Dissolve in Scents Using Pulse Ejection When Combinations of Scents Were Changed

Sayaka Matsumoto*, Shutaro Homma*, Eri Matsuura*, Shohei Horiguchi*, and Ken-ichi Okada**

* Graduate School of Science of Technology, Keio University, Japan
** Faculty of Science and Technology, Keio University, Japan
{matsumoto, honma, matsuura, shohei, okada}@mos.ics.keio.ac.jp

Abstract - A trial to raise a sense of reality by using scents with various types of media has lately attracted much attention. In addition, it is thought that we can raise a sense of reality more by not only adding scents, but also expressing the movement of scents with that of the picture. We aimed at the development of the presentation technique to express dissolve in scents with paying attention to changing the intensity of two types of scents. The results of experiments revealed that receivers may feel dissolve by presenting fade-in and fade-out in scents which are overlapped in three breathes. Then we examined whether they can feel dissolve in scents in different types of scents. It is expected that the technique can raise realistic sensations when scents are presented in accordance with pictures by establishing the technique of dissolve in scents.

Keywords: Olfactory display, Pulse ejection, Dissolve in scents

1 INTRODUCTION

Information transmission and communication tends to be limited to visual information and audio information. However, the transmission of information via all five senses (sight, hearing, touch, smell and taste) has lately attracted much attention [1]. Olfactory information recognized by the olfactory organs differs from the information recognized via the other four senses [2]. The sense of smell powerfully affects humans since olfactory information is directly transmitted to the cerebral limbic system that governs emotions. In addition, olfactory information has high importance since it is thought that the presentation of olfactory information is effective as a means to enhance the sense of reality like three-dimensional vision and sound [3].

For transmitting scents together with other media, it is necessary to control the presentation of scent in accordance with the changes in images/sounds over time. In doing so, it is more effective to enhance the sense of reality. Therefore, we paid attention to both the change of types and the intensity of scents and developed presentation techniques in scents changing the intensity of two types of scents. Among these, this study presents a technique in scents that enables the receivers to feel "dissolve", which we defined as "the second scent becomes gradually strong at the same time as the first scent becomes gradually weak".

First, we constructed presentation techniques in scents that the receivers to feel "fade-out in scents" (the scent becomes gradually weak) and "fade-in in scents" (the scent becomes gradually strong) using pulse ejection. Then, we expressed dissolve in scents with combining fade-out in scents and fade-in in scents, and examined whether the receivers can feel dissolve in scents.

2 RELATED WORK

2.1 The Study of Adding Scents

Trials on the transmission of olfactory information together with other media are currently being conducted. "Scents of Space" which Haque et al. developed is the art work of lights and scents, which can carry a scent with the wind from one wall of the room and send it to receivers [4]. A trial to present scents in accordance with movie at a movie theater carried out using a device called Aromageur [5] which is the scent generator can save the recipe of the scents [6]. These trials are aimed for the enhancing the sense of reality by adding scents in the room or with videos.

There are many scenes in videos and TV programs, such as the scene which many smelling objects appear at the same time, suddenly appear and gradually disappear. Therefore, it is necessary not only to present scents but also to control the presentation of scent in accordance with the changes in images/sounds over time. In doing so, it is more effective to enhance the sense of reality.

However, they paid attention only to adding scents with other media in related works and the study that are paid attention to changes of types and the intensity of scents are not performed so many. The conventional presentation method of scents which are used in related works continues emitting scent at high density for a long time that the receivers can feel enough scents. Too much scent emitted over a continuous period leaves in the air. If the scent presented before mixes with scent presented later, there is a possibility that the receivers cannot feel the change of the types of scents.

Moreover, too much scent causes human adaptation to the scent, and thus, the receivers may not feel the intensity of scents properly. From such problems, it was possible to add scents but it was difficult to change types and the intensity of scents.

2.2 Presentation Technique That Emit Scent for Very Short Periods of Time

In our previous research, we minimized the influence of the scents to spread in the air by emitting scents for just very short periods of time and reduced the fragrance which remained in the air. In this way, we can reduce human adapta-

tion and change scents without scents being mixed. We defined this presentation technique that emits scent for very short periods of time as “pulse ejection” [7], and we studied about the change of kind of scents and the intensity of the scents by using pulse ejection. About the change of the kind of scents, for example, we measured the interval of the ejection time that human can recognize two types of scents clearly without being mixed, and developed a presentation technique that the receivers can feel two types of scents in one breath [8]. Furthermore, applying this presentation technique, we developed presentation techniques that the receivers can feel the strength of the relation between two types of scents by presenting a weak scent earlier and a strong scent later [9]. Besides, when we paid attention to the change of kind of scents every fixed time, it was revealed that the receivers can feel the change of kind of scents every two breathes [10]. About the change of the intensity of scents, for example, we developed presentation techniques that the receivers can feel the scent is coming near or going away by changing the intensity of a scent every two breathes [11]. Like these, we enabled to present the change of scents by using pulse ejection.

3 DISSOLVE IN SCENTS

3.1 Presentation Technique of Dissolve in Scents

As it was previously mentioned at Section 2.2, we studied about the change of types and the intensity of scents independently to express the presentation of scents by using pulse ejection. In this study, we paid attention to both the change of types and the intensity of scents and devised presentation techniques in scents changing the intensity of two types of scents.

For transmitting scents together with video, it is thought that it is effective to use the presentation technique of scents that is suitable for scene conversions of the videos. Therefore, we focus on dissolve in scene conversions of the videos. In videos, dissolve is a scene conversion that “the next scene is gradually superimposed as the former scene fades out” [12]. We propose to express dissolve in scents based on dissolve in videos. This study presents a technique in scents that enables the receivers to feel “dissolve”, which we defined as “the second scent becomes gradually strong at the same time as the first scent becomes gradually weak”. To develop the presentation technique to express dissolve in scents, it is necessary to develop the presentation technique that the receivers can feel the scent becomes gradually strong and gradually weak. Therefore, we defined “fade-in in scents” as the presentation technique that the scent becomes gradually strong, and “fade-out in scents” as the presentation technique that the scent becomes gradually weak. Then, we present dissolve in scents with combining fade-out in scents and fade-in in scents.

