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The Visual Representation of Olfactory Perception

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ABSTRACT

Olfaction is directly transmitted to parts of the brain involved in emotions and memory, making it more persistent in memory compared to other senses. It is strongly associative, evoking memories, emotions, and experiences when a certain scent is perceived. However, tools that can effectively convey olfactory sensations and the emotions they evoke still need to be found.The main reason is the inherent ambiguity in olfactory representation, making it difficult to process this information. If we had a language to express olfaction, it could broaden our perception of the world. This study aims to visualize and document the emotions and memories triggered by olfaction, capturing specific moments of life along with their scents and associated emotions. The significance of this study lies in demonstrating the correspondence between shapes, colors, textures, and scents; creating sophisticated images by combining these elements; and showing that olfactory visualization images can evoke emotions and associations with scents.

KEYWORDS

Senses, olfaction, visualization, emotion, documentation

1. INTRODUCTION

Olfaction is transmitted to the limbic system, which is involved in emotions and memory in the brain, making it more enduring in memory compared to other senses and strongly associative with memories and experiences when a certain scent is perceived (Herz & Engen, 1996). Therefore, olfactory information has a direct and immediate impact on human moods, emotions, and behaviors, influencing even unconscious actions (Rouby et al., 2002). Visualizing and documenting the internal emotions and memories evoked by olfaction would allow us to capture life's moments along with their scents and emotions. Additionally, the synesthetic interaction between olfaction and vision could create more powerful perceptual and emotional stimuli. This study aims to concretize methods of visualizing and documenting the emotions and memories experienced through the sense of smell in everyday life, which could also be supported by AI-powered predictive modeling techniques (Na & Na, 2024). The goal is to enable a richer record of personal life.

To achieve this, we first examined the meaning of documentation. Second, we explain the rationale for selecting olfaction as the medium of documentation. Based on literature and previous studies related to olfaction, including the application of machine learning in psychological well-being (Kumar et al., 2023), we choose the classification system and scents to be used in this study. Third, we define visualization and analyze previous research on olfactory visualization to define visualization elements. Fourth, based on the defined visualization elements, we design olfactory visualization symbols and conduct preliminary surveys to select participants interested in olfactory documentation. We then conduct experiments to match scents with olfactory visualization symbols. Fifth, we create three-dimensional images using principles derived from the analysis of shapes, colors, and textures obtained from the experiments. Lastly, we formulate hypotheses for verifying the created images and conduct user surveys for validation.

The significance of this study lies in demonstrating the correspondence between shapes, colors, textures, and scents; combining shapes, colors, and textures to create three-dimensional compositions; and showing that olfactory visualization images can evoke emotions and associations with scents. This

process may benefit from improved environmental management models to ensure effective documentation (Hai & Duong, 2024).

THEORETICAL BACKGROUND

2.1.1. Documentation

Documentation is primarily defined as writing down facts with the intent of preserving them for future reference. In traditional writing systems, documentation was mainly carried out by humans, serving as a means to record the "significant moments" of daily life. However, with the advancement of digital and wearable devices, it has become possible to record or capture almost every moment of daily life automatically. The comprehensive recording of daily life through digital devices is collectively referred to as life logging (Lim & Choe, 2020). The development of digital storage, the internet, mobile devices, and technical media has made it easier to preserve and share records, eliminating the constraints of time and space. As personal health and body data can be stored and accumulated as individual life-log data, it is anticipated that an era of "complete memory" recorded by digital devices and equipment will be realized (Gu, 2022). Through this, documentation has gained a new meaning. However, one might question whether this life log, which records and stores human experiences as digital data, can truly replace human memory. Human memory is a "constantly reconstituted process," whereas digital memory remains in the same form as before (Carr, 2010). The automatic quantification of records may lead to the deterioration of the "organic" memory method, where humans reconstruct events to create their memories and reality. This method involves narrating oneself and building a consistent self-image through the act of remembering, which is how humans construct their identity (Gu, 2022). In the future, relying solely on digital records for memory might result in significant moments of life being recorded and stored indistinguishably from ordinary moments, causing even "memorable moments" to be lost among trivial logs and failing to become meaningful memories (Chiang, 2013). Therefore, it is necessary to seek methods to preserve meaningful records while taking advantage of digital benefits.

