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# Investigation of the Influence of Scent on Self-Motion Feeling by Vection

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***Abstract*** - Vection is an illusion that gives the feeling of motion in the absence of bodily movement. This phenomenon may occur with the presentation of a screen displaying patterns with optical flows. In an immersive environment that uses a head mounted display (HMD), including virtual reality (VR) systems, vection is frequently induced. In recent years, many trials have been conducted in which scents are displayed with VR systems. We aimed to investigate the effects of scents on vection perception. In the current experiments, the subjects were seated in front of an olfactory display while wearing an HMD and were presented with moving images to induce vection, under several conditions: scent presentation, sound presentation, and presentation of no additional stimuli. We found that scent stimuli do not affect the perception of vection. However, there were many positive correlations between perceived vection strength and perceived scent strength, especially in the lavender condition. It seems that there is some relation between the lavender scent and vection.

***Keywords***: vection, sense of smell, scent, sense of sight, HMD, olfactory display

## 1 INTRODUCTION

Vection is the visually induced illusion of self-motion [1], which may be felt when viewing a screen that is displaying patterns with optical flows. It is known that vection is induced not only by visual stimulation but also by auditory and somatosensory stimulation. Sakamot et al. [2] have reported that sound images of movement from front to back or from back to front induce linear self-motion perception and that the self-motion direction is influenced by the direction of the motion of auditory stimuli. This shows that auditory information also has a great influence on self-motion. Vection is also caused by somatosensory sensation. Murata et al. [3] performed experiments in which participants wore eye masks and were presented with white noise through a pair of earphones. A horse riding machine was used to produce bodily movement in the participant. Almost all of the participants in this condition felt the sense of forward motion on presentation of a constant stream of air to their front. As with the sense of vision and hearing, sense of smell can detect the object without touching it [4], so it is thought that olfactory stimulation may cause a sense of self-motion. However, research on olfactory vection has not been conducted.

It is known that auditory stimuli and cutaneous sensory stimuli promote vection perception by presenting them with visual stimuli. Riecke et al. [5] have reported that concurrently rotating auditory cues that match visual landmarks (e.g., a fountain sound) facilitated visually induced circular vection and presence. Seno et al. [6] have reported that consistent air flow to subjects' faces facilitated forward vection. The sense of smell is not as accurate as visual and auditory senses, but it can be a cue to estimate the distance to the object. Although it might be possible to promote vection perception, the effects of olfactory stimuli on visual vection have not been investigated at all.

In recent years, sense presentation technology in VR has been developed and using five senses in VR is much easier. Because of these developments in VR technology, senses other than visual and auditory senses can be and should be more used and investigated in science too. In fact, it was suggested in various articles that the importance of multimodal research is also increasing [7]. Many trials have been conducted in which scents are displayed in conjunction with movies or games using VR systems. For example, VAQSO, a device that adds a scent to the VR experience, is planned to be released for 2019 [8]. Because this device is compatible with any HMD, the contents using scent will increase. In an immersive environment, such as a VR game using an HMD, vection is frequently induced. However, few studies have investigated the relationship between vection and olfactory stimulation. Vection is closely related to VR sickness. Investigating the relationship between vection and olfactory stimulation, can enhance our understanding of vection and may become a clue to solving the VR sickness problem.

The aim of this research was to investigate the effects of scents on vection perception. We investigated whether olfactory stimuli affect vection perception and whether the effects are emphasizing or destructive. Furthermore, we researched whether the effect on vection perception changes depending on the type of scent. In this experiment, the subjects were seated in front of an olfactory display while wearing an HMD and were presented with two types of moving images, i.e., expansive and contractive optical flow, respectively under the conditions of with and without scents. During the moving image presentation, we measured the latency and duration of vection. After finishing the stimuli presentation, the subjects evaluated the strength of the vection that they experienced using subjective values. We examined the relationship between vection and olfactory stimuli using the results of this experiment.

