1. INTRODUCTION

Psycho-physiological effects of media contents are widely believed, and we use and enjoy them in our daily life. We expect the effects of them in terms of changing our mind to relaxation, excitation, and other positive feelings. The effects were investigated and clarified in many previous studies.

What will happen if we are afforded some media contents simultaneously, e.g., listening music piece and watching graphic? As one of the answers for this question, cross-modal effects may be achieved by different stimuli having the same direction of the effects. In contrast, their effects may be disappeared if they have quite opposite direction of the effects or in some special cases. The cross-modal effects have been investigated mainly in the areas of sight-hearing [1-4] and sight-audition [5-9]. The cross-modal effect of scent and a stimulus of different media has also been investigated: the scent was combined with various senses such as audition, vision, touch, and taste in previous studies [10]. The scent is used in aroma therapy [11,12] and store [13] to change our mind, and sense of smell is an important matter in affective engineering, because olfaction directly connects to the brain [14].

Thus, the cross-modal effect of the scent and other stimuli should be investigated more.

This study focuses on the cross-modal effect of music piece and scent in terms of using these media contents for changing and keeping users’ mind for a certain period of time. The cross-modal effects of sounds and scent were clarified in several previous studies [10]: music pieces having a certain time length were not included in the sounds.

There were not many related studies that investigated the cross-modal effect of music and scent. Becker et al. investigated the cross-modal effect on walking of elder people [15]. The result of their experiment showed that only music has the main effect on walking distance in the cross-modal stimuli by applying two-way ANOVA (analysis of variance), and subjective feelings were not investigated in their experiment. Mattila et al. have investigated the cross-modal effects in-store condition [16]. It is a very interesting application of the cross-modal, and their experimental results showed main effect of the music and interaction with two-way ANOVA. Chrisinel et al. have investigated existence of a soundtrack suited to an odor, and part of their experiment was successful [17]. The author and his colleague fundamentally investigated the cross-modal effect of music and scent on subjective feelings [18]. Significant differences were observed only pairs of conditions having different music piece, and there was a possibility that two scents used in the previous study might have a similar effect. Zhou et al. have investigated the cross-modal effect by employing different tempi of the same music piece and various scents [19]. The interesting results including increase in preference of higher arousal music by adding high arousal scent were observed.

As mentioned above, the main effect of the scent was not observed in the set of music and scent with two-way ANOVA [15,16], although we believe the effect of the scents and it was clarified in the previous studies [20]. The reason why we are unable to observe the main effect of the
scents is considered as lacking experimental setting with a repetitive evaluation of the same subjects, appropriate questionnaire, and appropriate contrast scents. Therefore, by referring to the previous studies, this study aims to investigate main effect of scent in the combination of music and scent. Two music pieces and two scents having contrast respectively are used as stimuli in the experiment, and the same subjects answer subjective impressions and preference of all of the four combined music piece and scent set.

The remainder of the paper is as follows. The next section describes the experimental setting with procedure and music pieces and scents as materials. The section 3 shows the experimental results. Based on the results, discussion and conclusion are performed in the sections 4 and 5, respectively.

2. EXPERIMENT

This section provides the experimental method for investigating the cross-modal effects of music pieces and scents. First, the outline of the experiment is described in terms of the experimental procedure. After that, the materials used in the experiment and the setting of the experiment are explained.

2.1 Procedure

The experimental procedure referred to the previous study [18], and time length of rest and scent stimuli were changed from the previous study. 29 Japanese persons (13 females and 19 males) participated in the listening and smelling experiment as subjects. The mean age of them was 20.8 years old. The subjects were asked to avoid taking foods and drinks excepting water from before one hour of the experiment, because the taste of the foods and drinks might affect the subjects’ evaluations. The subjects individually participated in the experiment in a quiet room, and they listened to a music piece and smelled a scent simultaneously in a sitting position.

Figure 1 shows a procedure of one set of the experiment. First, the subject had a rest during 60 s. After that, the scent and the music piece were afforded simultaneously by the experimenter, and its duration was 220 s: the duration was set at the same time length by changing the duration of the music piece from 240 s in the previous study [18] to 220 s to have concrete comparisons of the effects of the scent and music piece. Finally, a questionnaire asked the subjects five impressions and preference of the combination of the music piece and the scent. The subjects could have a rest 300 s between the experimental sets. During the rest, the subjects could smell coffee for recovering his/her sense of smell if they needed.

The outline of the procedure was explained to the subjects by the experimenter beforehand of the experiment. The subjects were told that the music piece and the scent were afforded simultaneously. To avoid the subjects to have a bias for the stimuli, the experimenter did not tell the subjects name of the scents and the music pieces. Each of the subjects participated in four sets of music piece and scent in the experiment. The four sets were different its combination of the music piece and the scent, and a sequence of the four sets were randomized and counter-balanced between the subjects. The experiment with all of the four sets for the subject were performed in one day.

