

# OdorV-Art: An Initial Exploration of An Olfactory Intervention for Appreciating Style Information of Artworks in Virtual Museum

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## ABSTRACT

Style information, such as tone, mood and genre of artworks is important for museum visitors to appreciate them better. However, such information can be challenging for non-art specialists to comprehend in the short period that they view artworks. The sense of smell is instrumental for humans to assist their image memory, color, emotion and shape association. However, it is rarely used in the appreciation of artworks. Taking Western landscape painting as an example, this research explores the following research questions (RQs): 1) How does the intervention of the sense of smell improve the acquisition of style information in paintings? 2) How does the intervention of the sense of smell enhance the immersion in painting appreciation? To answer RQs, we first recruited seven art specialists to participate in a co-design workshop to design a prototype of the virtual museum with olfactory intervention. We then conducted an experiment with 12 non-specialists who viewed several paintings in the VR museum while being exposed to olfactory stimuli that were designed to be correlated with style information of the paintings. We found potential effects of smell stimuli on enhancing the perception of style information for non-art specialists. Moreover, we found that olfactory intervention has both positive and negative impacts on immersiveness. Finally, we provide design implications for future virtual museum design with olfactory stimuli.

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## CCS CONCEPTS

• **Human-centered computing** → *Usability testing*; **Virtual reality**; • **Applied computing** → *Fine arts*.

## KEYWORDS

Virtual Reality, Virtual Museum, Olfactory Display, Art Appreciation, Landscape Painting

### ACM Reference Format:

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## 1 INTRODUCTION

Appreciating artworks is important for personal development but can be challenging for non-art specialists, who are not trained in art appreciation, which requires good aesthetic taste and the operation of experience and feeling [42]. When appreciating artworks, specialists tend to exert their professional knowledge and analytical skills in addition to their personal experiences and feelings, whereas non-specialists tend to rely more on the later [27]. Specialists tend to take a more systematic and objective approach when analyzing, communicating and evaluating artworks, which includes consideration of the style information, such as the color and genre in addition to the visual content itself. Non-specialists tend to describe what they see and feel based on intuition and personal associations. Such spontaneous appreciation may result in a bad appreciation experience [42]. Thus, it is an important challenge to help non-specialists better appreciate artworks.

One way to assist non-specialists in appreciating artworks is through multi-sensory design. For example, prior research investigated ways to reproduce masterpieces through non-visual channels and allow visitors to appreciate them through text and voice. While prior research focused more on visual or auditory channels to explore artworks [3, 31], we sought to investigate a relatively understudied sensory channel—olfactory sensory. Specifically, we aimed to explore how olfactory sensory might assist non-specialists to capture the style information of western landscape paintings, such as tone, mood, and genre, in virtual museums (**Figure 2**). When appreciating Western landscape paintings, artistic genres, styles, compositions, content perceptions, and historical contexts are presented to the viewer [14]. As one of the essential senses of human beings, odor is used to assist image memory [21, 45], color, emotion, and shape association [13, 29, 34, 36, 44, 47], art therapy [33]. Thus, olfactory intervention might be instrumental in the appreciation of paintings. Motivated by this line of work, we explored the following research questions (RQs):

**RQ 1:** How does olfactory intervention affect non-specialists' style information perception in VR museums?

**RQ 2:** How does olfactory intervention affect non-specialist audience's experience in a VR museum?

To answer RQs, we first recruited seven art specialists to participate in a co-design workshop with the goal of designing the prototype of a virtual museum with olfactory intervention, which is named *OdorV-Art*. We then conducted an experiment with 12 non-specialists to evaluate the prototype *OdorV-Art* to understand their experiences of using olfactory senses to appreciate artwork. We found that olfactory intervention contribute to both positive and negative feedback on stylized information and immersiveness perception. In sum, we have made the following contributions:

*Contribution 1:* We conducted an initial exploration of the method to co-design the olfactory intervention with art specialists to convey style information of Western paintings better. And from the user study, we evaluated how the olfactory intervention prototype support non-specialists in understanding the style information of Western paintings. Our experiments found that the selection of co-design scents and the setting of VR scenes impact the style information perception and immersion of painting appreciation, but this way of using specialists to design for non-specialists is effective.

*Contribution 2:* We offer insights into the effect of olfactory intervention on non-specialists' art appreciation experiences, including both positive and negative ones. Based on the findings, we further present design implications and future directions for better designing olfactory sensory interventions to enhance artwork appreciation.