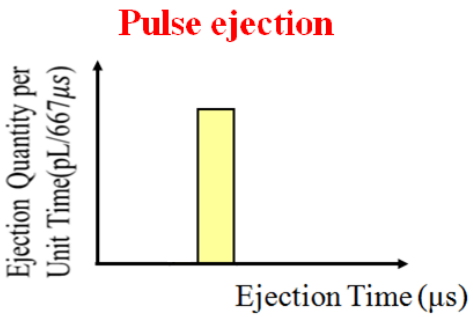

Figure 1: Image of pulse ejection

3.2 Pulse Ejection

When we present dissolve in scents, if we use the conventional presentation method of scents that emit scent at high density for a long time that the receivers can feel enough scents, the scent presented before mixes with scent presented later and it is difficult to feel scents as we expected. Besides, the scent which was presented for a long time causes human adaptation to the scent. The receivers may not feel the intensity of scents properly. In this study, we propose the scent presentation technique to create dissolve by using pulse ejection. An olfactory display we developed uses the technique used in ink-jet printer, and can use pulse ejection.

Pulse ejection is controlled scents as quantity by two parameters, ejection quantity of scent per unit time and ejection time (Fig 1). Besides, this device can change the ejection time at 667 μs intervals, so that it can present scent during only one breath. In presenting infinitesimal quantity of scent like this, pulse ejection can minimize the lingering of scents in the air.

4 EXPRESSION OF FADE-IN AND FADE-OUT IN SCENT

In this chapter, to determine how many times we should change the intensity of scents to express fade-in and fade-out at first. We examine how many times human can feel the change of the intensity of scents(Preliminary Experiment). After that, we developed the presentation techniques to express fade-in in scents and fade-out in scents.

4.1 Olfactory Display

We developed an olfactory display called “Fragrance Jet 2(FJ2)”. Figure 2 shows the condition of this experiment by FJ2. In this study, we used FJ2 which is a model to put in front of a participant. However, when we actually present scents together with video, it is more effective to use a mobile display that a participant puts on, so that it won't prevent viewing video.

This display uses the technique used in ink-jet printer in order to produce a jet which is broken into droplets from the small hole in the ink tank. This device can use pulse ejection for scent presentation so that the issue such as scent

Figure 2: The condition of this experiment by Fragrance Jet 2(FJ2)

lingering and care to eject scent can be minimized. The display can set up one scent ejection head. This head can store three small tanks and one large tank, thus this display can contain 4 types of scents. There are 127 minute holes in the head connected to the small tank and 256 minute holes in the head connected to the large tank. Moreover, the display can emit scent from multiple holes at the same time. We denote the number of minute holes emitting at one time as "the number of simultaneous ejections". So, the ejection quantity is adaptable to 0-127 (small tank), 0-256 (large tank) if the ejection time is set. In this study, the pulse ejection time is set to 100msec, so the ejection quantity is controlled by the change of the number of simultaneous ejections. We define the number of simultaneous ejections as the "intensity" of scents at this display.

4.2 Preliminary Experiment : The Number of Times of the Change

4.2.1 Experimental Method

At first, we measured the detection threshold of each participant. The detection threshold is the smallest density at which scent can be detected and where the user does not need to recognize the kind of a smell. The experiment to determine the detection threshold was conducted using the scent of banana stored in a large tank. The intensity was changed by 10 between 10 and 250. We use the triangle test [13] to judge the detection threshold in the measurement. In the triangle test, three stimuli are presented at random, where one of them is scented and the other two are odorless. The participant then answers when the scented odor was presented. Furthermore, we used the raising method (the first intensity was 10) to measured the detection threshold. The detection threshold was determined by the intensity which the participant answered correctly twice in a row. If the participant selected the wrong answer, the intensity was raised by 10.

After measuring the detection threshold, we examined how many times the participant could feel a change of the intensity of scent when the intensity was changed by 10 between the detection threshold of each participant and 250. We presented two scented ejections of different intensity to each participant. The interval between two scented ejections was 4 seconds. We presented first scented ejection in first breath and presented second scented ejection in second breath. We signaled the timing of breathing by sounds. When the scent is ejected, the countdown starts with the auditory cue. Scent emission then commences 0.5 sec after giving the cue "Go" according to previous study[14].

When we examine the number of times that the participant can feel the change of intensity of scent, we used two methods, rising method and dropping method. In rising method, we started the experiment from the intensity of detection threshold to 250. We prepared a reference value and a comparison value. The first reference value is the intensity of detection threshold and we started the experiment from the reference value. We presented two scented ejections to each participant in random order. One scented ejection was presented in the intensity of reference value and the other one was presented in the intensity of the comparison value which is larger than the reference value by 10. Then, we instructed the participant to answer which of the two was strong. If the participant answered correctly twice in a row, we judged that the participant can distinguish the intensity of the two, and recorded the comparison value. After that, we substituted the intensity of the comparison value for the next reference value and resumed the experiment. If the participant selected the wrong answer, we changed the comparison value to the value that is larger than the last comparison value by 10 and resumed the experiment. When the comparison value was reached 250(the maximum value), we finished the experiment. In dropping method, we started the experiment from 250 to the intensity of detection threshold. The same as the rising method, we prepared a reference value and a comparison value. The first reference value is 250 and we started the experiment from the reference value. We presented two scented ejections to each participant in random order. One scented ejection was presented in the intensity of reference value and the other one was presented in the intensity of the comparison value which is smaller than the reference value by 10. Then, we instructed the participant to answer which of the two was weak. If the participant answered correctly twice in a row, we judged that the participant can distinguish the intensity of the two and recorded the comparison value. After that, we substituted the intensity of the comparison value for the next reference value and resumed the experiment. If the participant selected the wrong answer, we changed the comparison value to the value that is smaller than the last comparison value by 10 and resumed the experiment. When the comparison value was reached the detection threshold of each participant (the minimum value), we finished the experiment.