2.1.2. Reason for Selecting Olfaction

Olfaction is a sensory organ that can evoke accompanying memories and emotions when a certain scent is perceived, as it is directly transmitted to the parts of the brain involved in emotions and memory (Kuczamer-Kłopotowska, 2017). This phenomenon stems from the associative function of olfaction (Stewart, 2022). Scents serve as a basis for remembering information, stimulating imagination, recalling memories, and creating emotional responses. The most basic expression of emotions is through language. However, compared to other senses, olfaction is challenging to visualize or accurately express in words. This difficulty arises from the inherent ambiguity in olfactory representation, making it hard to process the information. Although other senses have recently been digitized and recorded, scents can still only be experienced at their source location. Additionally, conveying scents requires using other methods. Despite the absence of olfactory language, the researcher selected olfaction as a medium for emotional documentation due to its associative nature.

When viewing a record through sight, one can roughly infer the situation by recalling and combining the five senses through the objects seen in the record, even without direct experience. However, olfactory information tends to fade rapidly from memory, with about 75-85% of the information disappearing within a month of exposure to the stimulus (Lawless & Cain, 1975). Therefore, visualizing and documenting the internal emotions and memories evoked by olfaction could not only complement the volatility of olfaction but also create stronger cognitive and emotional stimuli through the synesthetic interaction of olfaction and vision (AlZubi, 2023). It also allows us to capture life's moments along with their scents and emotions.**2.2.3. Olfactory Classification System**

Scents are perceived through subjective senses, and with the chemical composition reaching millions of variations, establishing a standard information system is challenging (Jang, Han, and Kim, 1999). Although scents can be categorized into certain groups based on their characteristics or ingredients, objective and clear criteria still need to be established. This study utilizes the classification system of Michael Edwards, widely used in the fragrance product industry and frequently cited by researchers domestically and internationally (Edwards, 2001). Edwards' classification system appropriately categorizes the spectrum of scents and is universally used and trusted across the fragrance industry to this day (Zarzo, 2020). Michael Edwards' fragrance classification system groups similar scent ingredients

into four major families and fourteen subfamilies. Figure 1 shows Michael Edwards's The Fragrance Wheel.

Figure 1. Michael Edwards's The Fragrance Wheel

In Michael Edwards' classification, the Floral, Oriental, and Woody families exhibit relatively uniform scent characteristics within their categories, whereas the Fresh family shows more distinct differences among its subcategories. Therefore, this study adopts only the upper categories for Floral, Oriental, and Woody families, while selecting five distinct scents from the subcategories of the Fresh family resulting in a total of eight clear categories. The classification of scents used in this study is shown in Table 1.

Table 1. Selection of Scents by Category

Scent Category	Characteristic	Selected Scent	Scent Category	Characteristic	Selected Scent
Floral	Various flower scents	Rose	Citrus	Citrus fruit scents	Bergamot
Oriental	Spicy scents like musk	Musk	Water	Scents of sea breeze, water, etc.	Rain
Woody	Wood scents	Sandalwood	Green	Scents of grass, leaves, etc.	Green Tea
Aromatic	Herbal scents	Lavender	Fruity	Fruit scents like apple, peach, etc.	Peach

2.3.1. Olfactory Visualization

Compared to other senses, attempts to visualize olfaction are relatively rare. This is because it is not easy to visualize an invisible sense objectively. However, it is anticipated that a system for visualizing olfaction can be established based on existing media and visual expressions commonly shared by people today.

The most important elements that constitute visual language are shape, color, and texture. Shape is a crucial element in conveying visual information, as it not only perceives but also adds emotions to colors and forms, creating images related to them. Among visual elements, the emotions conveyed by color are faster and have a significant impact on human psychology compared to any language. Color is also widely used as a means of conveying various emotions or meanings (Mori, 1996). Texture refers to the properties of an object's surface felt by touch or sight. Texture exists in all objects in the world and enriches visual experiences along with shape and color. This study aims to explore the use of elements for olfactory visualization by analyzing previous research on the relationship between olfaction and shape, color, and texture and by reinterpreting the results of user surveys to reflect them in olfactory visualization.