## 2 RELATED WORK

### 2.1 Virtual Museum

In the past, people could only appreciate artworks in physical museums; with the advent of virtual reality (VR) and augmented reality (AR) devices, people could enjoy museum artworks from anywhere [20]. Virtual reality acts as a medium that mediates the way art is experienced, changing the way people appreciate artworks, creating new experiences for viewers, and playing a key influence on the appreciation and understanding of artworks [22, 30, 35]. Of course,

different types of display devices can perceive viewers differently, leading to a growing demand for multi-sensory experiences in art and culture [23, 48]. Recently, researchers have begun to experiment with the application of touch [18], taste [38], and smell [12] to art appreciation, particularly in virtual museums and in color recognition for art appreciation [2, 5]. Computer vision also plays a vital role in the analysis of artwork content, including in the re-coloring of art paintings, the exploration of semantic segmentation schemes for art paintings, and the analysis of artworks [4, 8, 15].

### 2.2 Synesthesia in Art Appreciation

There has been widespread mention of fluency in art appreciation, a phenomenon of association between color and sound and different words occurring within human perception [44], which is used to enhance the creative process and artistic expression [36], and there are studies that demonstrate the link between fluency, creativity, and art [47]. odors are associated with different shapes and emotions [34] and stimulate memories [6]. The shape of an object is associated with a color and emotional arousal, and memories evoked by odor carry more emotion and recall [21], as well as different associations [29]. Many scholars have explored the link between odor and color and the interplay of language in this [13], and there is a cross-modal correspondence between vision and smell [26].

Multisensory experiences are crucial to the appreciation of artworks in virtual museums. Creating tactile, auditory, and olfactory interactions [43] and stimuli [16] in a virtual museum provides a more immersive experience and multisensory engagement for people with impairments. Playful interaction [37] and training through VR olfactory devices can foster a culture of caring for the sense of self-smell [1] and can also guide designers when using olfactory [32].

### 2.3 Appreciating Western Landscape Painting

According to the traditional art appreciation theory, a good painting appreciation experience is more immersive and can be experienced from professional knowledge and systematic analysis [9, 11]. However, it is difficult for non-specialists to gain a systematic and meaningful appreciation experience. The lack of prior knowledge makes non-specialists focus on their own experience and cannot immerse themselves in the paintings well, so they cannot obtain a good art appreciation experience [42].

Western landscape paintings are all derived from the expression of nature and life, the most important of which is rural life and scenes. In the works of painters of different genres, terms of the same theme and scene can be found [7, 40]. It also considers how landscape painting expresses ideas about identity, people, and the environment [14, 28].

For Western landscape composition, light, shade, color, and white space are all key elements that style information can determine the style of a painting. According to Kelly's research, meticulous composition is the primary way to help the elements of a painting express the author's emotions [24]. Different systematic procedures will be used in art appreciation for the more professional appreciation mentioned above [40].

**Table 1: Demographic information of participants in Study 1**

Participants	Gender	Art related experience
A1	Female	Visual Communication Designer
A2	Female	Visual Communication Designer
A3	Female	Oil painting artist
A4	Female	Visual Communication Designer
A5	Female	Graphic Designer
A6	Male	Graphic Designer
A7	Male	Visual artist

As in Csikszentmihalyi’s theory, art appreciation is divided into four dimensions: intellectual, communicative, perceptive, and emotional. Among these four dimensions, art appreciation is the interaction between the artwork and the audience, emphasizing professional aesthetic ability and wholehearted devotion [9, 10]. However, this is the art specialist’s way of appreciating paintings. When facing the same image, because there is no relevant aesthetic science and systematic method, the experience of non-specialists is often ambiguous [42].

In summary, art appreciation relies on the individual’s perception, experience, and cultural background, and these elements are provided by the colors and shapes in the paintings as well as the emotional and thematic messages. In virtual museums, multi-sensory experiences are essential to reproduce the colors and shapes in pictures and convey immersion, emotions, and thematic statements. For these aesthetic experiences that require professional analytical ability, more objective intervention methods are needed to assist non-specialists in obtaining systematic and accurate style information when appreciating Western landscape paintings. Therefore, in a unique sense, the smell can evoke more emotions and memories by associating odors, creating a more immersive art appreciation experience.

