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Development of Aromatic Image Map and Evaluation of Aromatic Oil Based on Brain Wave

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Abstract

The effect of fragrances on drivers has been examined, in order to optimize driver's condition during driving. A map that can clearly show the positioning of various fragrances is created as an initial step of this research and development. Sensory evaluation data of 12 kinds of fragrance samples, which are tested on 64 subjects, are used for the creation of this map. The "Aromatic Image Map" can be used to confirm the distribution of the characteristics and the subjects' preferences for each fragrance. Furthermore, the validity of the "Aromatic Image Map" is inspected experimentally, based on the difference in recovery from stress among the fragrances. Six subjects participate in the experiment, and the four kinds of fragrances that stand at the specific positions on the "Aromatic Image Map" are used. As a result, this enables us to inspect the validity of the position of each fragrance on "Aromatic Image Map".

Keywords

Driver, Fragrance, Aromatic Image Map, Brain Wave, Recovery from Stress

1. Introduction

"Healing" has become popular lately due to the anxiety caused by degradation in economic and social conditions. Among the various types of healing that is available in the market, the popularity of fragrance is high. There is a report [1] telling that, a major internet shopping site, "Rakuten Ichiba" (http://www.rauten.co.jp), has 142 products (15.3%) related to fragrance out of a total of 927 healing products, out of which fragrance comes

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second next to “accessories”.

There has been an increase in the number of drivers who are concerned over the scent (smell) in their vehicles. However, user’s needs are more leaned towards “eliminating undesirable odor”, rather than using a fragrance of their taste. Judging from the background of increasing fragrance boom mainly among women, it is estimated that there are increasing number of users who are not satisfied with aromatic substances already available in the market nowadays [2].

To conclude, “fragrance” is a popular social phenomenon. However, aromatic substances, which are available in the market, cannot satisfy some drivers’ need for fragrance.

Fragrance has psychological and physiological effects on human beings. As a result of basic researches on fragrance, the following findings have been obtained. If fragrance is evaluated in a hundred-point scale, citrus fragrances such as orange score favorably, while wood-type fragrances such as eucalyptus, are undesirable and score low [3]. It has been reported that a desirable fragrance brings comfort and is effective in reducing anxiety and stress [4]. Moreover, there is another report based on the variation of particular component in brain wave informing that the arousal level drops when lemon and rosemary are smelled, and rises when peppermint is smelled [5]. As above mentioned, it is known that the effect of fragrance on human beings is substantial.

These basic studies have shown that fragrance may be used as a means to optimize the driver’s condition during driving; not only just as a means to match the interior environment of the vehicle to the driver’s taste or as a healing item. The use of fragrance, which appeals to the sense of smell of the driver as a warning system, has become widely noticed as a succeeding system to current warning systems, which utilize sound (voice) and light in order to appeal to the auditory and visual senses of the driver.

In order to optimize the driver’s condition by enhancing comfort in the environment of vehicle interior and by realizing the fragrance warning system, it is essential to know which type of fragrance shall be chosen and to make an index that enables one to know what kinds of effects the fragrance will give to the driver.

In this paper, the position of each type of fragrance was clarified, an image map for easy identification was created, and validation of the feasibility of this image map was conducted.

2. Survey and Experiment

2.1. Study Based on Questionnaire Survey

2.1.1. Method of Survey

Sixty four subjects (31 male, 33 female) agreed to participate in the questionnaire survey. From the point of view of safety, we explained to the subjects about the face that “the effect of smelling commercially available natural aromatic oils and developed aromatic oils for vehicle to the body is very small.” The fragrances used in the survey consisted of 12 types of samples. We adopted a method to evaluate the fragrance of each sample using the questionnaire. The average age of the subjects was 30 and the standard deviation was 6.91.

Mouettes (sample fragrance paper) were used for the presentation of the samples. The subjects themselves immersed the mouettes in the aromatic oils and developed aromatic oils for vehicle, and then they placed the mouettes in front of their nose and shook it. The names of the test samples were concealed from subjects.