# 2 METHODOLOGY

## 2.1 Olfactory Display

We used the Fragrance Jet 2 olfactory display (Fig. 1). This display uses the techniques of an ink-jet printer in order to produce a jet, which is broken into droplets by a small hole in the ink tank. Bubbles are formed in the ink by instantaneous heating, and ink is ejected by the pressure of bubbles. The display can set up one ejection head. This head can store three small tanks and one large tank; thus, this display can contain a maximum of four kinds of scents. There are 127 minute holes in the head that is connected to the small tank and 256 minute holes in the head that is connected to the large tank. Because the display can emit scent from multiple holes at the same time, the ejection quantity can be set at 0 to 127 (in the small tank) or 0 to 256 (in the large tank). We denote the average ejection quantity at one time from each hole as "the unit average ejection quantity (UAEQ)", and the number of minute holes that are emitting at one time as "the number of simultaneous ejections (NSE)". The unit average ejection quantity from the one minute hole in the small tank is 4.7 picoliters (pl) and that from the one minute hole in the large tank is 7.3 pl. The reproducibility of these values was confirmed without depending on the residual quantity of ink on examination. Because the emission occurs 150 times per unit time (100 milliseconds), the ejection quantity (EQ) in the case of the small tank that we used in this experiment was calculated as follows.

EQ (pl) = 4.7 (pl)(UAEQ) × (from 0 to 127)(NSE) × 150 (times)

The ejection amount per unit time depends only on the NSE. In this experiment, we refer to NSE as the ejection level.

Additionally, the display is equipped with a fan and 9 phases of wind velocity control in the range of 0.8 m/sec-1.8 m/sec.

Figure 1: Olfactory Display: Fragrance Jet 2

## 2.2 Scent Stimuli

Two kinds of scents were used in this experiment: lavender (oil of lavender) and banana (iso-amyl acetate). We used lavender because it is said to affect the movement of the body [9], and is thought to have some influence on vection. Banana scent has not been reported to have any special effects the movement of the body. Therefore we used it for comparison. The scents were diluted to 5% with ethanol and water, and the component ratios of each perfume are shown in Table 1. In order to determine the ejection level at which the subjects could sense the scent, we measured the detection threshold, which is the minimum detectable concentration of scent. This method is based on the two-point comparison method that was proposed by the Japan Association of Odor Environment. The initial ejection level was set to 5. If the subject correctly identified the scent twice at the initial level, we reduced the level by 2 according to the descent method and ended the measurement when the subject could not identify the scent.

Table 1: Scent stimuli

| Scents | | Lavender | Banana |
|---|---|---|---|
| Component ratios | Scent (%) | 5 | 5 |
| | Ethanol (%) | 65 | 75 |
| | Water (%) | 30 | 20 |

Table 2: Result of olfactory detection threshold measurement

| | Lavender | Banana |
|---|---|---|
| Avg. | 2.67 | 3.67 |
| SD. | 1.97 | 2.07 |
| Max. | 5 | 7 |
| Min. | 1 | 1 |

When the subject was not able to correctly identify the scent at the initial level, we adopted the rising method and increased the level by 3. The measurement was considered to be complete when the subject (between the age of 20 and 30 years, male) correctly identified the scent twice. Based on this result, the ejection level to be used in the following experiment was determined. Table 2 shows the measurement values of 6 participants.

## 2.3 Vection Stimuli

To induce vection, two kinds of moving images were used. The expansion stimulus was used to induce a feeling of forward movement which is frequently experienced in everyday life and VR games. The contraction stimulus was used to induce a feeling of backward movement. In the case of the expansion stimulus, when a dot reached the edge of the screen and disappeared, a continuous stimulus presentation could be obtained by rearranging the dot from the center of the plane. In the case of the contraction stimulus, a dot was repositioned from the edge of the plane when it reached the center of the plane and disappeared. In each stimulus, a total of 2400 dots are displayed on the screen. The size of the dot on the screen was changed to be physically constant according to the distance change simulation. Because the dots do not have a density gradient and do not give a static depth cue, the depth cues were only provided by motion. The speed of each dot was about 3.7 degrees per second at the viewing angle. Figure 2 shows a still image of the vection-inducing visual stimulus. Arrows indicate movement of points. The visual stimuli were presented using Oculus Rift DK2. The viewing angle was set at 110 degrees in the diagonal direction and 90 degrees in the horizontal direction and the motion stimuli that induced vection was displayed almost over the entire screen.