3.1. Previous Research on Shapes

Analyzing previous studies on shape associations revealed that research related to the visualization of olfaction is scarce, particularly in South Korea, where there have been almost no attempts to visualize olfaction in terms of shapes. Studies focusing on the correspondence between olfaction and shape often emphasize the degree of pleasantness/unpleasantness (Seo et al., 2010) or the degree of angular/rounded feeling (Hanson-Vaux, Crisinel, and Spence, 2013) rather than explicitly matching specific scents with specific shapes. Therefore, it took a lot of work to find clearly verified results of olfactory visualization. Most studies described the source of the smell (Kaeppler, 2018) (Lee, 2023) rather than expressing the feeling of the scent. Many studies commonly mentioned the limitations of fully generalizing olfaction due to cultural factors and environmental development processes. Therefore, this study intends to use a method where basic geometric shapes are presented, and participants select the most similar shapes to combine them. The shapes to be used in the shape investigation of this study's user survey are shown in Figure 2.

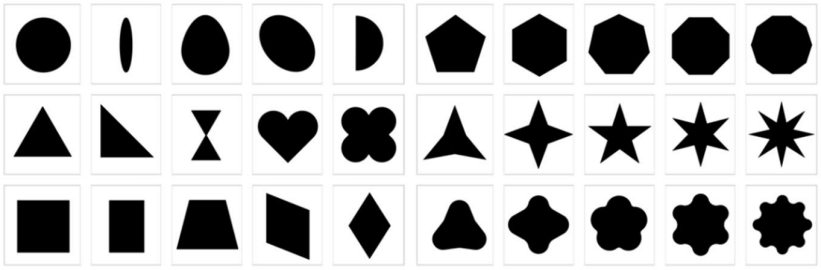


Figure 2. A Figure for Shape to be used in this Study

2.3.3. Previous Research on Colors

Scents and colors exhibit distinct interaction patterns, with the characteristics of associated colors and shades varying depending on the type of fragrance. One can directly or indirectly sense the smell or scent through colors and also associate colors with scents (Birren, 2013). Previous research has specifically identified the interactions between visual and olfactory senses. Although color is a visual element, it plays a role in amplifying senses such as hearing, touch, smell, and taste through synesthesia. Colors not only maximize the image carried by scents but also convey similar emotions through association, even when the actual scent is not present (Park, 2012; Marshall and Ni, 2012; Lee, 2013; Park; 2023).

The color system used by previous researchers is the I.R.I HUE & TONE 120(Image Research Institute Inc., 2003). This system simplifies color expression into hues and tones, making color distribution analysis easier. This study also determines the I.R.I Hue & Tone 120 Color System shown in Figure 3 is the most suitable tool for color evaluation.

Figure 3. I.R.I Hue & Tone 120 Color System

2.3.4. Previous Research on Texture

Texture refers to the surface characteristics of an object. It exists in all objects in the world and, along with shape and color, enriches visual experiences. Texture ranges widely from smooth, like a mirror, to rough, like the surface of a rock. Texture can be divided into two types: tactile texture, which can be felt by touch, and visual texture, which is perceived by sight (Lee, 2004). Based on adjectives describing images and tactile sensations (Park, 2009), this study reconstructed visual and tactile adjectives to be used and composed texture choices for creating olfactory visualization images. Since the texture is greatly

influenced by color (Park, 2009), the textures were presented in black and white. The texture choices used in this study are shown in Figure 4.

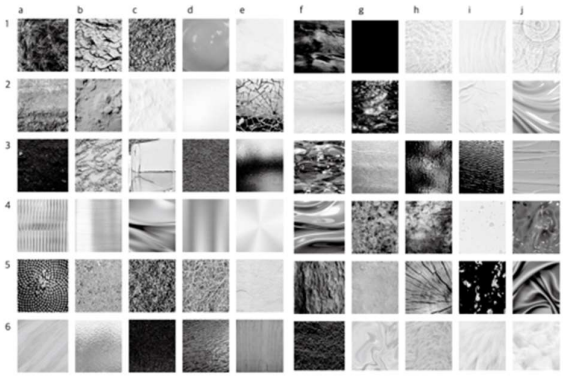


Figure 4. A Figure for Texture to be used in this Study

3. USER SURVEY FOR OLFACTORY VISUALIZATION EXPRESSION

3.1. Design of Olfactory Visualization Symbol Verification

The research procedure for olfactory visualization expression is as follows. First, an online survey was conducted to understand the participants' experiences with olfactory visualization and to select users with a high interest in olfactory documentation. The preliminary survey items and their responses are shown in Table 2.