In rising method, participants were 5 men and 3 women in their 20s. In descending method, participants were 4 men and 3 women in their 20s. Participants of the descending method were same as those of the rising method.

4.2.2 Results

The detection threshold of banana was 21±11.7 (average ± standard deviation). Figures 3 and 4 show the results of the

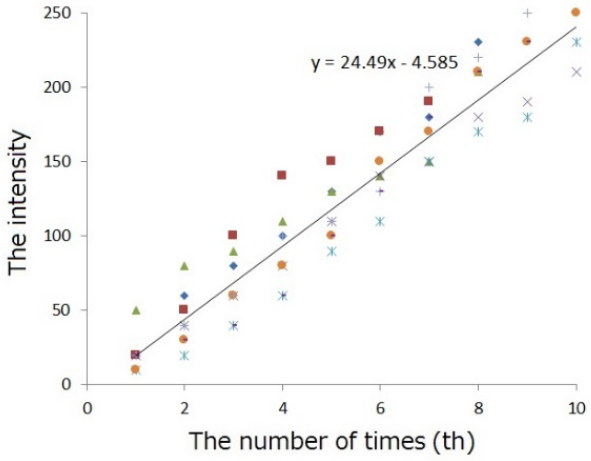

Figure 3: The intensity of scents that participants could notice (rising method)

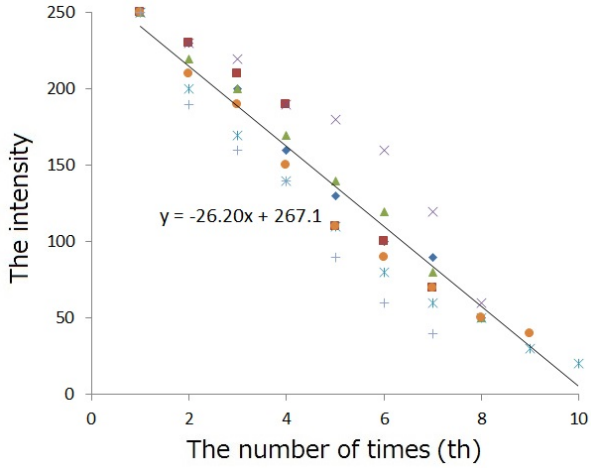

Figure 4: The intensity of scents that participants could notice (dropping method)

Table 1: Calculated values (rising method)

The number of times	1	2	3	4	5	6	7	8	9	10
Intensity	20	45	70	95	120	145	170	195	220	245

Table 2: Calculated values (dropping method)

The number of times	1	2	3	4	5	6	7	8	9	10
Intensity	247	220	193	166	139	112	85	58	31	4

number of times that participants felt the changes of the intensity in case of the rising method and the dropping method. The horizontal axis shows the number of times that participants could feel the changes of the intensity. The vertical axis shows the intensity of the scent that participants could notice. We plotted the intensity for each participant, such as the first change of the intensity that he or she was able to feel, and the second change of the intensity that he or she was able to feel. It is revealed that all participants could notice the changes of the intensity more than 7 times both in rising method and in dropping method. Furthermore, it is thought that the results of Fig. 3 and 4 can be approximated by a straight line. Fechner's law says subjective sensation increases proportional to the logarithm of the stimulus intensity. However, in this experiment, we checked whether participants could feel changes of the intensity of slightly small amount of scent by using pulse ejection. So we think that the result might become linearly. We calculate the average value of the intensity for each number of times and showed the approximation straight line to these graphs. Tables 1 and 2 show the values of the intensity of scent that are calculated by substituting the number of times for the approximation and rounded off to the first decimal place. Using these values, we developed the presentation techniques to express fade-in in scents and fade-out in scents.

4.3 Fade-in and Fade-out in Scents

Using the values of Tables 1 and 2, we examined whether the participant can feel fade-in in scents and fade-out in scents when we changed the intensity every 1 breath. When we presented one of the values of Table per breath to each participant and tested whether he/she can feel fade-in and fade-out. Participants were 5 people in their 20s. As a result, in fade-in, all participants answered that they felt “the scent becomes gradually strong”. However, most of them were not able to feel scent when the intensity of the scent was less than 45, and were not able to feel the change of the intensity when the intensity of the scent was greater than 170. From this, participants could feel six changes of the intensity. In fade-out, all participants answered that they felt “the scent becomes gradually weak”. However, most of them were not able to feel scent when the intensity of the scent was less than or equal to 31, and were not able to feel the change of the intensity when the intensity of the scent was greater than or equal to 193. From this, participants could feel six changes of the intensity.

Therefore, we decided the number of the changes of the intensity up to six times. We decided to present the intensity of scents in the range of 45 – 170 in fade-in. We decided to present the intensity of scents in the range of 35 – 170 in fade-out to make the maximum value of fade-out same to that of fade-in.

4.3.1 Experimental Method

We examined how short fade-in and fade-out in scents can be felt. As described above, we defined fade-in in scents as the presentation technique that the scent becomes gradually strong, and fade-out in scents as the presentation technique that the scent becomes gradually weak. In addition, we judged that participant can feel the change of the intensity smoothly when they can feel a lot of changes of the intensity. The experiment was conducted using the scent of banana stored in a large tank. In fade-in, we divided the intensity

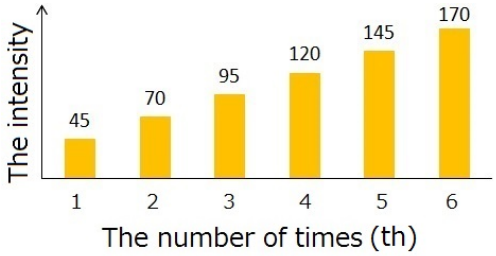

Figure 5: Image of (a) 6 phases (fade-in)

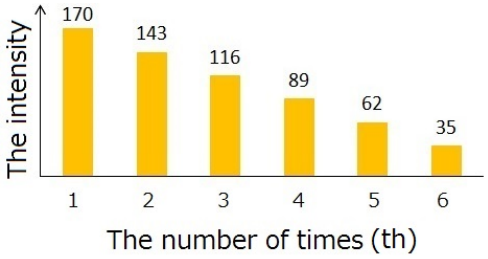

Figure 6: Image of (e) 6 phases (fade-out)