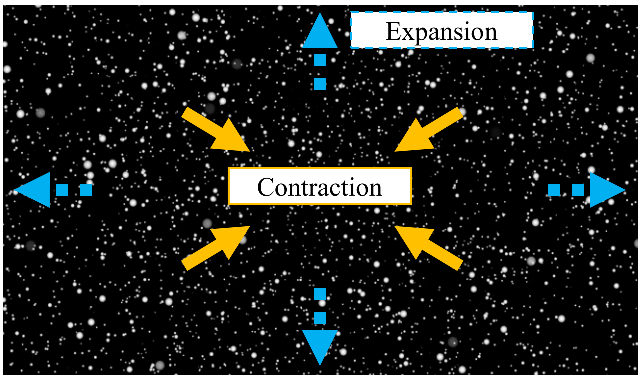


Figure 2: Still image of vection stimulus

Figure 3: The experimental condition

## 2.4 Sound Stimuli

As a control condition, sound stimuli using a pure tone at the frequency of 440 Hz and amplitude of 0.1 was presented in order to investigate the influence of olfactory stimuli on vection more clearly. For the sound presentation, a set of sealed dynamic headphones (SE-MJ 522, Pioneer) was used, and the playback volume was set to the sound that would normally be heard through a speaker.

## 2.5 Experimental Conditions

All experiments were carried out while the subject was seated on a chair with their jaw positioned on a chin rest. The subjects wore HMDs and headphones throughout the experiments. The distance from the ejection exit of the head of the olfactory display to the nose was fixed at 225 mm. The olfactory display was set up with the presentation port facing diagonally upward and the height of the jaws was adjusted by each subject so that the wind from the display hit their face firmly. Figure 3 shows the actual experimental conditions. The wind speed was set to level 9, which is the maximum setting (on a scale of 1 to 9). The measured wind speed under these conditions was approximately 1.8 m/sec. During the experiment, a fan was constantly in operation even when no scents were being emitted. Thus, the risk of a change in perception due to the presence or absence of the wind was eliminated.

## 2.6 Qualification of Subjects

Prior to performing the olfactory experiment, we conducted a test to confirm that the subjects had a general olfactory sense. In this test, we used odor panel analysis to qualify five standard odor solutions and tested whether each odor could be identified. The standard odor for panel selection was prepared based on the T & T Olfactory-meter, and it is used in national examinations to determine olfactory measurement operator [10]. Using odor solutions at the concentration determined by the Ministry of the Environment, the test was conducted according to the 5-2 method. Only subjects who passed the test were taken as subjects.

It is suggested that approximately 1 person in 20 people does not feel vection (vection blind). Therefore, subjects were screened before the experiment was conducted. We asked subjects to observe expansive and contractive moving images. Subjects were then asked to evaluate the vection they felt. In cases where subjects answered that they did not feel vection (intensity 0) in more than half of these tests, they were excluded from the experiment.

# 3 EXPERIMENT 1: PRESENTATION METHOD OF OLFACTORY STIMULI

It is necessary to examine the ejection method so that the subjects can continue to feel the scent without adaptation for 70 seconds including 30 seconds before the presentation of the vection stimuli. Therefore, a preliminary experiment was conducted with reference to a previous study [11].

## 3.1 Experimental Method

Two kinds of scents were used in this experiment: lavender and banana. Four times the average value obtained in the above detection threshold measurement experiment was set as a reference value 1, and 8 times the average value was set as a reference value 2.

Table 3 shows the respective ejection levels. As shown in Fig. 4, scent ejection with duration of 0.3 seconds and an interval of 1.3 seconds was repeated for 70 seconds.

After the stimuli presentation, subjects evaluated how they felt the continuity of scent ejection at the four stages in Table 4 and how they felt the intensity change for 70 seconds at five stages in Table 5. We determined a presentation condition that was suitable for this experiment; the selection of the condition was based on obtaining an average value of 2 or more, regarding the continuity, and at a level where no subjects selected 0 regarding the strength.