### 3 STUDY 1: WORKSHOP




To investigate the influence of olfactory associations on the appreciation of artworks, we divided our experiment into two sections. First, we conducted a workshop with participants who had an artistic background (N=7).

#### 3.1 Participants

A total of 7 participants with a background in art ( 5 females, 2 males, **Table1**), including 5 designers and 2 artists, took part in the workshop. Participants with an artistic background possess a heightened level of expertise in assessing paintings, enabling them to offer professional painting analysis and odor selection for Study 2. Furthermore, participants did not take any medication, had no history of sensory impairment such as anosmia, vision deficits, etc. (MONEX-40 Sniffin’ sticks test, [19]), and demonstrated an intact sense of smell, and normal visual acuity (Snellen’s visual acuity evaluation, [41]). After the experiment concluded, all participants were provided with compensation that complies with local experimental regulations. The recruitment and study were approved by the Institutional Review Board (IRB).

#### 3.2 Materials

We selected paintings through the literature about landscape painting. Three types of Western landscape paintings shared the same country life topic were determined for the second part of the workshop (**Figure 1**), including realistic landscape painting, romantic landscape painting, and impressionist landscape paintings [7, 40].

Paintings			
D1.Farthest distance Odor	Smoky flavour	Ocean	Bulgarian rose
D2.Middle distance Odor	Leather	Ink, Incense	Tree moss
D3.Clothest distance Odor	Pogostemon cablin	Coriander linalool	Pepper

**Figure 1: Painting selection and odor choice**

#### 3.3 Procedure

In study 1, we designed two sections of the workshop. First, participants who were art specialists were asked to finish an odor association training to get familiar with the association of visualization and olfactory. Next, participants were asked to co-design the odor and virtual environment construction for the prototype.

**3.3.1 Odor associations Training.** At first, participants were invited to a well-ventilated room, the researcher introduced the workflow and instructions. Then, participants were asked to try odor association by smelling 12 typical odors which used in previous odor association study (Chamomile, rosemary, sandalwood, daffodil, mint, citrus, green tea, lemon, vanilla, neroli, pepper, and Bulgarian rose were selected [13, 25]) and write down their associations using several words on paper. After the completion of each odor experience, the researcher organized participants to share their individual perceptions. Following this discussion, in order to minimize the impact of residual odors, participants utilized coffee beans to neutralize any lingering odors and rested for at least 5 minutes until they indicated no longer being influenced by the previous odor stimuli. This process was repeated for all 12 odors.

**3.3.2 Odor associations of paintings.** Before commencing the experiment, researchers took measures such as opening windows and activating air conditioning ventilation to eliminate any residual odors in the air until participants indicated no longer being influenced by olfactory stimuli. Once the experiment began, each participant was provided with a high-resolution original image of a painting, and they were given 5 minutes to write down their odor associations with the painting on paper. Upon the completion of the odor association task, the moderator facilitated a sharing session among the participants. After all three paintings were experimented with, the workshop concluded.

Participants’ discussions in both sections of the workshop were recorded by observers

### 3.4 Data analysis

To analyze the data we collected in the study, we analyzed the first part workshop of odors association and the second part workshop of paintings association by grounded theory, namely open coding, axial coding and selective coding [46]. Furthermore, the analysis of data determined the odors and distance matching in Study 2.

### 3.5 Findings

According to the first part of the workshop, the association of the odors, participants gained preliminary knowledge of odor associations, influenced by cultural backgrounds and sensitivities. Color associations were relatively similar.

In the second part of the workshop, paintings were associated with specific odors. The first painting evoked the smell of burning straw, conflict, anxiety, and searing heat, while also having hints of turpentine, paint, sweat, milk, and rust. The second painting conveyed scents of a vibrant summer or spring day, with floral aromas, wildlife, Bulgarian roses, woody atmospheres, aquatic plants, grass, mud, neroli, vanilla, and paint. The third painting evoked the odors of a fresh rain in the mountains, mixing animal and woody scents, reminiscent of a peaceful summer day from childhood, with traces of turpentine, paint, and faint hints of old objects. These odor selections formed the basis for future olfactory intervention experiments, demonstrating the interconnectedness of smell, color, shape, and emotion in evoking powerful emotions and memories for the audience (Figure 1).