The questionnaire asked the subjects degree of impressions and preference for each of the combinations of the music piece and the scent. The questionnaire was composed of six items, and semantic differential method [21] with a 5-point scale was used to evaluate its degree. The six questions were composed of five impressions related to Combination, Relaxation, Brightness, Happiness, and Furiousness, and one Preference. Correspondence of the detailed point and each adjective pair were as follows:

“Good Combination: 5 – Bad Combination: 1”

“Relaxing: 5 – Tension: 1”

“Like: 5 – Dislike: 1”

“Bright: 5 – Dark: 1”

“Happy: 5 – Sad: 1”

“Furious: 5 – Gentle: 1”

The word left side in these questionnaire items is related to a higher value. For example, in the questionnaire item “Good Combination – Bad Combination”, 5-point means “very good combination”, 3-point means “neither”, and 1-point means “very bad combination”. The questionnaire items were written in Japanese on a questionnaire sheet with its scale. The subjects evaluated the impression level for each questionnaire item and marked the score by themselves just after the affordance of the music and scent stimuli.

2.2 Material

As stimuli, two music pieces and two scents were used in the experiment. The music pieces and the scents were selected by referring to the previous studies as follows.
The two music pieces were orchestra performance and were selected from a suite by Holst entitled The planets by referring to a previous study [22]: in the previous study, psycho-physiological changes occurred by listening to music pieces were investigated. One of the music pieces was Mars, the Bringer of War. Another music piece was Venus, the Bringer of Peace. The contrast of property of the two music stimuli elicited difference of impression in relaxation and furiousness in the previous study that investigated cross-modal effects of music and scent [18]. As shown in Figure 1, the time length of both the music stimuli was clipped into 220 s (from 0 s to 220 s of the original music file), and they were finished with fade their volume out: fade-in was not applied.

As scent stimuli, Chamomile-Roman and Peppermint were selected. Both scents are used in aromatherapy frequently [11, 12]. In general, Chamomile-Roman has the effect of sedative, in contrast, Peppermint has the effect of arousal, and they were used in the previous study [15]. Additionally, Peppermint was used as a high-arousal or excitative scent in previous studies [18, 19].

As a summary, Venus and Chamomile-Roman were hypothesized as low-arousal, sedative, and relaxing stimuli. In contrast, Mars and Peppermint were considered as high-arousal and excitative stimuli. To have investigations of cross-modal effects of music piece and scent, four experimental conditions were made by combining these two music pieces and two scents as follows:

- Condition 1: Venus & Chamomile-Roman
- Condition 2: Venus & Peppermint
- Condition 3: Mars & Chamomile-Roman
- Condition 4: Mars & Peppermint

2.3 Experimental Setting

Both playing the music piece and presenting the scent were controlled by the experimenter via a personal computer. Figure 2 shows a set of the experiment. The subjects listened to the music piece via a headphone (K702, Harman International Industries). Aromageur, a kind of aroma diffusers, was used for presenting the scents. The intensity of the two scents was set as the same maximum value via the software of Aromageur; persistency of the scent during 220 s was also controlled by the software. The scent was presented to the subject by weak wind through a simple window tunnel. The width and height of the wind tunnel were 23 cm and 22 cm, respectively. A deodorizer was used to prevent remaining the scent in the room. In addition, the air of the experimental room was continuously ventilated during and between the experiments.

3. EXPERIMENTAL RESULTS

3.1 Impression Values and ANOVA

Figures 3 (a)–(f) show the mean and standard deviation of impression values for the four conditions. By overviewing mean impression values, quite a strong effect of music pieces was observed in “Relaxing – Tension” and “Furious – Gentle” (Figures 3 (b) and (f), respectively). In these items, the impression values were different beyond the difference of music pieces. For example, in relaxation, the values of relaxing feeling in conditions with Venus were obviously higher than conditions with Mars. In addition, the impression values were relatively higher in conditions with Peppermint than conditions with Chamomile. In some other items, similar trends of a relatively small difference beyond difference of music pieces were observed.

To statistically investigate the effects of the stimuli, two-way repeated measures ANOVA was applied to the impression values for investigating main effects and interaction of the music piece and the scent. Beforehand of the investigation, the impression values were standardized in each of the subjects for each item, because the impression value is in the ordinal scale. Table 1 shows the summary of the ANOVA including main effects and interaction for each questionnaire item. In three items of “Relaxing – Tension”, “Happy – Sad” and “Furious – Gentle”, significant main effects of music were observed.

| Table 1: Summary of ANOVA for each questionnaire item |
|---------------------------------|-----------------|-----------------|-----------------|
| Good – Bad Combination          | Main effect of Music | Main effect of Scent | Interaction   |
| Relaxing – Tension              | P<0.001         | P=0.103          | P<0.05        |
| Like – Dislike                  | P=0.104         | –                | –             |
| Bright – Dark                   | –                | P=0.091          | –             |
| Happy – Sad                     | P<0.01          | –                | –             |
| Gentle – Furious                | P<0.001         | P<0.05           | –             |

Meaningful significant levels are P=0.05, 0.01, and 0.001. P-values around 0.1 are also represented in this table for showing marginal difference.
Related to main effect of scent, a significant main effect was observed in the item of “Furious – Gentle”: a marginal main effect was observed in the “Bright – Dark”. Interaction was observed only in the item of communication. Note that similar results of ANOVA were obtained with the impression values without standardizations.

