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INFLUENCE OF MULTIMODAL INTEGRATION ON SPATIAL PERCEPTION

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ABSTRACT

To design affective spaces that promote stabilized living experience and user well-being, it is necessary to consider and be aware of how multiple perceptual information interact and influence the way we perceive space i.e. multimodal perception. This study aims to gain an understanding of how sensory cues influence the emotional evaluation of the spatial design. We analyzed how the change in levels of spatial elements was emotionally perceived in the presence and absence of scent and color. The results from the study presented that both scent and color significantly affected the emotional response to change in levels of spatial elements in different ways. The findings suggest that (1) in the absence of both color and scent, the spatial elements interacted to affect the participants' moods related to being confused and feeling strained and tensed, (2) in the presence of a cool color (purple) and relaxing scent (lavender), spatial elements interacted to affect the participants' mood related to feeling strained and tensed, (3) in the presence of a warm color (orange) and stimulating scent (orange), spatial elements interacted to affect the participants' mood related to being unhappy. The findings of the study are worthy as they provide an insight into the influence of multimodality in spatial perception. They will help establish guidelines for incorporating perceptual information in spatial designs that provide stabilized living experience and enhanced individual well-being.

Keywords: *Multisensory Perception, High-Level Cognitive Functions, Visual-Olfactory Stimulation*

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1 INTRODUCTION

1.1 Multisensory perception in spatial design

It is a common conception and practice in environmental design and research to place emphasis on vision as a predominant sense or take a sense-by-sense i.e., unisensory approach, to evaluate how the change in one sensory stimulant (ex: olfactory) affects the affective response to another (ex: vision). However, any given environment is a complex multisensory structure that is experienced through the integration of multiple sensory information which influences our reactions and experiences within it. *The model of explaining the relationship of an innate subjective filter and the individual modification process by the experiences* by Kim et al. (2012) (Figure 1) presents the *kansei* process of how perceptual information obtained from sensory organs (eyes, nose, ears, etc) are integrated into the brain and is output as affective reaction such as emotion or intuition, which then act as the scale of the aesthetic and logical judgments [15].

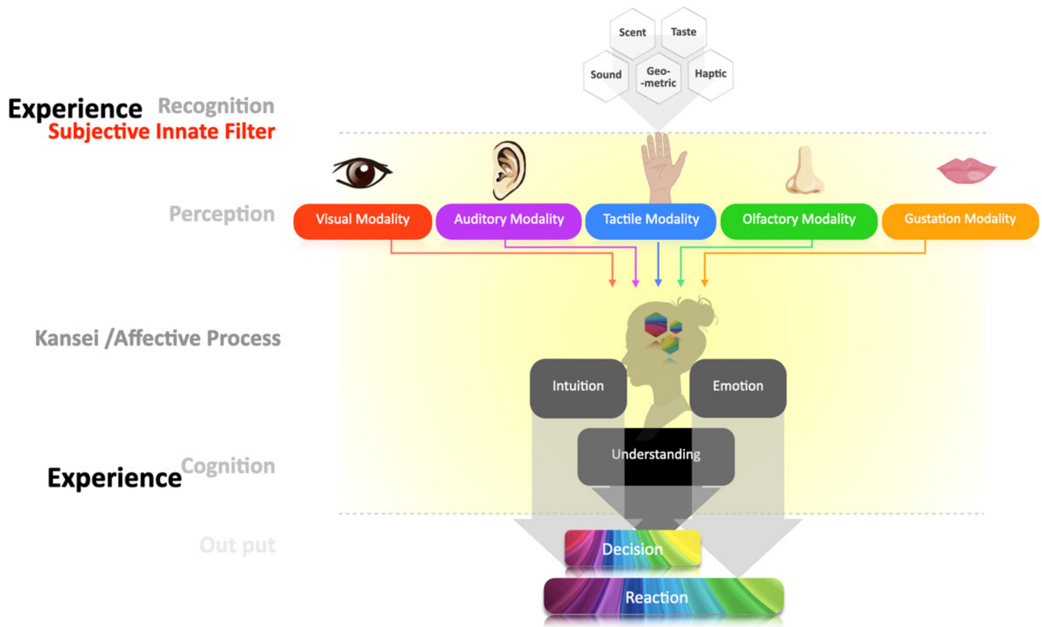

Figure 1. *The model of explaining the relationship of an innate subjective filter and the individual modification process* by the experiences by Kim et al (2012)

Nevertheless, there are insufficient findings on the extent to which our senses interact to affect our responses. Little consideration is given to the question of how the perceptual information from multiple sensory cues conjointly affects an individual's affective response in any given environment. A multisensory approach to spatial design practices will lead to the development of buildings and urban spaces that are matched to the users' social, cognitive, and emotional enhancement and well-being, rather than hindering it.