Measurements were made with a 1-minute break every 70 seconds and the presentation was repeated 4 times for each of the 2 scents. Taking the order effect into consideration, we determined the first and second scents randomly and adjusted them, so each order was presented approximately an equal number of times. Between the presentations of each scent, there was a five-minute break. Because of the nature of the experiment, it was assumed that the subjects could easily feel the scents. Therefore, prior to the first measurement, we confirmed verbally whether each subject could feel the ejection of scents twice. Next, we conducted the experiment with 5 subjects (between 20 and 25 years of age, male) using the reference value 1, and with 5 subjects

Table 3: Ejection levels

| | Detection threshold | Reference value 1 | Reference value 2 |
|---|---|---|---|
| Lavender | 2.67 | 11 | 21 |
| Banana | 3.67 | 15 | 29 |

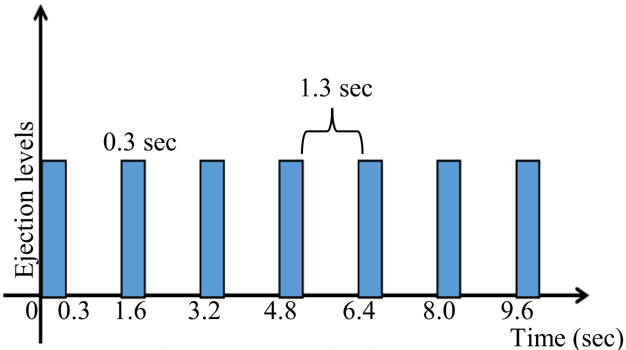

Figure 4: Scent ejection pattern

Table 4: Four-stage evaluation for continuity

| | |
|---|---|
| 0 | I did not feel the scent from midway during the exposure period |
| 1 | I felt it fragmentally |
| 2 | I felt it every breath |
| 3 | I felt it continuously |

Table 5: Five-stage evaluation for the strength

| | |
|---|---|
| 0 | I did not feel the scent from midway during the exposure period |
| 1 | I felt that the concentration gradually decreased |
| 2 | I felt that the concentration got increased or decreased |
| 3 | I felt that the concentration gradually increased |
| 4 | I felt no change in the concentration and felt the scent uniformly |

(between 20 and 30 years of age, male) using the reference value 2.

## 3.2 Experimental Results

Table 6 shows the average evaluation values, the standard deviation, and the minimum values in the case of reference values 1 and 2 for each scent. Because the average value of each cell is 2 or more, it can be said that the subjects are able to smell the scents without adaptation for 70 seconds with an ejection duration of 0.3 seconds and an ejection interval of 1.3 seconds. However, with reference value 1, the minimum value of the continuity of lavender scent and banana scent was 0. And with reference value 2, the minimum value of the continuity and intensity of lavender scent was 0. The results of this experiment revealed that some of the subjects could not sense the scent for 70 seconds.

When we interviewed the subjects who rated the continuity as 0, they made the following comments: "The ejection amount with the reference value 1 was too small to feel it", and "The ejection amount with reference value 2 was so large that my nose paralyzed". Thus, we asked three subjects (between 20 and 25 years of age, male) to rate the scent

Table 6: Evaluation values for the continuity and the strength of the scent stimuli

| | | Reference value 1 | | Reference value 2 | |
|---|---|---|---|---|---|
| | | Lavender | Banana | Lavender | Banana |
| Continuity | Avg. | 2.10 | 2.00 | 2.30 | 2.75 |
| | SD. | 0.76 | 0.52 | 1.31 | 0.46 |
| | Min. | 0 | 0 | 0 | 1 |
| Strength | Avg. | 2.55 | 2.06 | 2.20 | 2.80 |
| | SD. | 1.16 | 1.31 | 1.85 | 1.04 |
| | Min. | 1 | 0 | 0 | 1 |

Table 7: Six-level odor intensity indication

| | |
|---|---|
| 0 | Odorless |
| 1 | A faint smell that you can hardly perceive (Equivalent to detection threshold) |
| 2 | Weak smell you can recognize (Equivalent to cognitive threshold) |
| 3 | Easily perceptible smell |
| 4 | Strong smell |
| 5 | Intense smell |

Table 8: Scent intensity

| | Reference value 1 | | Reference value 2 | |
|---|---|---|---|---|
| | Lavender | Banana | Lavender | Banana |
| Avg. | 2.42 | 1.92 | 2..83 | 2.58 |
| SD. | 0.79 | 1.44 | 0.93 | 1.08 |

intensity with both reference values, using the six-level odor intensity indication method [12] (Table 7) consisting of odorless (0) to intense odor (5). This technique was devised in the field of odor control in Japan.

Table 8 shows the average and standard deviation of the evaluation values. Because the values are between 2 and 3, respectively, except for the banana scent reference value 1, we set the reference value 2 as the ejection level in this experiment so that the subject surely feels it in the experiment.