The twelve types of fragrance that were used this time as test samples are described in **Table 1**. In **Table 1**, “Type A” is the fragrance in which raspberry, cassis etc. are blended. “Type B” is the fragrance in which clary sage, coriander etc. are blended. “Type C” is the fragrance in which mimosa, rose, jasmine, violet etc. are blended. “Type D” is the fragrance in which orange, narcissus etc. are blended.

In this survey, which was performed to clarify the distribution of the characteristic of each fragrance, a 6-point method based on the SD-method (Semantic Differential method) was adopted. The SD-method clarifies

Table 1. Twelve test samples.

Natural aromatic oil					Developed aromatic oil for vehicle
Herb type	Spice type	Wood type	Floral type	Cirus type	
Peppermint	Black pepper	Pine Eucalyptus	Rose Jasmine	Orange (sweet) lime	Type A Type B Type C Type D

the psychological structure (main component) toward objects, and it is executed in the following procedure.

1) Prepare several pair of adjectives with opposite meaning in advance.

2) Evaluate and rank the impression of the subjects left by the objects for each pair of adjectives.

3) Analyze the result and clarify the psychological structure (main component) toward the objects.

The evaluation items in the questionnaire survey consisted of a total of 20 pairs of adjectives, such as "favorite vs. least favorite", "dark vs. bright, flowery vs. not flowery." [6].

The survey was held in two days. The evaluation was based on testing the fragrance of six samples on the first day, and the remaining six samples on the second day. In order to avoid the effect of insensibility of smell, and to prevent the subjects from getting used to the fragrance as a result of excessive inhalation of test samples, the six samples were tested separately: the first three in the first, and the remaining three in the second session. A break of 10 minutes was taken between these sessions. The survey flow is indicated in **Figure 1**.

2.1.2. Results of Survey

1) Distribution of fragrance characteristic

Except for the item "favorite vs. least favorite" out of 20 survey items, the main components for 19 items were analyzed, and three major components were extracted. And these 3 major components were named. The representative adjectives based on each of these components and the SD methods are shown on **Table 2**.

Among these three major components, the map was based on the first and second major components (cumulative contribution ratio 58%). For this reason, the fragrance of each sample was distributed over the two dimensional plane consisting of the first and second major components (**Figure 2**). The ellipses in **Figure 2** represent values that were calculated from the following formula:

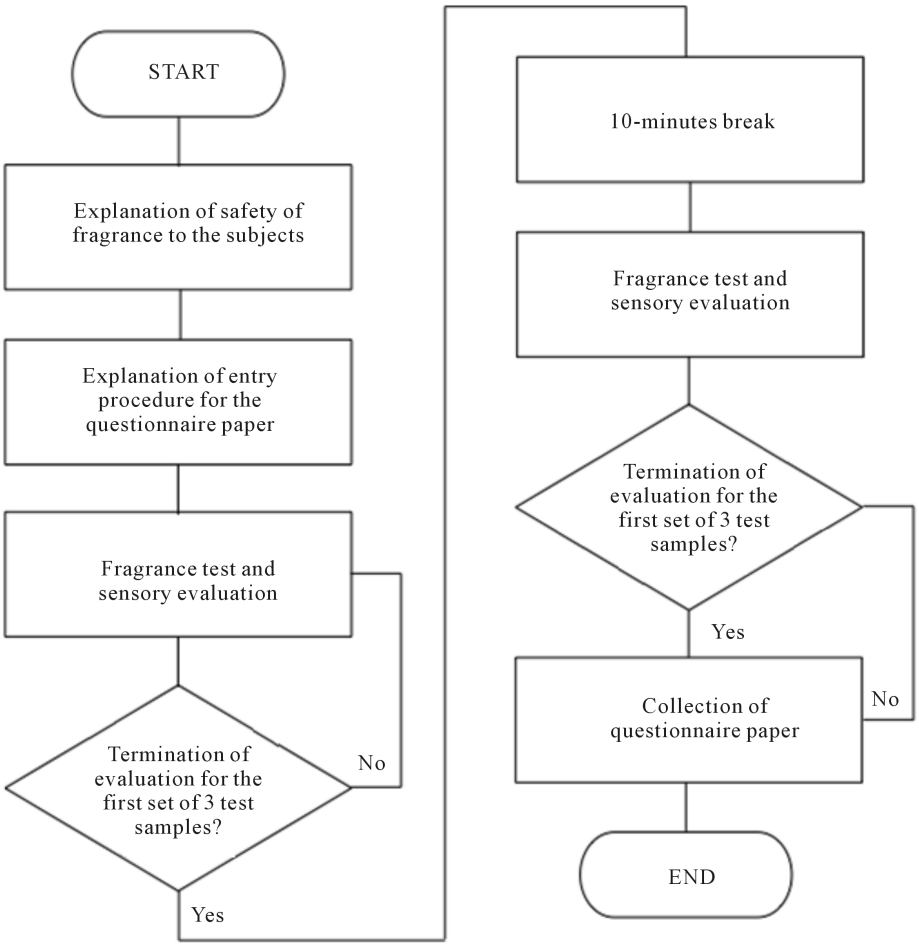

Figure 1. Flowchart of sensory evaluation experiment.

Table 2. Extracted major components.

	Name	Adjectives used in SD method (representative examples only)
First major component	Mellow and healing	"Smooth vs. Rough" "Flowery vs. Not flowery" "Elegant vs. Not elegant" "Feminine vs. Masculine"
Second major component	Awakening sharpness	"Clear vs. Vague" "Sharp vs. Blunt" "Drowsy vs. Not drowsy"
Third major component	Exciting	"Exciting vs. Not exciting"

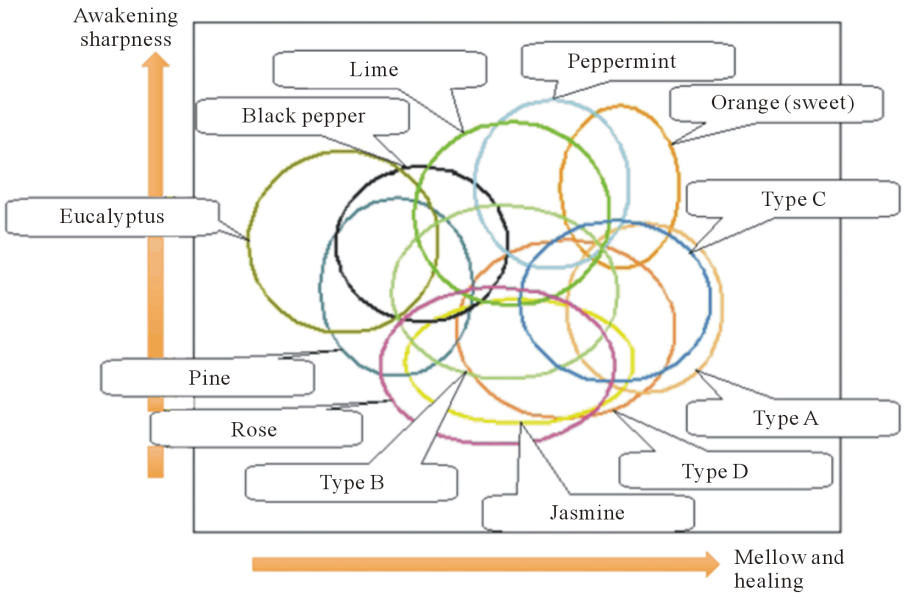

Figure 2. Result of sensory evaluation experiment.

$$\left(\frac{x-v_{xmean}}{\mathrm{SD}_x}\right)^2+\left(\frac{y-v_{ymean}}{\mathrm{SD}_y}\right)^2=1 \quad (1)$$

where,

v_{xmean}: Average value of 1st main component.

v_{ymean}: Average value of 2nd main component.