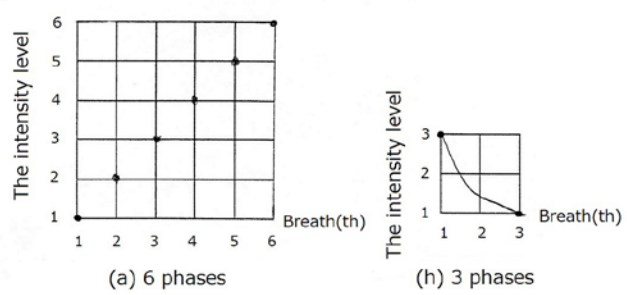

Figure 7: Example in a way of answering graphs

between minimum 45 and maximum 170 linearly into (a) 6 phases, (b) 5 phases, (c) 4 phases and (d) 3 phases. In fade-out, we divided the intensity between minimum 35 and maximum 170 linearly into (e) 6 phases, (f) 5 phases, (g) 4 phases, (h) 3 phases. As examples, Fig. 5 and 6 show the images of presentation of scent about (a) 6 phases and (e) 6 phases. The horizontal axis shows the number of times and the vertical axis shows the intensity of the scent that we presented. We presented each scented ejection once per 1 breath, and numbers in Fig. 5 and 6 show the intensity of scents that we presented for each breath. The interval between each breath was 4 seconds. The same as preliminary experiment, we signaled the timing of breathing by sounds. After we presented 1 series of phases, we asked the participant how they felt about the changes of the intensity of scent. For example, when we presented (a) 6 phases in fade-in, we presented 6 shots in a row. After taking a short break, we presented another 1 series of phases to the participant. We instructed them to answer by 2 ways, multiple choices and graphs, when they answered. In a way of answering by multiple choices, the participant was instructed to choose the most suitable item from seven evaluation items as follows; "The scent becomes strong suddenly", "The scent becomes gradually strong", "The scent becomes weak suddenly", "The scent becomes gradually weak", "There was no change in feeling the scent", "There was no scents as a whole","The scent irregularly changed from feeling strong or weak". In a way of answering by graphs, we used plotting paper like Fig. 7. Figure 7 also shows the example of drawing and plotting. The horizontal axis shows the number of times and the vertical axis shows the intensity level of scent. Level 1 is the weakest, and Level maximum ((e) 6 phases: level 6, (h) 3 phases: level 3) is the strongest. In fade-in ((a) 6 phases - (d) 3 phases), we set the intensity in first breath to level 1. In fade-out ((e) 6 phases - (h) 3 phases), we set the intensity in first breath to level maximum. Before beginning this experiment, we presented the scent of level 1 and level 6 to each participant in advance and instructed them to memorize the sense of the intensity of these levels. We instructed each participant to draw or plot the changes of the intensity of scents that he or she felt after second breath based on these levels. Participants were 10 men and 6 women in their 20s.

Table 3: The number of participants that answered "The scent becomes gradually strong"

Fade-in	(a) 6 phases	(b) 5 phases	(c) 4 phases	(d) 3 phases
The number of participants	12	7	8	8

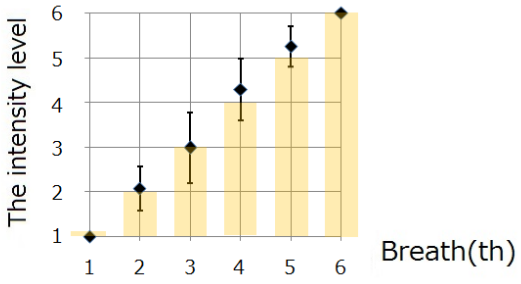

Figure 8: The result of the graphs in (a) 6 phases

4.3.2 Results and Considerations

At first, we describe the result and the consideration of fade-in in scents. Next, we describe the result and the consideration of fade-out in scents.

- **Fade-in in Scents**

First, we describe the results about a way of answering by multiple choices. We judged the most suitable phases to create fade-in in scents with the number of participants that answered "The scent becomes gradually strong". Table 3 shows the number of the answers for four types of phases to create the impression of "gradually strong". It is revealed that the largest number of participants answered "gradually strong" in (a) 6 phases. The result of fade-in in multiple

choices indicates that the participants could feel fade-in the best in (a) 6 phases.

Next, we describe the results about a way of answering by graphs. We judged that participants could feel the changes of the intensity smoothly when the number of the changes of the intensity participants could feel was the largest. We plotted the average values that are calculated from the values that each participant drew in each breath in each phase. For example, Fig. 8 shows the plotting points of (a) 6 phases. The horizontal axis shows the number of times and the vertical axis shows the intensity level of scent. The bar graph expresses the intensity of the scent that we presented. To examine whether the participants could feel the change of the intensity of scent between contiguous two breaths, such as the first breath and the second breath, the average values between contiguous two breaths were analyzed using t-test. If there was no significant difference between contiguous two breaths, the average values between n-th breath and (n+2)-th breath were analyzed. Significant differences were found in all contiguous two breaths at (a) 6 phases, (c) 4 phases and (d) 3 phases ($p < 0.05$). The result of these indicates that the participants could feel all changes of intensity of scent that we presented in those three phases. That is, the participants could feel six changes of the intensity in (a) 6 phases, four changes of the intensity in (c) 4 phases, three changes of the intensity in (d) 3 phases. On the other hand, in (b) 5 phases, it follows that participants could feel four changes of the intensity. The result of fade-in in graphs indicates that the participants could feel fade-in the most smoothly in (a) 6 phases. In light of results of two ways above, the participants were likely to feel fade-in in scents the best in (a) 6 phases.