## 4 STUDY 2: EXPERIMENT

Based on the results of the workshop and a review of previous studies, we designed a prototype for Study 2. Subsequently, we conducted a user experiment with participants without an artistic background (N=12) and conducted post-study interviews after the experiment. In the following sections, we will provide a detailed description of our experimental procedure.

### 4.1 Participants

A total of 12 participants (6 females, 6 males) were recruited for this experiment. None of these participants had any art-related background (e.g., HCI, Fintech, etc.), which facilitated our exploration of the impact of the olfactory intervention on the art appreciation of individuals without discerning abilities. Additionally, participants did not take any medication, had no history of sensory impairment such as anosmia, vision deficits, etc. (MONEX-40 Sniffin' sticks test, [19]), and demonstrated an intact sense of smell, and normal visual acuity (Snellen's visual acuity evaluation, [41]). After the experiment concluded, all participants were provided with compensation that complies with local experimental regulations. The recruitment and study were approved by the Institutional Review Board (IRB).

### 4.2 Materials

**4.2.1 Experiment Apparatus.** For the VR museum demo, we made a VR prototype called OdorV-Art (Figure 2). First, we determined the user flow of the VR prototype, which is divided into three stages (1) Entry, (2) Selection, and (3) Appreciation. In the Entry scene, the user will Read the guide of this experiment. In the Selection scene, the user needs to select the painting scene. In the Appreciation

scene, the user can appreciate art. We defined three different distances for users to adjust the distance from the painting to explore the correspondence between distance and fragrance. This VR prototype is made based on the Unity platform. The VR head-mounted device used is Oculus Quest 2.

For the olfactory display, an Arduino module enabled controlled odors release, allowing manual selection (Figure 3). A nebulizing driver module regulated odors release through a 20mm nebulizer. Operating on a 5V DC output, it required 300mA. The nebulizer vibrated at 110KHz, breaking water into vapor-like particles. Scented sponge pads, soaked in liquid odor materials, were packed into a container, ensuring full contact with the atomizer. The system converted essential oils into a fine mist, rapidly dispersing the odors for an immersive olfactory experience.

**4.2.2 Questionnaire.** After the completion of appreciating each artwork, participants were required to fill out an art appreciation questionnaire. The questionnaire consisted of five multiple-choice questions, including the color palette of the artwork (2 questions), the subject matter (1 question), the emotional tone (1 question), and the artistic genre (1 question). The answers to these five questions were derived from online art websites and previous research on the respective artwork.

### 4.3 Procedure

**4.3.1 Experiment.** Before the experiment, participants were randomly divided into 6 groups, with each group consisting of participants assigned to either the experimental group or the control group. To mitigate any selection bias from participants being aware of the experimental objective in advance, they were only informed that they would be taking part in a virtual reality art appreciation experiment. The actual purpose of the experiment was disclosed to the participants after its conclusion.

To strictly control variables and ensure that participants were not affected by residual odors in the experimental setting, the researchers prepared 5 well-ventilated rooms for conducting the experiment. After the completion of the experiment in the experimental group, researchers utilized measures such as opening windows and doors, as well as activating air conditioning systems to remove any residual odors in the room. The room was only continued to be used when there were no longer noticeable odors present.

To begin with, participants entered the VR environment and accessed the painting selection interface. They were instructed by the researcher to choose one painting for appreciation. To avoid the order effect, the sequence of painting selection was randomized for each participant. Then, researchers provided a brief introduction to the environment, such as the distance control button, the brief information button, and the back and close button.

Following the instructions, participants navigated from the farthest-distance area (D1) to the closest-distance area (D3): Researchers gently put the olfactory device on the table in front of the participants (The distance had been pre-tested in the experiment to ensure that the participants could clearly smell the odor released by the device). In the D1 area, the researchers operated the device to release odor1. When the participants reached the D2 area, the



Figure 2: OdorV-Art Prototype and the Conducting of User Experiment

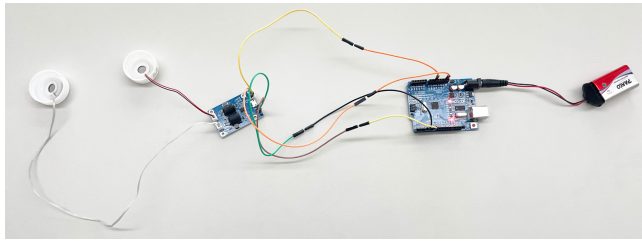


Figure 3: olfactory display for experiment

researchers released odor2 while keeping the odor1 release ongoing. Upon reaching the D3 area, with odor1 and odor2 still being released, the researchers released odor3.

