learning.

It is concluded that compared with the computer interface, the art metaverse can significantly improve the subjects' art attitude. In comparison, the virtual reality group's knowledge level, flow state, and cognitive load were not significantly different from those of the computer group, while the attention effects brought by virtual reality extended to art painting activities. This subtle finding deserves further exploration.

In response to the research question " compared with the computer interface, does the virtual reality metaverse cast a more significant impact on the subjects' art attitude?", the study found that the virtual reality metaverse cast a more significant effect on subjects' art attitude than the computer environment. The immersive virtual reality environment placed the issues in a metaverse of Van Gogh's artworks. It allowed the subjects to see many of the characters in Van Gogh's paintings, including a virtual avatar of Van Gogh himself. On the one hand, the artistic stylization of the entire perspective enhances the subject's sense of identity and interest. On the other hand, the participants can see the figures in Van Gogh's paintings with their own eyes and interact with them by walking around. The participants' attitudes towards Van Gogh's works of art were enhanced by this realistic process of experience and perception. Existing studies have also shown that virtual reality can affect subjects' attitudes and decision-making to a certain extent (Mannopovna et al., 2020).

This outcome aligns with previous studies, which have demonstrated that virtual reality environments can improve the immersive experience and increase participation with cultural content like art. For instance, Challenor and Ma (2019) found that virtual reality heightened empathy and emotional connection with art pieces displayed in museum settings. Another study showed that virtual reality exposure led to higher emotional involvement and enhanced recall of artworks compared to 2D representations (Krokos et al., 2019). However, existing studies have not experimentally confirmed the significant effects of virtual reality and the environment of the metaverse on the subjects' art attitudes, which is a new finding of this study. These findings emphasize the potential of virtual reality as a valuable resource for advancing art appreciation and education.

In response to the research question " compared with the computer interface, does the virtual reality metaverse cast a more significant impact on the subjects' art knowledge?", the study found that there was no significant difference in the knowledge level test between the virtual reality group and the computer group. Both groups did well in the knowledge test of identifying the style and content of Van Gogh's artwork, but there were no statistically significant differences between the groups. The existing research found that two-dimensional learning materials can significantly improve students' learning effects, while three-dimensional learning materials hinder students' understanding of concepts (De Boer et al., 2016). Some scholars pointed out that there is no significant difference in improving learners' knowledge acquisition in an immersive virtual environment (Merchant et al., 2014). One possible explanation is that previous research has indicated a lack of significant difference between two-dimensional and three-dimensional materials concerning learning and memory recall, both in the short and long terms (Bamatraf et al., 2016). This suggests that the environment, whether virtual reality or computer, may not significantly impact the knowledge level, flow state, or cognitive load. Other factors, such as the content of the art appreciation activities or participants' differences, may have played a more significant role in determining the results. Further research is required to examine these factors and their impact on the experiment's outcome. This conclusion is in line with the findings of this study.

In response to the research question " in the art appreciation activities, what are the impacts of the virtual reality metaverse on the subjects' flow state and cognitive load?" there was no significant difference in either flow state or cognitive load between the groups in the art appreciation activity. The two different ways of acquiring information, virtual reality, and computer screen, were consistent in terms of the cognitive load of the subjects. Previous studies have shown that three-dimensional environments may bring a higher cognitive load to the issues, which is different from this experiment (OuYang et al., 2010). The results of a study revealed that vertigo in virtual reality spaces could contribute to cognitive overload for users in virtual reality environments (Breves & Stein, 2022).Therefore, we selected the HTC VIVE as our virtual reality device, which is very advanced in technology to avoid vertigo. From the perspective of artistic style, the setup gave the subjects a consistent and smooth perception and did not increase the cognitive load of subjects. Studies have also shown that subjects who perform creative activities in a virtual reality environment experience a higher level of flow state (Tsai et al., 2016). The setting of this activity in virtual reality was art appreciation, not a challenging task or an activity that required creativity. Therefore, this experiment found that the virtual reality scene did not lead to a higher flow state than the computer screen appreciation of artworks in this type of activity.

In response to the research question "In art appreciation and art painting activities, what are the comprehensive effects of the virtual reality metaverse on subjects' brain states?" this study found that in art appreciation activities, students' attention value during their watching artworks on a computer screen was significantly higher than that of virtual reality environments. This experimental result also confirms the research findings of Chen et al., who monitored the attention of learners in scientific simulation experiments based on desktop monitors and virtual reality environment through brain waves, and the results show that learners in virtual reality environment show a lower level of attention (Chen & Huang, 2014). This may be because the scenes in the immersive virtual environment were more complex and diverse, thus distracting the subjects' attention and affecting their overall attention level (Ding & Lyu, 2021). However, some researchers have pointed out that the virtual environment's multi-channel perception can help learners concentrate (Yang et al., 2018). This may be related to the specific tasks that subjects have to undertake in virtual reality.