- **Fade-out in Scents**

First, we describe the results about a way of answering by multiple choices. We judged the most suitable phases to create fade-out in scents with the number of participants that answered “The scent becomes gradually weak”. Table 4 shows the number of the answers for 4 types of phases to create the impression of “gradually weak”. It is revealed that the largest number of participants answered “gradually weak” in (e) 6 phases. The result of fade-out in multiple choices indicates that the participants could feel fade-out the best in (e) 6 phases.

Next, we describe the results about a way of answering by graphs. We judged that participants could feel the changes of the intensity smoothly when the number of the changes of the intensity participants could feel was the largest. We plotted the average values that are calculated from the values that each participant drew in each breath in each phase. For example, Fig. 9 shows the plotting points of (e) 6 phases. The horizontal axis shows the number of breaths and the vertical axis shows the intensity level of scent. The bar graph expresses the intensity of the scent that we presented. To examine whether the participants could feel the change of the intensity of scent between contiguous two breaths, such as the first breath and the second breath, the average values between contiguous two breaths were analyzed using t-test. If there was no significant difference between follows that participants could feel three changes of the intensity. In (h) 3 phases, it follows that participants could feel two changes of the intensity. The result of fade-out in graphs indicates that the participants could feel fade-out the most smoothly in (e) 6 phases. In light of results of two ways above, the participants were likely to feel fade-out in scents the best in (e) 6 phases.

Table 4: The number of participants that answered “The scent becomes gradually weak”

Fade-out	(e) 6 phases	(f) 5 phases	(g) 4 phases	(h) 3 phases
The number of participants	12	6	6	5

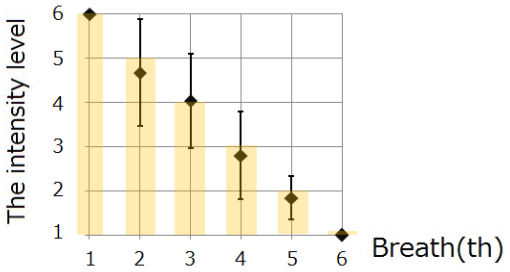

Figure 9: The result of the graphs in (e) 6 phases

From these results, we combined (e) 6 phases in fade-out and (a) 6 phases in fade-in, and examined whether the participants can feel dissolve in scents.

5 EXPRESSION OF DISSOLVE IN SCENTS

We defined dissolve in scents as the presentation technique that “the second scent becomes gradually strong as the first scent becomes gradually weak” and “two types of scents were felt in a single breath”. In addition, we judged that participant can feel the change of the intensity smoothly when they can feel a lot of changes of the intensity. That is, there are the parts that two types of scents are presented in one breath to express dissolve in scents. In this experiment, we examined how many overlapping parts the presentation technique have that participants can feel dissolve the best when we presented the overlapping part that two types of scents are presented once per one breath.

5.1 Experimental Method

The experiment was conducted using the scent of banana stored in a large tank to express fade-out in scents and the scent of mint stored in a small tank to express fade-in in scents. In fade-out, we changed the intensity of scents six times using (e) 6 phases in the experiment 4.3. In fade-in, as the size of the tank was different from the experiment 4.3, we converted the intensity of scent (stored in a large tank) of (a) 6 phases in the Experiment 4.3 into those of scent stored in a small tank. Additionally, we measured the detection threshold of mint using the similar method to measure the detection threshold and similar participants in Section 4.2.1.

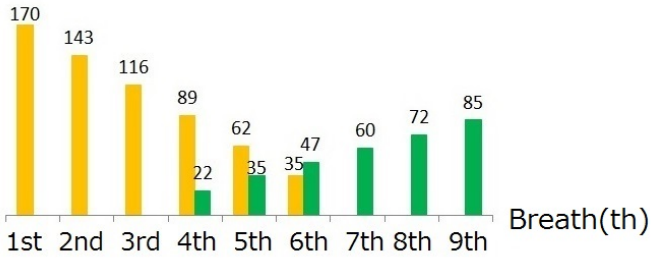

Figure10: Image of overlapping (“Dissolve 3”)

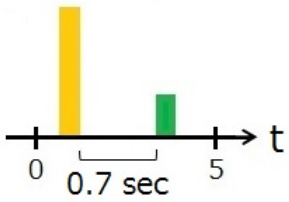

Figure 11: A presentation of the overlapping part

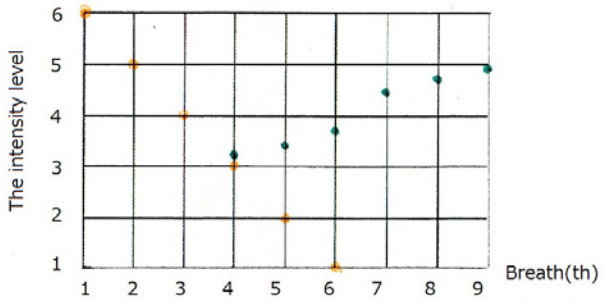

Figure 12: Example in a way of answering graphs (“Dissolve 3”)

As a result, the detection threshold of mint was 14±7.3 (average ± standard deviation). In this experiment, we prepared five patterns, from “Dissolve 1” to “Dissolve 5”. For example, “Dissolve 1” is a presentation that there is one overlapping part at which two types of scents are presented in one breath, and “Dissolve 5” is a presentation that there are five overlapping parts. Figure 10 shows the image of a presentation of “Dissolve 3”. The “Dissolve 3” has three overlapping parts, so there are nine breaths overall in “Dissolve 3”. In Fig. 10, yellow shows the scent of banana, and green shows the scent of mint. Numbers in Fig. 10 shows the intensity of scents that we presented for each breath. When combining fade-out and fade-in, we used a presentation technique that the receivers can feel two types of scents in one breath [8]. Figure 11 shows a presentation of the overlapping part. The horizontal axis shows the breaths and the vertical axis shows the intensity of the scent. The interval between two types of scents was set to 0.7sec [8]. We presented the scent of banana before and the scent of mint after, in spite of the intensity of the scents. The interval between each breath was 4 seconds in the Experiment 4, for smelling two types of scents, the interval between each breath was set to 5 seconds in this experiment. The same as

Table 5: The number of participants that answered “I felt two types of scents in “Dissolve n”