Table 2. Pre-Questioning and Result

Question	Yes			No	
Experience with olfactory documentation	21			9	
Experience recalling images or situations when smelling a scent	28			1	
Experience of recalling a scent when seeing an image	26			4	
Experience recalling a scent when seeing a specific word	23			7	
Interest in scents (1-5 points)	1pt.	2pts.	3pts.	4pts.	5pts.
	0pt.	2pts.	4pts.	16pts.	8pts.

A user survey was conducted to create olfactory visualization symbols based on the 30 users selected through the preliminary survey. The survey was conducted in person from March 23, 2024, to March 25, 2024. The user survey targeted 20 adults aged 20-30 who had no visual or olfactory impairments and were interested in scents and documentation. The images used in the experiment are shown in Figure 5.

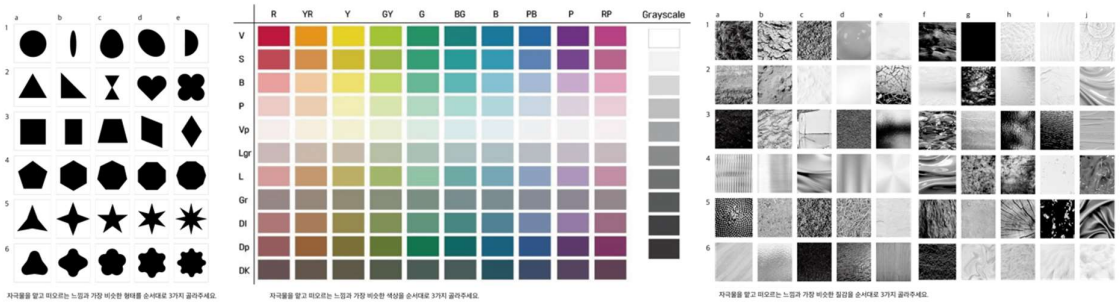


Figure 5. Selection of Shapes, Colors and Textures

3.2. Results of Olfactory Visualization Symbol Verification

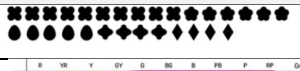
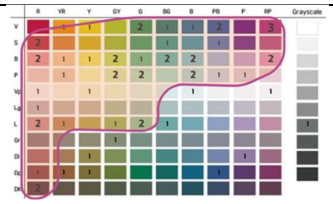
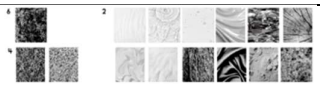
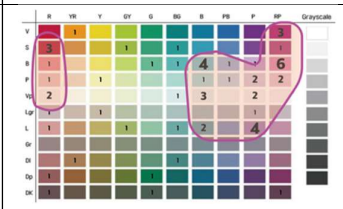
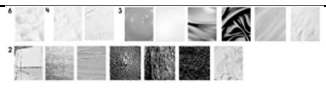
The olfactory tools used were eight fragrance materials classified by the researcher based on Michael Edwards' fragrance classification system. To ensure uniform results, materials produced by the Korea Fragrance Education Institute were used. The experiment was conducted in a well-ventilated, odor-free indoor environment with minimal sensory stimulation. The olfactory test was performed using olfactory test strips (15mm wide, 120mm long, and 2mm thick) with one drop of the stimulus applied 10mm from the end. Participants were not informed about the type of scent beforehand and were asked to select shapes, colors, and textures for each scent. Additionally, to extract a variety of associative information,