3.2 Paired Comparisons

For showing the difference between each pair of four conditions, Multiple test (Shaffer’s multiple comparison) was applied to the impression values: Wilcoxon test was used for paired comparison with impression value without standardization. The results of the test were attached in the graphs when the $p$-value was smaller than significant levels of 0.05 and 0.01 between pair of the conditions (Figure 3).

With the multiple test, in three impression items, significant differences were observed. In “Relaxing – Tension” impression, the condition 1 and 2 elicited significant higher relaxing impression than conditions 3 and 4 (Figure 3 (b)). The same trend was observed in “Furious – Gentle” impression: both of conditions 3 and 4 elicited furious impression than both of conditions 1 and 2 (Figure 3 (f)). In “Happy – Sad” impression, between condition 1 and 3, a significant difference was observed. As a summary of the results, significant differences in the paired comparisons were observed only pair of conditions having different their music pieces.

![Figure 3: Mean and standard deviation of impression values for six questionnaire items](image-url)

Higher value in the graphs is related to the word left side in the adjective pair in each questionnaire items described in 2.1. Results of multiple test are also included (*: $P<0.05$, **: $P<0.01$).
4. DISCUSSION

The experimental results showed the main effect of scent in “Furious – Gentle” and the marginal main effect in “Bright – Dark”. The previous study [18] did not show the main effect of scent although it used the same questionnaire items. These results naturally show the importance of selections of the music piece and scents. Furthermore, repetitive evaluations by the same subjects seems also important because there are the individual differences of feelings and preference on music pieces, scents, and their combinations.

Comparing the main effects of music and scent, the main effect of music was observed in three questionnaire items. Furthermore, in the paired comparisons, no significant difference between the conditions with the same music piece and different scent (conditions 1 and 2, conditions 3 and 4) was observed. Based on the results, the main effect of scent seems to be weaker than music in the combination. This must be the reason why the previous studies could not obtain the result of the main effect of scent on walking distance [15] and impressions [16]. However, the previous studies and the present study uses relatively pleasant scents which can be used in aroma therapy. Using various scents including bad odors may show strong effects in the combination.

In the item of “Good combination – Bad combination”, the significant interaction was obtained. Mattila et al. found Interactions in Satisfaction, Impulse buying, etc. in their research [16], and Crisinel et al. found a suitable soundtrack for an odor from three tracks [17]. Thus, the result of the present study supports the findings of these previous studies. Additionally, a similar trend of change in the mean value in Preference and Combination was observed as same as the result of a previous study [19]. However, unexpectedly, the higher points of the good combinations were found in incongruent conditions: condition 2 with low arousal music and high arousal scent, and condition 3 with high arousal music and low arousal scent. The reason why the higher points were obtained in conditions 2 and 3 is difficult to explain, and there must be a complicated relationship between music and scent. For example, although Zhou et al. had a careful preliminary experiment for selecting scents, inverted trends on impression were observed in the two arousal scents for one music piece [19]. A recent study has tried to extract common dimensions on the impression of different type of stimuli including music and scent [23]. Using the impression commonly related to music and scent may reveal the complicated relationship between them.

5. CONCLUSION

This study investigated the cross-modal effects of music and scent on change in subjective feelings and preference. Especially, the main effect of scent which has not been observed in the combination was investigated. Two music pieces and two scents were used in the experiment. The results of two-way ANOVA showed the main effects of scent in Furiousness and the main effects of music in Relaxing, Happiness, and Furiousness. With paired comparisons, significant differences were only observed between the conditions with different music pieces. With these results, the main effect of scent exists in the combination, however, the effect seems to be weaker than the effect of music. Significant Interaction was observed in the combination, as same as the previous study. The better combination was observed in the incongruent combination, therefore, there must be many unknown and complicated things in the combinations of music and scent.

It is widely believed that human has a poor sense of smell; however, a recent study denies this matter [24]. Thus, the role of the sense of smell should be reconsidered. Combining scent with music must be a useful method for making people relaxing, exciting and other purposes. As future studies, by referring to the previous study [15], some tasks should be used in the experiment. Moreover, the scent is used for enhancing the interface and use of multimedia [25, 26]. Therefore, in affective engineering, investigations by employing various music pieces and various scents with psycho-physiological analyses are expected to make a new scenario of use of media contents.

NOTES
1. This study is the extended version of the previous paper [27] which was presented in ISIS2019 & ICBAKE2019.

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