1.2 Purpose of the study

This study aims to gain an understanding of how sensory cues influence the emotional evaluation of the spatial design. For this purpose, we analyzed how the change in levels of spatial design elements (ceiling height, wideness) was emotionally perceived in the presence and absence of visual-olfactory cues (scent and color).

2 METHOD

Sixty-two native Japanese students (male:39, female:23, average age:21.1 SD:2) participated in the experiment.

2.1 Stimuli

Olfactory stimuli: Orange and lavender essential oils were selected and used as olfactory stimuli in the experiment [2,3]. The olfactory stimuli were presented by applying 0.05 cc (1 drop) of the essential oil on a mask. The participants wore the scented masks during the with scent *(orange scent/lavender scent)* conditions.

Visual stimuli: Nine types of VR (virtual reality) spaces with three levels of *ceiling height* (*lower, default, higher*) and *wideness* (*narrower, default, wider*) were prepared and presented in three color conditions (*no color, orange color, purple color*). A total of twenty-seven visual stimuli were produced by combining each level of the *ceiling height* and *wideness* in each color condition.

The visual stimuli used in the experiment were designed using Unity 2019.1.14f1, a cross-platform game engine, and were presented via Oculus Quest Head Mount Display (HMD). VR was used as a medium for visual stimuli in this experiment as it has been reported to be an effective tool for studying the emotional response to spatial conditions and has been widely applied in the psychiatric treatment of space-related phobia (ex: claustrophobia, acrophobia) [4, 5, 6]. The colors of the VR spaces were: greyish white (Hex Value: #f8f8f8) in *no color* condition, orange (Hex Value: #db9c7b) in *orange color* condition, and purple (Hex Value: #b0a3b6) in *purple color* condition. Greyish white was set by the authors, while orange and purple colors were selected from a previous study about the influence of wall colors on patients' recovery [7]. The size specification of the three levels of *ceiling height* and *wideness* are as presented in Table 1.

Table 1. Size specification of the three levels of the *ceiling height* and *wideness* of the VR spaces as set in Unity 5.5 (1m=1 Unity unit)

Spatial Design Element	Levels	Specification (m)
wideness	narrower	2.64×2.64
	default	5.282×5.282
	wider	10.56×5.282
ceiling height	lower	1.37
	default	2.4
	higher	4.2

The scale of measurement for wideness and ceiling height were set in Unity units (1 Unity unit = 1 meter). The default wideness level was set at 27.9 square meters, which is the standard floor space per person in Japan (Kanemoto, 1997) [8]. The default ceiling height was set at 2.4 meters, which is the average ceiling height used by housemakers in Japan [9]. The size setting for the levels other than those for the default levels was decided by the authors. In the case of the ceiling height element, the lower and higher levels were adjusted from the eye level in a seated position. As for the wideness element, the narrower and wider levels were set two times wider and narrower than the default level. This was done by checking the condition in the VR environment. The level of brightness was maintained the same in all the VR spaces.

2.2 Experiment method

The emotional evaluation was performed by using thirteen mood state evaluation phrases (Japanese), which were selected from previous studies on the influence of visual-olfactory stimulation on spatial perception [10,11]. The phrases were rated on a 5-point scale from 0 to 4 (0= not at all; 1= a little; 2= moderately; 3= quite a bit; 4= extremely). The evaluation phrases are as follows: *is confused, is unhappy, feel lonely, is worn out, feel strained and tensed, feel restless, feel panicky, feeling anxious, feeling nervous, feel stressed, feel refreshed, is not confident, feel gloomy.*