Dissolve	1	2	3	4	5
The number of participants	15	15	16	15	15

Table 6: The number of participants that answered “I felt two types of scents in one breath”

Dissolve	1	2	3	4	5
The number of participants	8	10	9	10	9

Table 7: The number of participants that could feel dissolve

Dissolve	1	2	3	4	5
The number of participants	8	7	8	7	7

preliminary experiment, we signaled the timing of breathing by sounds. After we presented one “Dissolve” to the participant, we asked the participant how they felt. After taking a short break, we presented another “Dissolve” to the participant. We instructed them to answer by two ways, sentences and graphs, when they answered. In a way of answering by sentences, the participant was instructed to answer about the “types” and the “intensity” of scents. In a way of answering by graphs, we used plotting paper like Fig. 12. The horizontal axis shows the number of times and the vertical axis shows the intensity level of scent. Level 1 is the weakest, and Level 6 is the strongest. The numbers of breath were different for each “Dissolve”, so we changed the size of plotting paper for each “Dissolve”. Figure 12 shows the example of “Dissolve 3”. We set the intensity in first breath to level 6. Before beginning this experiment, we presented the scent of level 1 and level 6 of each scent to each participant in advance and instructed them to memorize the sense of the intensity of these levels. We instructed each participant to draw or plot the changes of the intensity of scents that he or she felt after second breath. At the time, the participant was instructed to change the color of the pen when he/she felt some types of scents. Figure 12 also shows the example of plotting. Participants were 10 men and 6 women in their 20s.

5.2 Results and Consideration

First, we describe the results about a way of answering by sentences. In questions about the types of the scents, we asked participants “How many scents do you feel in “Dissolve n((n) is integers, $1 \leqq n \leqq 5$)” ?” Table 5 shows the number of the participants that answered “I could feel two types of scents in “Dissolve n”.” for five types of Dissolves. Table 5 indicates that about 80% of participants could feel two types of scents. There were few participants that felt only one kind of the scent because they could not notice the changes of scents, and felt three types of scents because the scents were mixed. Also, in questions about the types of the scents, we asked participants “Can you feel two types of

scents in one breath?" Table 6 shows the number of the participants that answered "I could feel two types of scents in one breath." for five types of Dissolves. Table 6 indicates that more than half of participants could feel two types of scents without mixed in one breath from "Dissolve 1" to "Dissolve 5". We judged that the participants who answered "I felt two types of scents in one breath" (the question about the types of scents) and "I felt the first scent becomes gradually weak and the second scent becomes gradually strong" (the question about the intensity of scents) could felt dissolve. Table 7 shows the number of the answers for five types of "Dissolve" to create the impression of dissolve. It is revealed that the half number of participants could feel dissolve in scents in all "Dissolve"s. Even out of those, the number of participants that could feel dissolve in scents at "Dissolve 1" and "Dissolve 3" was the largest.

Next, we describe the results about a way of answering by graphs. We judged that participants could feel the changes of the intensity smoothly when the number of the changes of the intensity participants could feel was the largest. We plotted the average values that are calculated from the values that each participant drew in each breath in each "Dissolve". For example, Fig. 13 shows the plotting points of "Dissolve 3". The horizontal axis shows the number of breaths and the vertical axis shows the intensity level of scent. The level which participants could not feel scents was set to the level 0. The bar graphs express the intensity of the scent that we presented. In "Dissolve 3", the scent of banana was presented in between the first breath and the sixth breath and the scent of mint was presented in between the fourth breath and the ninth breath. That is, we presented two types of scents in between the fourth breath and the sixth breath. The bar graph expresses the intensity of the scent that we presented.

To examine whether the participants could feel the change of the intensity of scent between contiguous two breaths, such as the first breath and the second breath, the average values between contiguous two breaths for each scent were using t-test. If there was no significant difference between contiguous two breaths, the average values between n-th breath and (n+2)-th breath for each scent were analyzed.

In this paper, we describe the result about "Dissolve 3". As a result of comparison in the scent of banana at "Dissolve 3", significant differences were found in between the first breath and the second breath, the second breath and the third breath, the third breath and the fourth breath and the fourth breath and the sixth breath ($p < 0.05$). The result of this indicates that the participants could feel changes of intensity of scent at the first, second, third, fourth and sixth breath. That is, the participants could feel five changes of the intensity in the scent of banana at "Dissolve 3". As a result of comparison in the scent of mint at "Dissolve 3", significant differences were found in between the fourth breath and the sixth breath, the sixth breath and the seventh breath and the the intensity in the scent of mint at "Dissolve 3". The similar comparison was also conducted for other "Dissolve"s, and it was found that the number of changes of the intensity that participants could feel was the largest in "Dissolve 3". Therefore, the result of dissolve in graphs indicates that the participants could feel dissolve the most smoothly in "Dissolve 3". In light of results of two ways above, the partici

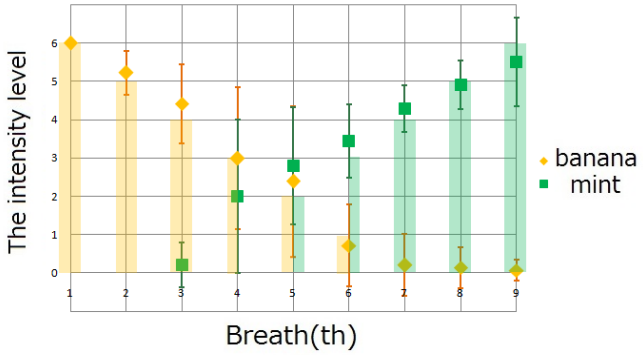

Figure 13: The result of the graphs in "Dissolve 3"

pants likely to feel dissolve in scents the best at "Dissolve 3" in those five presentation methods.

5.3 Expression of Dissolve in Differences in Kind of the Scents

Based on Experiment 5.1, we examined whether the participant can feel dissolve in scents in different types of scents in this sections.