# 4 EXPERIMENT 2: EXAMINATION OF THE EFFECTS OF SCENT ON VECTION

In experiment 1, we confirmed the olfactory stimuli presentation method, which enables the subjects to continue to perceive scent without adaption for 70 seconds. Using this method, we investigated the influence of scent on vection perception in experiment 2. The subjects wore an HMD and were presented with a moving image that induced vection under scent or sound presentation condition or movie only condition, and evaluated its strength.

## 4.1 Experimental Method

The vection stimuli presentation time was set to 40 seconds. The scent and sound stimuli started 30 seconds

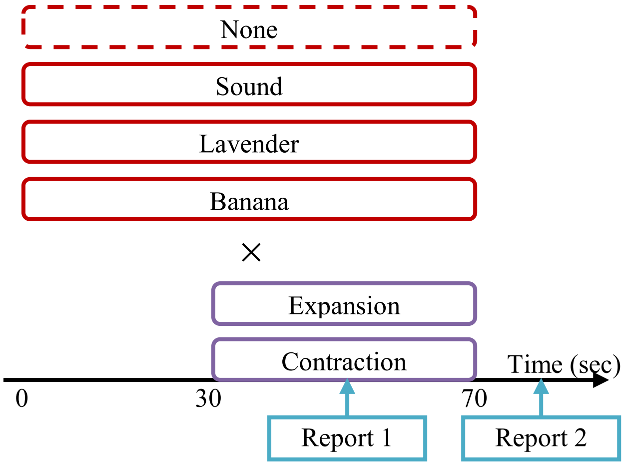

Figure 5: Flow of presenting stimuli

before the presentation of the vection stimuli and continued to be presented for 70 seconds. The flow of one trial is shown in Fig. 5. During the period in which the moving stimuli were presented, the subjects were asked to report the duration of time for which they were experiencing vection (Report1). This was reported by pressing the left button of the mouse. At this time, the time required for the first button press was recorded as the latency of vection. The total time during which the button was pressed in the 40 second period was recorded as the duration of vection. After the stimuli presentation was completed, the subjects were asked to report the strength of the vection by rating 0 when they did not feel vection, and 100 when they felt vection very strongly (Report 2). Acquisition of these three variables has been repeatedly used in previous vection experiments (e.g. Seno et al., 2013 [13]). Furthermore, in cases where an olfactory stimulus was presented, subjects were also asked to report the subjective intensity value of the scent by selecting from the six-level odor intensity indicator that is displayed in Table 8 after the stimuli presentation was completed (Report2). Under each condition, the flow of one trial, as shown in Fig. 5, was repeated 4 times, with a 1-minute break between each trial. The experiment consisted of 8 conditions, and each condition was carried out as one block with 4 consecutive trials.

The order of 8 block experiments was randomized for each subject. A 5-minute break was set between the blocks.

## 4.2 Experimental Results

The results under expansion stimuli conditions are shown in Fig. 6 and that under contraction stimuli conditions are shown in Fig. 7. The subjective vection strength in each condition was compared. It is known that when vection is strong, the latency is short, the vection duration is long, and the magnitude is large.

In the expansion stimuli condition, the order of the duration of latency was as follows, from the shortest to the longest: sound, lavender, none and banana. The order of the duration of vection was as follows, from the longest to the shortest: sound, none, lavender and banana. The order of the magnitude of vection was as follows, from the largest to the smallest: lavender, sound, banana and none. Therefore, it can be said that the sound condition had the largest effect on the time of vection as perceived by subjects and the lavender condition had the largest effect on the magnitude of vection. A nonparametric test, using the Friedman method, showed a significant difference only in the latency ($P < 0.01$). Therefore, when multiple comparisons were performed using the Bonferroni method, the results showed no significant difference ($P > 0.05$). Therefore, there is almost no statistical difference.