2.3 Procedure

The participants were assigned to one of the nine *scent-color* conditions, where they observed the nine VR spaces in the presence or absence of scent and color. The nine *scent-color* conditions are as follows: *no scent-no color, no scent-orange color, no scent-purple color, orange scent-no color, orange scent-orange color, orange scent-purple color, lavender scent-no color, lavender scent-orange color, lavender scent-purple color.* Before commencing the experiment, the participants were given a brief introduction to the experiment such as instructions on how to observe the stimuli and regarding the evaluation process. They were not informed about the presence or absence of scent and color to avoid biased impressions. They observed the VR spaces by freely turning around, looking in different directions, while remaining seated throughout the experiment. The stimuli were each presented to the participants for ten seconds in random order. The ten-second display duration was based on a previous study on impression evaluation of spatial conditions using fMRI that set the stimulus display time to 3000 milliseconds [12]. After this, the participants evaluated the evaluation phrases. This was treated as an inter-trial interval before they observed the next stimulus. The duration of the experiment per subject was twenty to thirty minutes.

2.4 Results

Two-way ANOVA was used for data analysis in this study to analyze how the change in levels of spatial design elements (ceiling height, wideness) was emotionally perceived in the presence and absence of visual-olfactory cues (scent and color). Significant interactions were reported in the *no scent-no color, orange scent-orange color,* and *lavender scent-purple color* conditions (Table 2). Data are reported as statistically significant at $p < .05$ and highly statistically significant at $p < .01$.

Table 2. Two-way ANOVA results for the significant interaction effect of ceiling height and wideness in *scent-color* conditions ($p < .05$*, $p < .01$**)

scent-color condition	evaluation phrase	independent variable	p-value
no scent-no color	*is confused*	*wideness[wider-default]*ceiling height[default-lower]*	0.0212*
	feel strained and tensed	*ceiling height[higher-default]*	0.0370*

		*wideness[default-narrower]*ceiling height[higher-default]*	0.0333*
orange scent-no color	*is confused*	*wideness[default-narrower]*	0.0026**
		*wideness[default-narrower]*ceiling height[default-lower]*	0.0066**
orange scent-orange color	*is unhappy*	*wideness[default-narrower]*ceiling height[higher-default]*	0.0413*
lavender scent-purple color	*feel strained and tensed*	*wideness[wider-default]*ceiling height[higher-default]*	0.0437*

No scent-no color condition: Significant interaction effect between ceiling height and wideness (p<.05*) (Figure 2, left) was reported for the evaluation phrase *is confused* (Table 4). A main effect of ceiling height (p<.05*) and significant interaction effect between ceiling height and wideness (p<.05*) (Figure 2, right) were reported for the evaluation phrase *feel strained and tensed*.

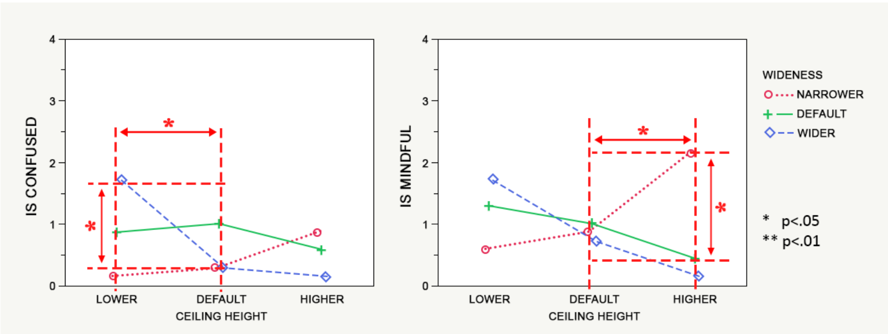

Figure 2. Significant interaction effect in the *no scent-no color* condition between *ceiling height* and *wideness* for the evaluation phrase *is confused* (p<.05*) (left) and *feel strained and tensed* (p<.05*) (right).