Participants were required to spend at least one minute at each distance, and the researcher confirmed that they had completed the artwork appreciation at that distance before proceeding to the next distance. After completing the art appreciation at all three distances, participants were instructed to take off the VR headset and proceed to an odorless empty room to fill out a pre-prepared questionnaire. During this process, the researchers utilized measures such as opening windows and activating air conditioning ventilation to eliminate any residual odors from the experimental room. Once participants completed the questionnaire and the researchers confirmed that there were no lingering odors in the experimental room, participants returned to the room and continued to appreciate the next painting. This process was repeated until all three artworks were appreciated and the questionnaire was filled out (Figure 2).

**4.3.2 Post-study interview.** After the experiment, participants were invited to participate in a post-study interview. The interview aimed to explore participants' impressions and suggestions regarding their art appreciation experience in the VR virtual museum. The researchers utilized a 7-point Likert scale to collect participants' level of immersion and their preference of olfactory intervention, ranging from 1 (not immersive or like) to 7 (very immersive or like). In addition, researchers also utilized three open-ended questions, including "What aspects of the experiment contributed to your sense of immersion?" "What factors diminished your sense of immersion during the experiment?" "What are your opinions and expectations regarding olfactory intervention and virtual art appreciation?". The entire interview process was audio-recorded, with the consent of the participants.

#### 4.4 Data analysis

We calculated the mean of accuracy rate of questionnaires answering by color, author's emotion, main subjects and genres. Moreover, we transcribed the audio recordings from the post-study interview and analyzed it using open coding and thematic analysis. Also, to analyze the results of 7-point Likert scale, we calculated the median and IQR to show the distribution of ratings.

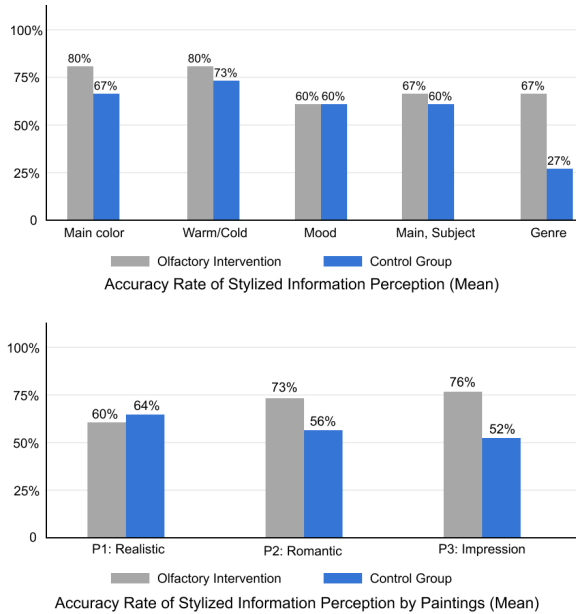
#### 4.5 Findings

Our experiment explores the use of olfactory intervention in the VR museum to enhance art non-specialist's perception of style information and immersiveness, such as color and genre, to be the same as art specialists' systematic perception. Among the existing museum-related researchers, multi-sensory experiences are constantly being tried [16, 21, 29, 43]. The addition of an odor intervention in the study by Elgammal et al. did not demonstrate positive results [17]. However, in this study, due to human's ability to associate odors with colors, shapes, emotions, and so on. [13, 21, 29, 34], we intervene in olfactory associations based on the hue, subject, mood, and genre of Western landscape paintings to assist non-specialist to admire the paintings. Through the experimental results, we found that smell positively and negatively affects style information capture and immersiveness when appreciating paintings. Specifically, we found *potential effects on style information perception, potential effects on immersiveness perception, distraction of immersiveness, and attitudes and insights* from the experimental results.

**4.5.1 Potential Affects on style Information Perception.** The data shows that the sense of smell impacts the systematic and objective appreciation of paintings.(Figure 4). Generally speaking, the introduction of the sense of smell positively impacts style information, improving the non-specialist's objective cognition of tone, the author's mood, subject matter, and genre.