5.3.1 Combination of the Scents

We used the presentation technique of "Dissolve 3" and examined whether the participants could feel dissolve when we changed the types of scents. The experiment was conducted using the scent of banana stored in a large tank, and the scent of mint, rose and lavender stored in a small tank. In fade-out, we changed the intensity of scents six times using (e) 6 phases in the experiment 4.3 at a large tank. As the size of the tank was different from the experiment 4.3, we converted the intensity of scent (stored in a large tank) of (e) 6 phases in the Experiment 4.3 into those of scent stored in a small tank. In fade-in, we changed the intensity of scents six times using (a) 6 phases in the experiment 4.3 at a large tank. As the size of the tank was different from the experiment 4.3, we converted the intensity of scent (stored in a large tank) of (a) 6 phases in the Experiment 4.3 into those of scent stored in a small tank. Additionally, we measured the detection threshold of lavender and rose using the similar method to measure the detection threshold and similar participants in Section 4.2.1. As a result, the detection threshold of lavender was 11±3.2 and the detection threshold of rose was 16±5.2 (average ± standard deviation).

We prepared six patterns of combination of the scents, "banana / rose", "banana / lavender", "rose / banana", "rose / mint", "lavender / banana" and "lavender / mint". In terms of notation, for example, "banana / rose" represent that the scent of banana is used to express fade-out in scents and the scent of rose is used to express fade-in in scents. We presented the scent which expresses fade-out before and the scent which expresses fade-in after, in spite of the intensity of the scents. Before conducting this experiment, we considered about all conceivable combinations of these four types of scents. When we used the scent of mint to express fade-out in scents ("mint / banana" etc.), we found that it was

Table 8: The number of changes of intensity in each combination of scents

combination	Fade-out	Fade-in
banana / mint (Experiment 5.1)	5	4
banana / rose	4	2
banana / lavender	4	2
rose / banana	4	3
rose / mint	5	4
lavender / banana	4	3
lavender / mint	5	4

difficult to feel the scents which express fade-in in scents because of refreshing feeling of mint. Also when we used the scent of lavender and rose ("lavender / rose" and "rose / lavender"), we found that it was difficult to distinguish these two scents because both of them were the scents of flower. Therefore, we omitted these combinations in this experiment.

The same as Experiment 5.1, we signaled the timing of breathing by sounds. After we presented 1 combination to the participant, we asked the participant how they felt. After taking a short break, we presented another 1 combination to the participant. We instructed them to answer by graphs, when they answered. Participants were 7 men and 5 women in their 20s.

5.3.2 Results and Consideration

In Experiment 5.1, we judged that participants could feel dissolve the most at "Dissolve 3", which they could feel five changes of the intensity in the scent of banana in fade-out and four changes of the intensity in the scent of mint in fade-in. Therefore, we examined the number of changes of the intensity of each scent and considered it comparing with the result of Experiment 5.1 that we showed in Section 5.2. Same as Section 5.2, we plotted the average values that are calculated from the values that each participant drew in each breath in each combination of the scents. The scent that expressed fade-out was presented in between the first breath and the sixth breath and the scent that expressed fade-in was presented in between the fourth breath and the ninth breath. That is, we presented two types of scents in between the fourth breath and the sixth breath. To examine whether the participants could feel the change of the intensity of scent between contiguous two breaths, such as the first breath and the second breath, the average values between contiguous two breaths for each scent were using t-test. If there was no significant difference between contiguous two breaths, the average values between n-th breath and (n+2)-th breath for each scent were analyzed. In this paper, we describe the result about "rose / mint" as an example. As a result of comparison in the scent of rose at "rose / mint", significant differences were found in between the first breath and the second breath, the second breath and the third breath, the third breath and the fourth breath and the fourth breath and the sixth breath ($p < 0.05$). The result of this indicates that the participants could feel changes of intensity of scent at the first, second, third, fourth and sixth breath. That is, the participants could feel five changes of the intensity in the scent of rose at "rose / mint". As a result of comparison in the scent of mint at "rose / mint", significant differences were found in between the fourth breath and the fifth breath, the fifth breath and the seventh breath and the seventh breath and the ninth breath ($p < 0.05$). The result of this indicates that the participants could feel changes of intensity of scent at the fourth, fifth, seventh and ninth breath. That is, the participants could feel four changes of the intensity in the scent of mint at "rose / mint". The similar comparison was also conducted for other combinations. Table 8 shows the number of changes of the intensity that the participants could feel in each combination of scents. Table 8 indicates that the number of changes of the intensity that participants could feel was the largest when the scent which expresses fade-in was mint. We obtained this result because the scent of mint was easy to distinguish from other three types of scents. In addition, this table indicates that it tends to be hard to feel the changes of the intensity of the scent when we choose two types of scents from the scent of banana, rose and lavender. Because the scents of banana, rose and lavender are classified in "sweet" scents, it is thought that it was not easy for participants to notice the changes of the intensity. Therefore, it is likely to feel dissolve in scents more when we use two scents which is easy to distinguish. Moreover, Osako et al. [15] studied that the unpleasant smell increases the sensory intensity. Therefore, it is thought that results of this experiment are possible to be changed when we present the unpleasant scents. In this experiment, we presented scents to participants many times, so we used the scent of banana, mint, lavender and rose which are relatively comfortable for human so as to reduce the discomfort of the participants.

6 CONCLUSION

Studies on transmitting scents together with various media to enhance the sense of reality are currently conducted. There are many scenes in videos and TV programs, such as the scene which many smelling objects appear at the same time, suddenly appear and gradually disappear. Therefore, it is necessary to control the presentation of scent in accordance with the changes in images/sounds over time. In doing so, it is more effective to enhance the sense of reality. However, the conventional presentation method of scents continues emitting scent at high density for a long time and gives problems of human adaptation to the scent and scents lingering. The receivers may not feel the intensity of scents properly. Therefore, it was difficult to present scents in accordance with videos.

To solve such problems, we studied about the change of kind of scents and the intensity of the scents by using pulse ejection which emits scent for very short periods of time. In this study, we paid attention to both the change of types and the intensity of scents and devised presentation techniques in scents changing the intensity of two types of scents.