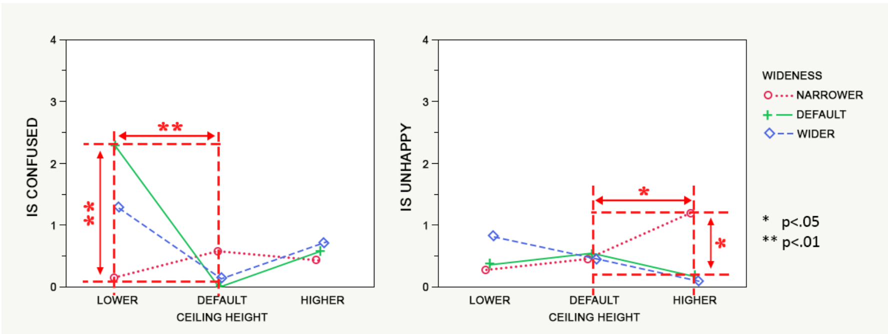

Figure 3. Significant interaction effect between ceiling height and wideness in the *orange scent-no color* condition for the evaluation phrase *is confused* (p<.01**) (left) and in the *orange scent-orange color* condition for the evaluation phrase *is unhappy* (p<.05*) (right)

Orange scent-no color condition: A main effect of wideness (p<.01**) and significant interaction effect between ceiling height and wideness (p<.01**) (Figure 2, left) was reported for the evaluation phrase *is confused*.

Orange scent-orange color condition: Significant interaction effect between ceiling height and wideness (p<.05*) (Figure 3, right) was reported for the evaluation phrase *is unhappy* in the orange scent-orange color condition.

Lavender scent-purple color condition Significant interaction effect between ceiling height and wideness (p<.05*) (Figure4) was reported for the evaluation phrase *feel strained and tensed* in the *lavender scent- purple color* condition.

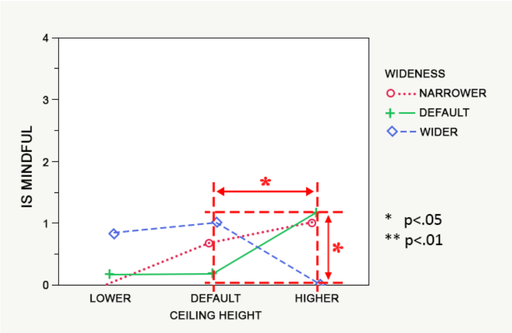

Figure 4. Significant interaction effect in the *lavender scent-purple color* condition between ceiling height and wideness for the evaluation phrase *feel strained and tensed* (p<.05*)

3 DISCUSSION AND CONCLUSION

This study aimed to gain an understanding of how sensory cues influence the emotional evaluation of the spatial design. We analyzed how the change in levels of spatial elements (ceiling height and wideness) was emotionally perceived in the presence and absence of scent and color. The results from the study presented that both scent and color significantly affected the emotional response to change in levels of spatial elements in different ways. The results present that:

(1) *No scent-no color:* The evaluation of *is confused* reduced greatly (*moderately* to *not at all*) in *wider* level of wideness as the ceiling height increased (*lower* to *default*). Conversely, there was only a slight difference in rating (*a little*) for the *default* level of wideness when the level of ceiling height increased (from *lower* to *default*) (Figure.2, left). The evaluation of *feel strained and tensed* increased greatly (*a little* to *moderately*) in *narrower* space as the ceiling height increased (*default* to *higher*). Conversely, the evaluation of *feel strained and tensed* decreased (*a little* to *not at all*) in *default* level of *wideness* as the ceiling height increased (*default* to *higher*) (Figure.2, right).

(2) *Orange scent-no color:* The evaluation of *is confused* reduced greatly (*moderately* to *not at all*) in *default* level of wideness as the ceiling height increased (*lower* to *default*). Conversely, the evaluation of *is confused* increased (*not at all* towards *a little*) in *narrower* level of wideness as the ceiling height increased (*lower* to *default*) (Figure.3, left).

(3) *Orange scent-orange color:* The evaluation of *is unhappy* increased (*not at all* to *a little*) in *narrower* level of wideness as the ceiling height increased (*default* to *higher*). Conversely, the evaluation of *is unhappy* reduced (*not at all* towards *a little*) in *default* level of wideness as the ceiling height increased (*default* to *higher*) (Figure.3, right).

(4) *Lavender scent-purple color:* The evaluation of *is feel strained and tensed* increased (*not at all* to *a little*) in *default* level of wideness as the ceiling height increased (*default* to *higher*). Conversely, the evaluation of *feel strained and tensed* reduced (*a little* to *not at all*) in *wider* level of wideness as the ceiling height increased (*default* to *higher*) (Figure.4).