SD_x: Standard deviation of 1st main component.

SD_y: Standard deviation of 2nd main component.

2) Distribution of preference

Since age and sex difference were not detect in the average value and dispersion, the data of all subjects were processed together.

The plane consisting of the first and second main components was divided into meshes. The number of subjects and evaluation points, which is included within the divided area, was standardized from −1 to +1, and each mesh was color coded by this value. The result is shown in **Figure 3**. In **Figure 3**, the blue color indicates the area with many subjects that liked the fragrance; the red color indicates the area with many subjects that disliked the fragrance; the yellow color indicates the area with many subjects that did not have any particular impression for the fragrance. Mixed feelings of likes and dislikes were not observed in the same area.

3) Aromatic Image Map

By superposing **Figure 2** and **Figure 3**, a map that indicates both the characteristics and preferences for each test sample is created (**Figure 4**). We call this map as "Aromatic Image Map."

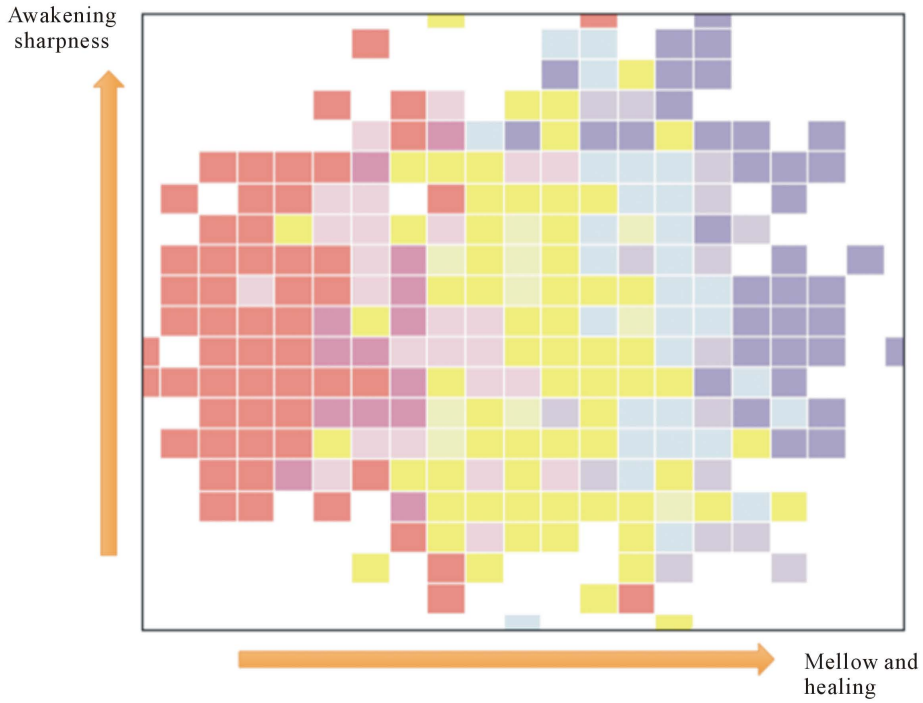

Figure 3. Result of preference distribution. Red zone means dislike, blue zone means like.

2.1.3. Consideration Based on Survey Results

Here, consideration is centered on the Aromatic Image Map (**Figure 4**).

1) Distribution of fragrance characteristics

Peppermint and orange (sweet) are sharply awakening; while rose and jasmine are vague (causing drowsiness). It is clear that this result confirms the previous research conducted by Okazaki [5]. Moreover, preference leans toward the "citrus" fragrance of orange (sweet) and Type A. Wood type fragrances, such as eucalyptus and pine, and spicy fragrances such as black pepper were disliked by the subjects. In addition, not any particular likes and dislikes were shown towards floral type fragrances such as rose and jasmine. It is therefore clear that these floral fragrances have moderate character. This result is nearly congruent with the previous study conducted by Kawai [3].