6 Conclusion, limitations and implications

This study found that subjects' art appreciation activities in virtual reality affected their attention to art painting activities. This phenomenon can be called attention extension and transfer. In the same art painting activity, the experimental group who had experienced virtual reality showed higher attention value in the drawing activity. The subjects' brains were more active during the drawing process, and their attention values were significantly higher when they looked back at the virtual reality scene. In existing studies, Bamatraf et al. (2016) have studied the effects of two-dimensional and three-dimensional educational content on learners' learning and memory through brainwave technology. The results found that although the two methods did not significantly affect the learners' performance in recalling the learning content, the activeness of the learners' brain regions was different. Through experiments, the researchers further confirmed that the subjects' brains were more active when recalling educational content in three-dimensional scenes. This study confirms this relevant finding and is also applicable to art learning.

There are several limitations of this study despite its theoretical and practical significances in virtual reality on art learning. Firstly, the art metaverse in this study adopted a VR project, which included immersive virtual space, virtual avatars of art characters, and thoroughly artistic virtual scenes. This prototype construction is an initial attempt, but it is also an important exploration of applying the metaverse to artistic experience and appreciation. Secondly, the data collected in this study come from college students who volunteered to participate in this experiment. They are curious about new things and have a thorough understanding of virtual reality. Many people have experienced virtual reality and other related technical equipment in advance, so the subjects cannot represent the whole population. Also, given the current quality of virtual reality equipment, people can't stay in virtual reality for too long. In this experiment, the art appreciation activity of the subjects in virtual reality lasted only five minutes (Madjar & Shalley, 2008). Although this technical factor is consistent with other experimental studies related to immersive virtual reality, it has certain limitations for exploring the value of the metaverse. In the end, the art metaverse is still very young, which may require consideration of the novelty effect. Research shows that some performance decrease as students become familiar with new technologies and media (Poppenk et al., 2010).

This study provides several practical implications for researchers, developers, and educators. For the researchers, this study further confirms the positive impact of the metaverse constructed by virtual reality on subjects' attitudes. It is necessary to pay more attention to its influence on emotions and attitudes, not only in art learning but also in other application fields of virtual reality. The virtual world facilitates not only our acquisition of knowledge and the improvement of skills but also cognition and emotion, and even our value choices. For developers, building a metaverse of digital existence still requires constant exploration and a series of technological breakthroughs. The full-scene art stylization in this study helps subjects quickly enter a stylized art world from an artistic perspective. This brings an unprecedented perspective and experience to the subjects. In addition, the characters in the artworks appeared in the virtual reality scene through virtual avatars, which was a breakthrough point in the art metaverse of this research. This is just the beginning, and its value needs further verification. For educators, virtual reality brings new ways to art appreciation. This first-perspective perception of art enhances learners' positive attitude toward art. Follow-up research can further explore the value of virtual reality for different artistic learning activities such as creative expression and artistic creation.

Appendix 1. The art attitude questionnaire

(a) I think learning Van Gogh's artwork is interesting and valuable.
(b) I would like to learn more and observe more about Van Gogh's artwork.
(c) It is worth learning those things about Van Gogh's artwork.
(d) It is important for me to learn the Van Gogh's artwork well.
(e) It is important to know Van Gogh's artwork in relation to our living environment.
(f) I will actively search for more information and learn about Van Gogh's artwork.
(g) It is important for everyone to learn Van Gogh's artwork.

Appendix 2. The flow status scale

(a) I felt in control of what I was doing during the learning activity.
(b) I was absorbed intensely by the activity.
(c) I found the activity enjoyable.
(d) I found the activity interesting.
(e) I was completely immersed in this learning activity.
(f) During the learning activity, time seemed to pass fast.
(g) The activity excited my curiosity.
(h) I knew the right thing to do in the learning activity.

Appendix 3. The cognitive load scale

(a) The learning content in this learning activity was difficult for me.
(b) I had to put a lot of effort into answering the questions in this learning activity.
(c) It was troublesome for me to answer the questions in this learning activity.
(d) I felt frustrated answering the questions in this learning activity.
(e) I did not have enough time to answer the questions in this learning activity.
(f) During the learning activity, the way of instruction or learning content presentation caused me a lot of mental effort.
(g) I need to put lots of effort into completing the learning tasks or achieving the learning objectives in this learning activity.
(h) The instructional way in the learning activity was difficult to follow and understand.

Appendix 4. The adapted copy of Van Gogh's painting "Van Gogh's Bedroom in Arles"

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Data availability The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests The authors declare that they have no conflict of interest.

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