Among these, we especially studied a presentation technique in scents that enables the receivers to feel "dissolve" which we defined as "the second scent becomes gradually strong at the same time as the first scent becomes gradually weak". First, we developed presentation techniques in scents that the receivers to feel "fade-out" and "fade-in" using pulse ejection. As a result, the participants were likely to feel fade-out in scents and fade-in in scents the best in 6 phases. From these results, we combined 6 phases in fade-out and 6 phases in fade-in, and examined whether the participants can feel dissolve in scents. We aimed at the development of the presentation technique to express dissolve in scents with paying attention to the change of two scents and the intensity of the scents. The results of experiments revealed that participants could feel dissolve in scents the best by presenting fade-in and fade-out in scents which are overlapped in three breath. Based on this experiment, we examined whether the participant can feel dissolve in scents in different types of scents. As a result, it was revealed that it is likely to feel dissolve in scents when we use two scents which is easy to distinguish. It is expected that the technique can raise realistic sensations more when scents are presented in accordance with pictures by establishing the technique of dissolve in scents.

REFERENCES

[1] Ministry of Posts and Telecommunications in Japan, Reports of the Association for Information and Communications Technology Using Five Senses (2007) (in Japanese).

[2] J. Naomi, G. Hunsaker, P.E. Gilbert and R.O. Hopkins, "The Role of Human Hippocampus in Odor-Place Associative Memory," Chemical Sences, Vol.34, No.6, pp.513-521 (2009).

[3] C. Oshima, K. Nakayama and H. Ando, "Aroma That Enhances the Reality of Visual Images," Review of the National Institute of Information and Communications Technology, Vol.56, Nos.1/2 (2010) (in Japanese).

[4] U. Haque, "Scents of space: an interactive smell system," ACM SIGGRAPH 2004 Sketches (2004).

[5] ITmedia LifeStyle, the Lessons of Aromatherapy with Internet by OCN, http://www.itmedia.co.jp/lifestyle/articles/0505/23/news096.html (in Japanese).

[6] INTERNET Watch, NTT Com creates the movie called "New World" with a fragrance, http://internet.watch.impress.co.jp/cda/news/2006/04/11/11594.html (in Japanese).

[7] A. Kadowaki, J. Sato, Y. Bannai and K. Okada, "Presentation Technique of Scent to Avoid Olfactory Adaptation," Proc.of ICAT 2007, pp.97-104 (2007).

[8] K. Ohtsu, J. Sato, Y. Bannai and K. Okada, "Measurement of Olfactory Characteristics for Two Types of Scent in a Single Breath," IFIP INTERACT 2009, pp.306-318 (2009).

[9] D. Noguchi, K. Ohtsu, Y. Bannai and K. Okada, "Scent Presentation Expressing Two Smells of Different Intensity Simultaneously," 2009 Joint Virtual Reality Conference of EGVE-ICAT-EuroVR, pp.53-60 (2009).

[10] S. Sugimoto, K. Ohtsu, Y. Bannai and K. Okada, "Scent Presentation Technique to Enable High Speed Switch of Scents," The Journal of the Virtual Reality Society of Japan, Vol.15, No.SBR-1, pp.17-22 (2010) (in Japanese).

[11] J. Sato, K. Ohtsu, Y. Bannai and K. Okada, "Pulse Ejection Technique of Scent to Create Dynamic Perspective," In proc. Of ICAT 2008, pp.167-174 (2008).

[12] CUERBO English Dictionary, http://english.cheerup.jp/eedict/search?name=dissolve

[13] Japan Association on Odor Environment, The guidebook of the Simplified measurement of Smell (2005).

[14] D. Noguchi, S. Sugimoto, Y. Bannai and K. Okada, "Time Characteristics of Olfaction in a Single Breath," CHI'11 Proceedings of the 2011 annual conference on Human factors in computing systems, pp.83–92 (2011).

[15] M. Osano, K.Nishida and K. Shishida, "Impact of Odor Hedonics on Sensory Odor Intensity - Physiological intensity and sensory intensity-," Environmental Health and Preventive Medicine (EHPM), Vol.44, No.5, pp.1002-1008 (1989).

(Received September 30, 2015)
(Revised December 12, 2015)

Sayaka Matsumoto B.S. degree from the Department of Information and Computer Science of Keio University, Japan in 2015. She is currently working toward an M.S. degree in Open and Environment Systems at Keio University. She received Best Paper Awards from IWIN 2015. Her research interests include fragrance information processing work.

Shutaro Homma B.S. degree from the Department of Information and Computer Science of Keio University, Japan in 2014. He is currently working toward an M.S. degree in Open and Environment Systems at Keio University. He received Excellent Presentation Awards from DICOMO 2015. His research interests include fragrance information processing work.

Eri Matsuura B.S. degree from the Department of Information and Computer Science of Keio University, Japan in 2014. She is currently working toward an M.S. degree in Open and Environment Systems at Keio University. Her research interests include fragrance information processing work.

Shohei Horiguchi B.S. degree from the Department of Information and Computer Science of Keio University, Japan in 2015. He is currently working toward an M.S. degree in Open and Environment Systems at Keio University. His research interests include fragrance information processing work.

Ken-ichi Okada received his B.S., M.S. and ph. D. in instrumentation engineering from Keio University, in 1973, 1975, and 1982, respectively. He is currently a chief professor in the Department of Information and Computer Science at Keio University. His research interests include CSCW, groupware, human computer interaction, and ubiquitous computing. He has published 140 journal papers, 170 international conference papers, and 18 books entitled “Collaboration and Communication,” “Designing Communication and Collaboration Support Systems,” “Introduction to Groupware” and so on. He is a member of IEEE, ACM, IEICE and IPSJ. He was a chair of SIGGW, a chief editor of IPSJ Magazine, and a chief editor of IPSJ Journal. Dr. Okada received the IPSJ Best Paper Award in 1995, 2000, and 2008, the IPSJ 40 the Anniversary Paper Award in 2000, IPSJ Fellow in 2002 and the IEEE SAINT Best Paper Award in 2004.