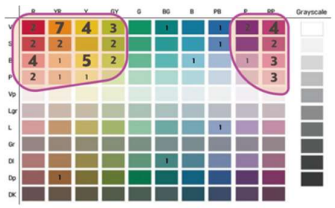
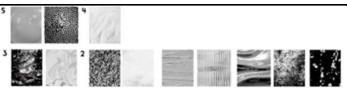
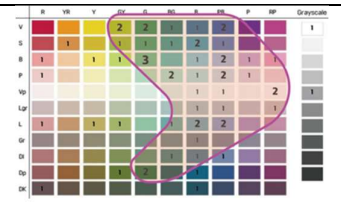
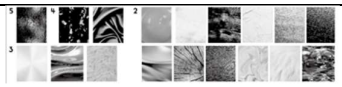
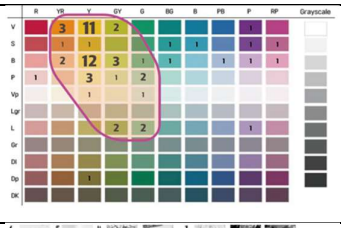
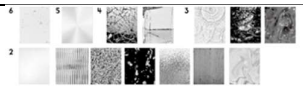
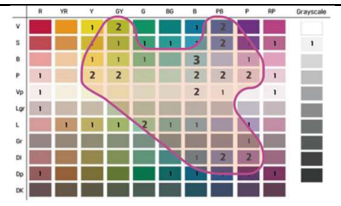
participants provided three responses for each sensory attribute. The data obtained from the survey were analyzed to determine the tendencies in shapes, colors, and textures associated with each scent. The results of the survey are shown in Figure 6.

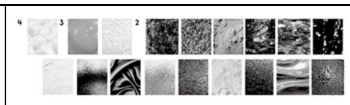
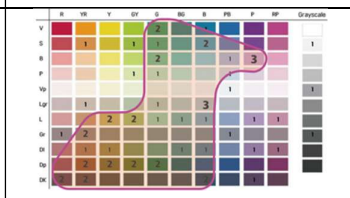
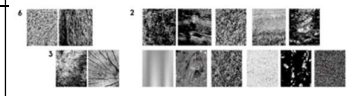
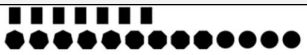
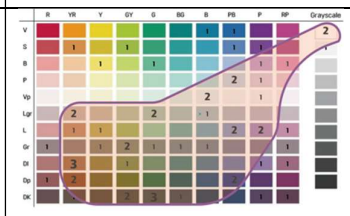
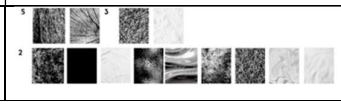
Figure 6. Answer Shape, Color and Texture

The summarized results of the user survey on visual associations for shapes, colors, and textures for the eight fragrance materials are presented in Table 3.

Table 3. Results and Interpretations

1	**Floral : Rose**	
Shape		Preferred curved and symmetrical shapes
Color		 A wide range of colors, including red, light green, green, blue, and purple, makes it difficult to identify a specific color tendency, but clear, bright, and soft hues were observed.
Texture		Textures that seemed intertwined; fuller textures preferred compared to other scents.
2	**Oriental : Musk**	
Shape		Curved and round shapes.
Color		 Colors are red, blue, purple, and magenta Color tones mostly tend to be bright and subtle.
Texture		There is a noticeable trend in texture selection Soft, cosy, and smooth textures are the most frequently

		chosen.
3	**Fruity : Peach**	
Shape		Jagged forms
Color		 Colors such as red, orange, yellow, light green, purple, and magenta are predominantly selected. Among them, orange and yellow are the most commonly chosen. Color tones are distributed among clear, strong, bright, and vivid tones.
Texture		Soft and inward-converging textures.
4	**Water : Rain**	
Shape		Preference for horizontally compressed forms.
Color		 In terms of color, light green, green, blue, and navy blue tones are preferred Color tones are diversely distributed.
Texture		Moist, sticky, soft, and flowing textures are prominently observed.
5	**Citrus : Bergamot**	
Shape		Distinctive characteristics of the shape pointed and jagged forms
Color		 Color also shows the most prominent characteristics. Selection of colors within the yellow, light green, and green. Color tones are concentrated in bright and vivid tones.
Texture		Pointed or bubbly forms that appear broken.
6	**Green : Green Tea**	
Shape		Overall, shapes tend to be round, with a preference for variations over basic geometric shapes.
Color		 Selection of cool colors. Rather than vivid and strong color tones, there is a general preference for subtle tones.