In the contraction stimuli condition, the order of the duration of latency was as follows, from the shortest to the longest: lavender, none, banana and sound. The order of the duration of vection was as follows, from the longest to the shortest: lavender, none, banana and sound. The order of the magnitude of vection was as follows, from the largest to the smallest: lavender, sound, banana and none. Therefore, it can be said that vection was perceived most strongly by subjects in the lavender condition. In addition, the sound stimulation that tended to promote vection perception in the expansion stimuli was the weakest vection promoter in the contraction stimuli condition. Similar to the case of the expansion stimuli, we examined a nonparametric test using the Friedman method, and the results showed that there was no significant difference in the responses to any of the three variables ($P > 0.05$). However, when the significance level was set at 10%, there was a tendency towards a difference in the latency ($P < 0.10$) and magnitude ($P < 0.10$), respectively. Therefore, there is no statistical difference. However, the results indicate that the lavender stimuli tended to promote the perception of vection.

We next examined for a change of scent intensity. The result of Experiment 1 is used as a condition without HMD. In addition, the same operation as in Experiment 1 was conducted with three subjects (early 20s, male) presenting a gray scale image of Fig. 8 wearing HMD, and using the results of this as a condition without vection. The results of strength of scent under each visual stimuli condition are shown in Fig. 9. For each scent, a nonparametric test between visual stimuli was performed using the Kruskal-Wallis method. As a result, a significant difference was found in the main effect of visual stimulation in lavender condition ($P < 0.001$), but a significant difference was not found in banana condition. Therefore, when multiple comparisons were performed using the Bonferroni method in lavender condition, significant differences were observed between without HMD and the expansion condition ($P<0.05$), between without HMD and the contraction condition ($P<0.01$), between without vection and contraction condition ($P<0.05$), respectively. Consequently, it was found that vection stimuli with HMD reduced the olfactory strength in lavender scent.

In two presenting scent conditions, we performed a correlation analysis by Pearson's product moment correlation using SPSS by pooling the expansion and contraction conditions. Correlation analysis using SPSS can perform an uncorrelated test at the same time. It examines whether there is a relationship between the two variables. The strength of relevance is judged by the correlation coefficient. The results are shown in Table 9. In the table, R value represents the correlation coefficient of Pearson and P value represents