In terms of the style information, in our experiments, the olfactory intervention significantly improved the non-specialists' perception of color, subject, and genre information. Among them, the impact on the genre is the greatest, and the average correct rate of the olfactory intervention group is 40% higher than that of the control group. For the color tone and the main object, the correct average rate of the olfactory intervention group is also significantly higher than that of the control group without odor intervention. However, there was no significant improvement in the average correctness of the answers to the objective expression of the mood of the painting author.

Furthermore, for different paintings from different genres, it reveals that olfactory enhances the capture of style information for both Romantic and Impressionist paintings. However, for the realistic painting, the fragrance has the opposite effect, and the average answer rate of the control group (64%) for this painting is higher than that of the experimental group (60%), which introduces the sense of smell.



**Figure 4: The Accuracy Rate of Questionnaires**

**4.5.2 Potential Affects on Immersiveness Perception.** According to the 7-point Likert scale, the participants believed that the virtual museum with the sense of smell was immersive (median=5, IQR=2.5). Moreover, according to the post-study interview, the main reason for the sense of immersion was caused by the olfactory intervention are the following two points: *odors match audience's imagination* and *odors have apparent tendency*.

First, odors match audience's imagination will bring a strong sense of immersion. In the experiment, we provided participants with different odors according to the style information reflected by different distances. When the participants stand at different distances in the virtual museum and receive information that matches the preset smell, they will feel a strong sense of immersion and guidance. For example, most of the participants in the experimental group (N=4) recognized Monet's paintings from the three distances of far and near, so most of the participants felt that the appreciation experience of the painting was very immersive. In addition, odors have an apparent tendency to bring a strong sense of immersion. In the post-study interview, most of the participants in the experimental group (N=3) mentioned that intense aromas and strong odors would shape the impression of Romantic and Impressionist genres.

**4.5.3 Distraction of Immersiveness.** According to the post-study interview, the main reasons for the distraction of immersion are

as follows: *distraction of virtual environment, odors mismatch, high intensity of the odors, and association to personal experience*.

In the experimental virtual museum prototype, since the paintings do not cover the screen of the entire prototype's virtual environment, the size of the paintings will change at different distances. In the long-distance and intermediate-distance appreciation experience, the dark background wall will contrast with the painting, weakening the sense of immersion to a certain extent. Furthermore, odors mismatch is also responsible for distracting immersion. Each participant may have different perceptions of odors and images. Only two participants could accurately name all the odors used. In addition, when the odors released in the experiment do not meet the participants' expectations, the sense of immersion will be weakened, and the smell will become an isolated element outside the painting.

Furthermore, most of the participants (N=3) could associate the smell with the vision in the experiment, but a small number of participants (N=2) responded that the connection between the smell and the vision was not so strong, especially for romantic paintings. The rich aroma will distract you from looking at the painting. In addition, in some experiments, the odors used were the odors that the participants were very familiar with in their daily lives. As expressed in existing research, odors can have very strong associations with past experiences [21, 45]. When browsing the virtual museum, familiar odors will guide participants (N=2) to associate with their own lives, which also reduces the immersion of the virtual museum experience.

**4.5.4 Attitudes and Insights.** In the post-interview study, participants gave positive feedback to the virtual museum in the form of olfactory intervention (median=5, IQR=1), using 7-point Likert scale. Participants responded in the post-study interview Odor and visual synesthesia to varying degrees. Two participants were new to the introduction of the smell, but at the same time they wanted to have words or other ways to help them understand the smell. Most of the participants wanted more objective odors, such as odors that were more in line with the author's biography or other relevant characteristics, or even unpleasant odors. In addition, the participants believed that the addition of more senses is needed, such as hearing, playing the sound of the scene in the picture.

## 5 DISCUSSION

This article is based on the immersive and olfactory Western landscape art appreciation experience provided to art non-specialists in a VR environment, which has received positive and negative feedback. Based on the feedback results, we came up with the following relevant design implications: *odors association with objects and style, odors association with the virtual environment, synesthesia preference of people*. It can be used to reference other painting types and exhibition environments, such as figure paintings or physical art museum scenes.

### 5.1 Odors Association with Objects and Style

Although olfactory intervention always studied together with other sensory, [16, 17, 29, 43], in our study, we mainly use olfactory to explain the colors, moods, main subjects and genres of the landscape paintings. Our results do not mean that the intervention of olfactory

must play a positive role in the acquisition of style information. But our study revealed the odors has potential affects on the virtual museum experience. Besides, the choice of smell is also very critical. When audiences were looking at the specific objects, matching odor selections were helpful to non-specialist, while mismatching smell will create ambiguity. However, the exploration of the possibility of smell is not carried out in general, but needs to be narrowed down.