3.1 Visual-olfactory integration in spatial perception

With most of our lives spent indoors, the space we occupy has a major role in our psychological behavior. Research works in the field of environmental psychology [13] have presented significant findings on how the environments affect individuals who inhabit them. The relationship between spatial design elements (ex: color, size, brightness, etc.) and user experiences is an important aspect of environmental design. Sakuragawa (2006) reported on how the users' perceptions and preferences were affected by the change in design features of a given space [14]. Ceiling height tends to influence users' aesthetic judgment and visual perception of the room [12] and the variation in the level of ceiling heights can affect the feeling of freedom and confinement within a given space [15]. Perception of an interior space can be influenced depending on the direction of illumination, and the type of light. Light is also reported to provide a sense of depth to the interior space [16]. Color has been reported to play an effective role in human emotions and perception in work and living environments [17]. Warm colors (such as orange) are associated with arousing, stressful and exciting moods, while cool colors (such as blue) are associated to calm, serene and comfortable moods [16]. Warm colors appear to be closer, and cool colors appear to be farther away [18].

Another sense which has been reported to effectively influence spatial perception is olfaction. It plays an active part in our daily lives and is strongly linked to the brain's emotional centers and has beneficial effects on people's mood, perception, and memory of environments. Lehrner et al. (2005) investigated the effect of ambient scents on mood improvement in a dental office and presented that ambient scents (orange and lavender) reduced anxiety and improved mood in patients waiting for their treatment [2]. Another study analyzing the effect of ambient scents on the waiting experience in a given environment presented that, orange scent elevated the evaluation of physical properties of the room such as brightness and height [3]. Gérard Brand and Jean-Louis Millot's (2010) study presented that, women have heightened sensitivity to scents and tend to be superior in terms of olfactory skills [19]. In recent years, it is widely used in retail spaces to improve the users' mood and impression about the product being displayed [20]. Environmental scents (ex: orange, lavender, ginger, mint) resulted in a mood enhancement of the customers in a retail environment, and also resulted in a positive evaluation of the environment and approach behavior [21]. Cho and Sai (2019) studied the interaction effect of the spatial design elements and scent on the psychological mood state. They reported that the presence of olfaction helped reduce the negative mood of the participants and improved positive mood states in deficit spatial conditions such as narrow spaces with low ceiling heights [10]. In another study on the influence of visual-olfactory stimulation on affective response to spatial design elements, they reported that spatial design elements interacted to affect emotions related to anxiety in the presence of orange scents and emotions related to decision making in the absence of an olfactory stimulus [11].

While there is growing interest in the significance of visual-olfactory stimulation in spatial perception, researchers mostly focus on how the condition of one sensory cue affects the evaluation of another and whether that interaction affects the users' mood, behavior, or performance. However, there is a lack of experimental evidence on how our perception of space changes when multiple sensory cues are simultaneously stimulated. The present study attempted to answer this question by analyzing how the change in levels of spatial design elements (ceiling height, wideness) was emotionally perceived in the presence and absence of scent and color. Emphasis was placed on scent and color since they are common interior and ambient features in spatial design. Gaining an experimental understanding of how these sensory cues affect the way we perceive spatial design will provide simple, minimal, and impressive ways to change the user experience of any given space. The findings of this study suggest that (1) In the absence of both color and scent, the ceiling height and wideness interacted to affect the participants' moods related to confusion, strain, and tension. (2) In the presence of a stimulating scent (orange), ceiling height and wideness interacted to affect the participants' mood related to confusion. (3) In the presence of a warm color (orange) and stimulating scent (orange), ceiling height and wideness interacted to affect the participants' mood related to unhappiness. (4) In the presence of a cool color (purple) and relaxing scent (lavender), ceiling height and wideness interacted to affect the participants' moods related to strain and tension. These findings are worthy as they add to the previous evidence of the effectiveness of visual-olfactory stimulation on the way we perceive space. Further research will provide deeper experimental knowledge about the relationship between multimodal perception and spatial design and will aid in the development of guidelines for affective spatial designs that will provide more stable living environments and positively impact improved individual well-being.

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