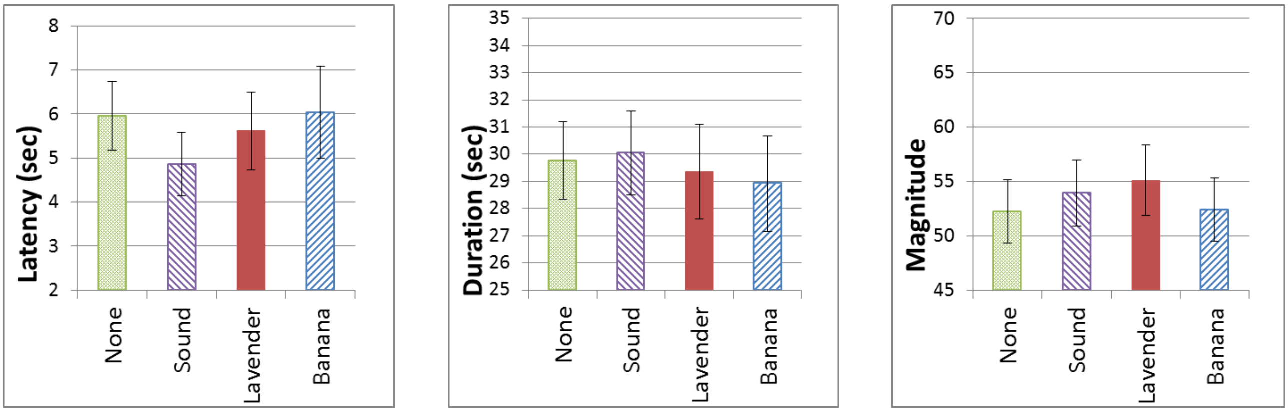

Figure 6: Expansion stimuli results

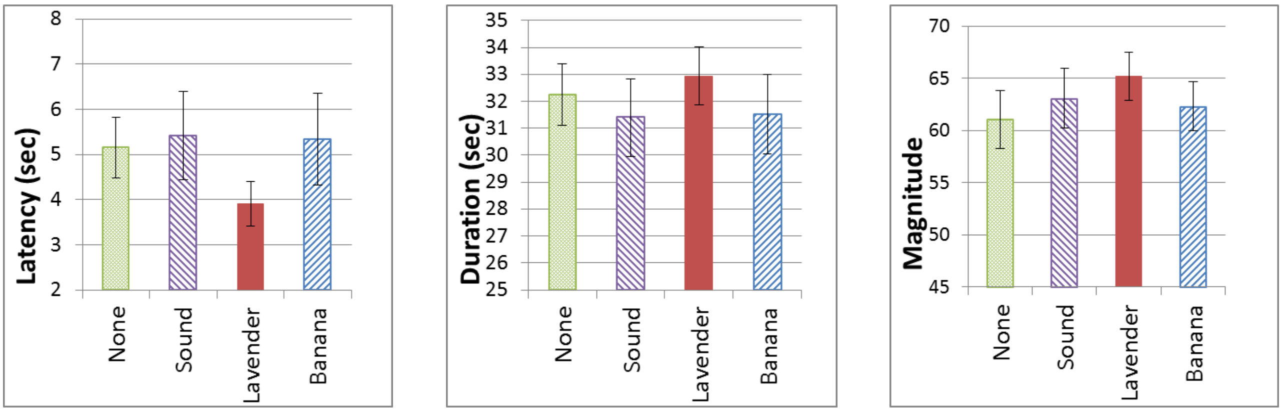

Figure 7: Contraction stimuli results


Figure 8: Gray scale image

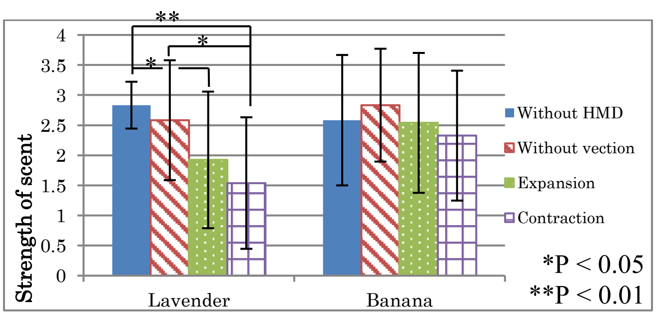

Figure 9: Strength of scent under each stimuli condition

Table 9: Correlation between vection perception and scent perception

| | Scent | Value | Latency | Duration | Magnitude |
|---|---|---|---|---|---|
| Expansion & Contraction | Lavender | R | -0.326 | 0.346 | 0.308 |
| | | P | $\mathbf{0.001}^{**}$ | $\mathbf{0.000}^{***}$ | $\mathbf{0.001}^{**}$ |
| | Banana | R | -0.256 | 0.212 | 0.313 |
| | | P | $\mathbf{0.009}^{**}$ | $\mathbf{0.031}^{*}$ | $\mathbf{0.001}^{**}$ |
| Expansion | Lavender | R | 0.484 | 0.422 | 0.442 |
| | | P | $\mathbf{0.000}^{***}$ | $\mathbf{0.002}^{**}$ | $\mathbf{0.001}^{**}$ |
| | Banana | R | -0.237 | 0.195 | 0.210 |
| | | P | 0.091 | 0.167 | 0.137 |
| Contraction | Lavender | R | -0.238 | 0.352 | 0.265 |
| | | P | 0.089 | $\mathbf{0.010}^{**}$ | 0.057 |
| | Banana | R | -0.287 | 0.272 | 0.540 |
| | | P | $\mathbf{0.039}^{*}$ | 0.051 | $\mathbf{0.000}^{***}$ |

the significance probability. In Table 9, *** is added to those that are significant at the 0.1% level, ** is added to those that are significant at the 1% level, and * is added to those that are significant at the 5% level. Furthermore, they are shown in bold. Significant differences are seen in all items by pooling the expansion and contraction conditions. Since the absolute values of the R values are about 0.2 to 0.3, it can be judged that the strength of the correlation is low. Then, we found that three vection indices were correlated with the perceived strength of lavender and banana scents. We also performed correlation analysis for expansion condition and contraction conditions individually and respectively. These results are also shown in Table 9. In the expansion condition, a correlation was found mainly in lavender condition but not seen in banana condition from significance probability. The R values in the item where a significant difference was observed are about 0.4, so it can be judged that the strength of the correlation is low. On the contrary, in the contraction condition, a correlation was mainly observed in banana condition rather than in lavender condition. When looking at the absolute values of R values in the item where a significant difference was observed, they are about 0.3 for the duration under lavender condition and about 0.2 for the latency under banana condition, so it can be judged that the strength of the correlation is low. In the magnitude under the banana condition, the highest correlation is found to be 0.5 R value. Thus, we could say that there was an interaction between the direction of vection and the types of scent.