Texture		Soft textures that seem to be fluffy and flowing are mostly chosen. Subordinate textures also have similar feelings.
7	**Aromatic : Lavender**	
Shape		Angular forms with more straight elements than curves.
Color		 Color selection shows a diverse distribution, but Color tones are dull, murky, deep, and dark.
Texture		A rough feel like wood. A consistent distribution in texture selection.
8	**Wood : Sandal Wood**	
Shape		Simple and chunky basic forms.
Color		 A variety of colors are chosen. For color tones, there is a preference for dull, calm, deep, and dark tones.
Texture		Mainly rough textures like wood, with no soft textures observed.

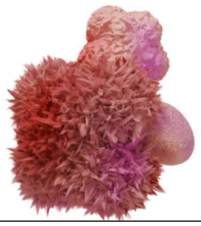
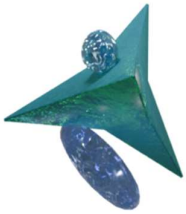
The survey results show tendencies similar to those found in previous studies on the association between scents and shapes, and colors. Additionally, responses related to the scent's type or ingredient appeared in the miscellaneous comments for all scents, indicating that distinguishing scents without additional explanation was easy. The researcher hypothesized that there would be a tendency for scents to correspond with visual symbols and designed olfactory visualization symbols based on the analysis of previous studies. The consistent results across different scents suggest that it is possible to record the scents experienced in specific situations. Based on the survey results from 30 participants, it was confirmed that shapes, colors, and textures associated with each scent showed generally consistent patterns.

3.3. Creation of Olfactory Visualization Images

By analyzing the data obtained from the study on the correspondence between scents and visual symbols, we derived the shapes, colors, and textures corresponding to eight different scents. These data, extracted through experiments, were reconstituted into three-dimensional images to provide visual diversity and enjoyment. The olfactory visualization images for the eight scents are shown in Table 4.

Table 4. Input data

Fragrance	Combination Image	Individual Image

Floral [Rose]		
Oriental [Musk]		
Fruity [Peach]		
Water [Rain]		
Citrus [Bergamot]		
Green [Green Tea]		
Aromatic [Lavender]		

Wood [Sandal Wood]		

3.4. User Survey for Verification of Olfactory Visualization Images

The user survey to verify the olfactory visualization images was conducted on April 29, 2024. The survey involved face-to-face experiments and interviews with 30 adults residing in Seoul who have no visual or olfactory impairments and have an interest in scents and records. The purpose of the olfactory visualization image verification survey was to determine if the subjects felt the same sensations when viewing the images if they could match the olfactory visualization images with the corresponding scents, and if the images could evoke olfactory memories. The hypotheses and questions for this survey are listed in Table 5.

Table 5. Input data

Hypothesis	Questions
1. It will be possible to associate a scent through visual images	Can you recall a scent by looking at this image?
	If you recalled a scent, what was it?
	How difficult was it to associate the image with a scent?
	What are the differences in association between individual images and combined images?
2. There will be similar trends in the images that come to mind when smelling a scent.	Please select the image that comes to mind when you smell each scent.
	What is the reason for your choice?
3. It will be possible to visualize scents.	This image was created based on scent number n. Does it match the image you selected?
	If it matches/doesn't match, what is the reason?
	What aspects of the image should be improved to make it easier to match the scent and the image?
4. It will be possible to evoke emotions through the visualization of scents.	Do you feel any emotions when looking at the image?
	What type of emotion do you feel?
5. There will be a need for the visualization of scents.	Do you find it meaningful to express scents visually?
	What is the reason?

The following are the results of verifying olfactory visualization images. Regarding Hypothesis 1, "It will be possible to associate scents through visual images," more than 80% of respondents, except for Image 7, reported that they could associate a scent with the image. Generally, the scent evoked by the image correctly corresponded to the image. The difficulty level of the association was also mostly reported as easy, except for Stimulus 7. This indicates that associating scents with images is relatively easy.

In an investigation where respondents were presented with both combined images and individual elements to determine which better aids in olfactory associations, slightly more respondents preferred combined images. Those who chose the combined images stated that they evoke various thoughts, making association easier. In contrast, those who selected individual elements mentioned that the segmented feel made perception easier. Additionally, some noted that combined images facilitate easier associations by not interfering with each other's scents, while individual images allow a focus on the visual aspect, stimulating emotions.