*Design Implication:* In order to design a virtual museum that provides a better experience, both style information and immersive capture need to be concentrated. The choice of odor for a particular object needs to satisfy what the audience sees visually. For example, color, mood, and genre in style information are more abstract concepts, and the choice of flavor needs to be considered, which will have positive and negative effects. When facing a specific object in the painting, the audience can create a visual and olfactory connection more quickly. If an eye tracker is added to future experiments and designs, it can better help the release of smells and help non-professionals better understand abstract and specific information.

## 5.2 Odors Association with the Virtual Environment

In Study 2, we found that some participants were not aware of the relationship between the odors and the paintings. One reason for this was that some participants were not sensitive to the odors and thus overlooked the influence of olfaction. Another significant reason was that they perceived the odors as originating from the virtual museum rather than the paintings, which was particularly evident when viewing the paintings from a distance. Previous research has shown that odors can serve as cues or warnings, automatically capturing attention towards the most likely relevant sources in the environment [39]. Therefore, we speculate that some participants, who had previous experiences visiting museums or similar settings where ambient fragrances were used, did not initially associate the odors with the paintings. Especially when viewing the paintings from a distance, the content and objects in the paintings were not prominently displayed, and participants could only perceive the colors and faint scenes, making it difficult to immediately link the odors with the paintings. However, when the distance between the participants and the paintings was shortened, or when the paintings occupied their entire field of view, participants were relatively more likely to associate the paintings with the odors, especially when the odors matched the objective targets or content in the paintings, leading to gaze attraction.

*Design Implication:* When conducting olfactory intervention in art appreciation-related work, it is important to consider the influence of the environment in which the artworks are presented on participants' olfactory associations, particularly when odors are easily associated with the environment.

## 5.3 Synesthesia Preference of People

We have found that including odors in a virtual museum helps improve the public's understanding of an artwork's style information. The synesthesia preference of different non-specialists depends on their personal experience, cultural background. De Valk et al. conducted a study on odour-colour associations with people from

three different cultural backgrounds and found that the content of the associations differed for each individual [13]. This suggests that odor associations were directly influenced by the participants' life circumstances, educational background, life experiences, and other factors [21], ultimately producing different association results. Whereas our participants came from a homogeneous cultural background, specific associations showed similarities throughout the experiment but presented different associative outcomes more often. The non-specialists' preference of synesthesia when appreciating a painting also affects the style information and immersiveness perception.

*Design Implication:* To design a virtual museum that incorporates scents, flavor choices that can be personalized based on the associative preferences of audiences with different backgrounds need to be considered.

## 6 LIMITATION AND FUTURE WORK

The noise of the prototype seriously affected the immersion of the participants. Participants wanted a more silent release of the odors. We noticed that the noise of the prototype seriously affected the immersion of the participants. Participants wanted a more silent release of the odors.

At the same time, the virtual environment will affect the user's perception of smell. For example, the proportion of paintings in the current prototype is not large, and the environment can easily affect the user's feelings. Some participants will think that the smell is from the environment. Also, more categories of painting and more recruitment would make the findings stronger.

Finally, the participants mentioned that the types of paintings in the experiment were not enough and could not be used to generalize common types of art paintings. In short, the ideas above are areas where future work may be strengthened.

## 7 CONCLUSION

This study examines the olfactory intervention in enhancing the ability of non-specialists to interpret Western landscape paintings in virtual museums. While smell is a significant human sense, it is rarely utilized in the appreciation of visual art, despite its association with image memory, color, emotion, and shape. Therefore, this research aims to address the following inquiries: 1) How does incorporating smell improve the acquisition of style information in paintings? 2) How does the integration of smell enhance the immersive experience of appreciating paintings?

To design a virtual museum with olfactory intervention, we organized a co-design workshop involving 7 art specialists. Subsequently, we conducted an experiment involving 12 non-specialists who evaluated our prototype. Through this study, we made the following contributions: 1) The olfactory intervention facilitated the perception of style information (such as color, the artist's mood, subject matter, and genre) during art appreciation. 2) We investigated the impact of olfactory intervention on the immersiveness of the virtual museum, observing both positive and negative effects.

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