# 5 CONSIDERATION

We examined whether olfactory stimuli affect the perception of vection by presenting subjects with visual stimuli while also presenting scents, using an olfactory display. No significant effect of scent presentation was observed in three variables, representing vection intensity. However, it was suggested that there were some effects of lavender scent on vection perception. The visual stimulus has a strong influence on the sense of smell in cases where the color of the liquid affects the scent identification [14] and in cases where the photos suitable for scent improve the intensity evaluation [15]. Furthermore, as mentioned earlier, the influence of visual stimuli on the sense of self-movement is large. The reason why there was no effect of scent on vection perception is possibly because olfactory stimuli were not sensed as consciously as vision and auditory stimuli. Olfactory information is not processed as much as visual and auditory information is, even if it does become consciously sensed. We believe that the visual stimuli were too strong for the scents to be consciously sensed. On the other hand, it was also found that vection stimuli reduced the intensity of lavender scent.

Moreover, we could find many positive correlations between perceived vection strength and perceived scent strength, especially in lavender scent. This is consistent with the result that discrimination function will be higher than normal when the HMD is worn and when vection stimuli are presented, as indicated by the research by Toju and Bannai [16]. However, this result is inconsistent with the result that the scent intensity is weakened under the condition that the vection stimuli presented. One of the reasons for this discrepancy is that the direction of attention is different in the case of evaluation only of scent (without HMD) and in evaluation of scent while evaluating a vection (HMD & vection available). In this experiment, it was not clear whether the scent is felt strongly when vection intensity is strong, or vection is felt strongly when scent intensity is strong. However, since there was little difference between the vection strength in the presence or absence of scent, we can assume that strong perception of scent will not always result in strong vection perception. If this assumption is correct, it suggests a causal relationship between strong perception of vection and perception of a strong scent. However, this is also inconsistent with the result that the scent intensity is weakened under the condition that the vection stimuli presented. With stronger olfactory or weaker vection stimuli, a more detailed investigation is necessary for this part.

In any case, from the above, it was suggested that the effects on vection perception differ depending on the type of scent. It seems that there is some relation between lavender scent and self-motion feeling induced by the vection. Lavender essential oil has a sedative effect and is believed to have an inhibitory effect on the central nervous system and the autonomic nervous system [17]. In addition, it has been reported that the fall rate of elderly people who smelled lavender scent for one year decreased [9]. These studies indicate that the scent of lavender has some effect on the human body. It is necessary that more detailed investigation using different scents be undertaken.

Sound stimuli are not considered to affect vection perception and though no significant difference was observed, a change was observed for each vection stimulus.

# 6 CONCLUSION AND FUTURE WORK

We investigate the effects of scents on vection perception by presenting subjects with visual stimuli while also presenting them with scents using an olfactory display. The findings were as follows:

(1) Using a scent ejection time of 0.3 seconds and an ejection interval of 1.3 seconds, it is possible to present a subject with the scent at a level of about 8 times the detection threshold for 70 seconds without adaptation.

(2) There was no significant difference between the perceived vection in the presence or absence of scent presentation in the three variables representing vection intensity. However, in the contraction stimuli, there was a tendency towards a difference.

(3) Many positive correlations were observed between perceived vection strength and perceived scent strength, especially in lavender scent. Even though it was not clear whether vection affected smell perception or smell perception modified vection strength, these two perceptions were positively correlated.

(4) From the findings that were presented in (2) and (3), it we can conclude that there is a relationship between interaction with vection and the type of scent. Lavender scent may promote vection perception.

In the future, the effect of scent stimuli on vection perception should be further examined. We plan to conduct experiments using weaker vection stimuli or stronger scent stimuli than what was used in the current study. Furthermore, we will investigate the effects of vection stimulation on scent perception, and we would like to clarify the causal relationship between vection perception and scent perception. We are also interested in exploring the transition of consciousness between visual, auditory, and olfactory senses and the mutual influences between these senses.

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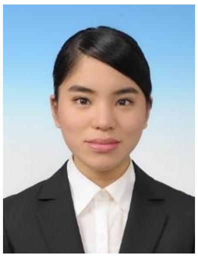

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