Hypothesis 2, "There will be a similar tendency in the images evoked by specific scents," the questions and answers did not entirely match. Still, they showed a trend where many respondents correctly associated scents with images. This tendency was particularly pronounced with familiar scents like fruity, water, and citrus. Despite many finding it difficult to associate lavender with an image, they could correctly match the scent to an image when prompted with the scent first.

Hypothesis 3, "Visualizing olfaction will be possible," the questions and answers revealed subjective responses heavily influenced by personal opinions. There was a preference for images related to the physical appearance of scent ingredients. Even incorrect respondents often said that knowing the answer helped them associate the scent correctly. Overall, the images visualizing the scents matched well, but preferences for color representation varied depending on the scent's complexity, weight, and texture. Despite this, applying texture to 3D forms showed that single colors could be perceived as diverse, enhancing the visual-olfactory connection and allowing for more immersive and descriptive experiences based on individual social contexts, experiences, and learning. This demonstrates that varied colors enrich sensory reflections. For more vivid and immersive associations, diverse colors should be applied to visual images rather than single colors.

Hypothesis 4, "It will be possible to evoke emotions through the visualization of olfaction," more than half of the respondents indicated that they could associate emotions with the images. Many participants answered with emotions likely felt from the forms and textures.

Hypothesis 5, "There will be a need for olfactory visualization," all respondents answered affirmatively to the question of whether visualizing olfaction felt meaningful. The ability to evoke scents through images was the main reason for their response.

The hypotheses and verification results for the effectiveness of olfactory visualization are summarized in Table 6.

Table 6. Input data

Hypothesis	Verification
1. It will be possible to associate a scent through visual images.	O
2. There will be similar trends in the images that come to mind when smelling a scent.	O
3. It will be possible to visualize scents.	O
4. It will be possible to evoke emotions through the visualization of scents.	O
5. There will be a need for the visualization of scents.	O

The results from the general user survey on olfactory visualization images revealed that these images can indeed evoke emotions and that associating scents with images is not difficult. Additionally, a need for olfactory visualization was identified. In conclusion, olfactory visualization stimuli help recall the emotions and scents experienced at the time of recording. These findings validate the researcher's hypothesis.

4. ACKNOWLEDGEMENTS

The researcher believes that visualizing and recording emotions and memories evoked by olfactory stimuli can capture meaningful moments in life, complete with their associated smells and emotions. Additionally, consistency can be found in the selection of forms, colors, and textures related to olfactory stimuli. In that case, it should be possible to visualize and record specific scents experienced in particular situations. To verify this, a hypothesis was formulated stating that there would be a tendency for olfactory stimuli to correspond with visual symbols. Based on the analysis of existing research, visual symbols for olfactory visualization were devised for this study.

To test the hypothesis, an olfactory visualization symbol correspondence survey was conducted with 30 users. The results showed a consistent pattern in the forms, colors, and texture symbols selected for each scent. The selected symbols for each scent were combined in three dimensions to increase visual complexity and provide diversity and enjoyment. The researcher verified five hypotheses with participants interested in scent and olfactory records to test the effectiveness of olfactory visualization.

The survey results indicated that olfactory visualization stimuli influence the emotions and scent associations recalled at the time of recording. It was also found that these stimuli can evoke emotions and that associating scents with the stimuli is not difficult.

Prior studies on the visualization of olfaction have yet to attempt to present and combine symbols for visualization. This research is significant in that it demonstrates the possibility of corresponding forms, colors, and textures with scents, constructing three-dimensional representations of these correspondences and showing that olfactory visualization images can evoke emotions and scent associations.

However, this study has limitations because it used specific single-scent ingredients, suggesting that different results might occur with other or more complex scents. Additionally, the survey was conducted among individuals in their 20s and 30s residing in Seoul and the metropolitan area, thus not considering the results that might vary with different ages, cultures, and regions. Future research should expand the scope of participants and consider various scents. It is hoped that further studies will explore additional elements beyond form, color, and texture to record emotions more comprehensively.

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