2) Distribution of characteristics of developed aromatic oil for vehicle

Regarding the four developed aromatic oil for vehicle among all the fragrances, we discovered that they are not awakening and sharp. These four fragrances are sedate, yet refined and healing characters that match with the concept of the car and have the tendency to be well accepted. In particular, "Type A" is positioned at the extremely well-liked zone. It is estimated that it contributes to enhance the comfort of the vehicle interior. However, all the four fragrances of developed aromatic oil for vehicle are closely located on the map. It can be said that there is not much difference in the property of their fragrance.

Type B, which is one of the four fragrances, is wide in preference. Moreover it is located at the center. This is attributed to the blend of floral type fragrances.

3) Consideration of distribution of preference

"Awakening sharpness" can be understood as a functional element of fragrance. This does not have any effect on the preference for a certain fragrance. When creating a new aromatic oil for vehicle, a method is conceived, where the preference level is positioned on the same coordinate axis of the map, and the direction of "sharpness" of the fragrance is tuned.

2.2. Experimental Study Based on Brain-Wave Measurement

Based on the questionnaire survey, the Aromatic Image Map was created and the characteristic for each fragrance was found. In order to ensure its validity, an evaluation based on brain wave was performed.

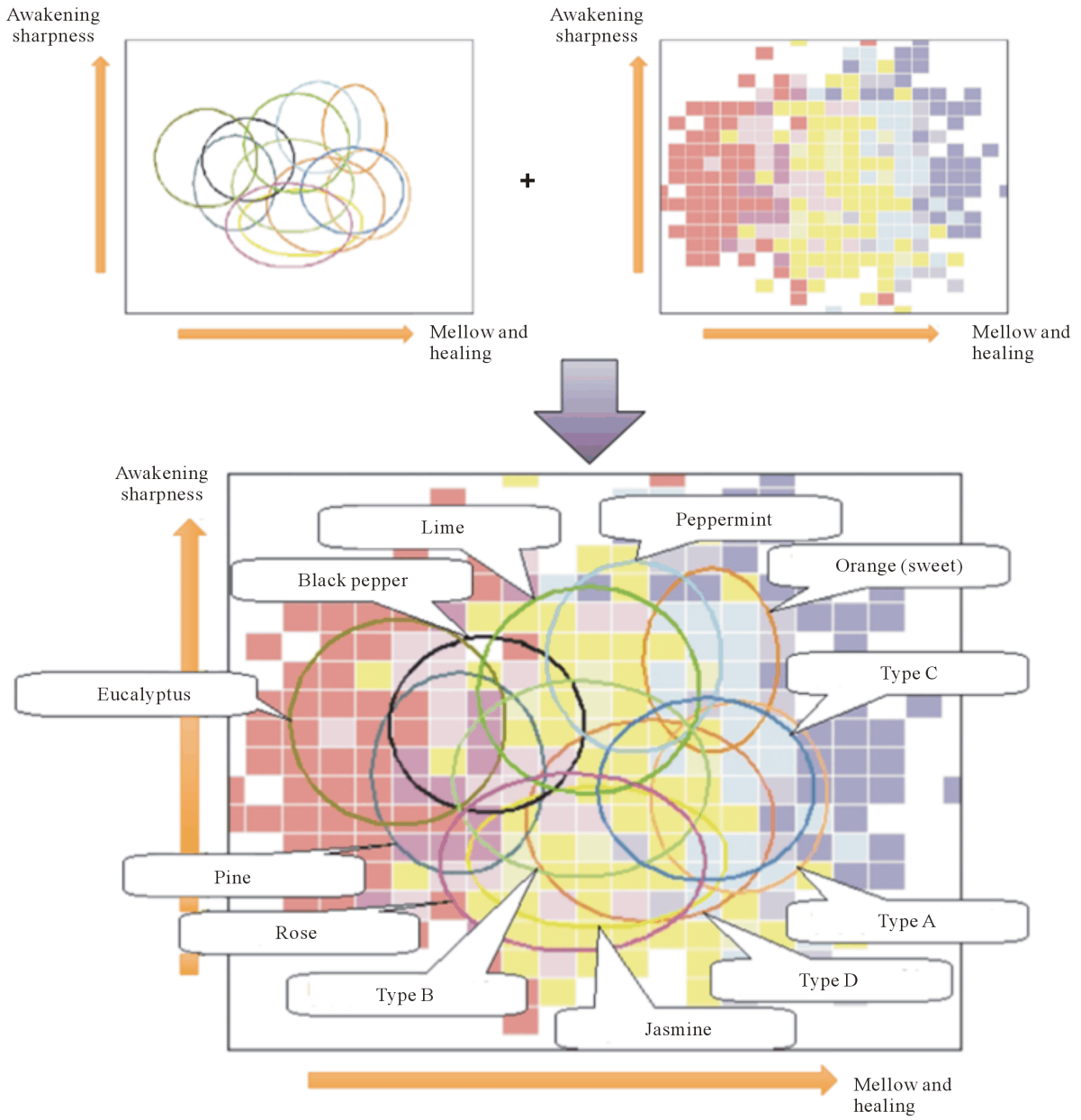

Figure 4. Aromatic image map. This map is consisted of result of sensory evaluation experiment and result of preference distribution.

2.2.1. Experimental Method

In the experiment, in addition to the explanation of safety of fragrance during the survey, the fact that "brain wave measurement does not have any effects on the human body" was explained to the subjects. The measurement was conducted on six subjects who consented to participate in this experiment. HSK central rhythm monitor system SLIM (made by Human Sensing Co., Ltd.) was used as a device to measure and analyze brain waves. This system is hairband-like device and measures the brain waves of the right and left parts of the forehead with a hair band sensor (Fp1 and Fp2 of International 10/20 method). It is used for like evaluation of products by a quantitative evaluation of the activity and comfort levels of the brain from the fluctuation component of α-wave band (8 - 13 Hz) in the brain waves. (For the evaluation outline, refer to supplementary note.)

In the experiment, the same level of stress load was given to all subjects, and a method to examine recovery from stress owing to smelling the fragrance was used. For the stress load, the Uchida and Kraepelin Mental test

[7], which continues to add one digit in a given length of time, was used.

The Uchida and Kraepelin Mental Test was conducted on the subjects for five minutes. By letting them smell the fragrance after that, recovery from stress was examined through the brain waves. This time the Uchida and Kraepelin Mental Test was used with the objective to apply stress. For this reason, the test result has not been studied.

Four types of fragrance samples that are located in a characteristic plane in the Aromatic Image Map were used to measure the brain wave: orange (sweet), eucalyptus, rosemary, and Pleasure Time (**Figure 5**).

Figure 6 indicates the experiment flow. Within **Figure 6**, the result of the Japanese version of STAI and subjective symptom survey are not included in this analysis.

2.2.2. Result of Experiment

The data, which are measured and analyzed using HSK Center Rhythm Monitor System SLIM, are considered as primary processing data. In this primary processing data, the level of comfort (%) ranges from 30 to 240 degrees and exceeds 50% by all means as shown in **Figure 7** [8].

However, the changing behavior with time such as the recovery from the stress load used in this experiment is not sufficiently grasped by this process. For this reason, as for the four types of fragrances, a fragrance is considered as "comfort" if its direction of comfort feeling falls in the range of 30 to 240 degrees.

Fragrances that are outside this direction are defined as "discomfort." The secondary processing, which is shown below, is performed to calculate the "stress recovery level."

Firstly, Comfort index (C_i) and Discomfort index (DC_i) were defined by Equation (2) based on the angle calculation Equation (2) based on the angle calculation equation of HSK Center Rhythm Monitor System SLIM.

$$\begin{aligned} C_i &= N_i\left(\theta_1\right) \\ D_i &= N_i\left(\theta_2\right) \end{aligned} \tag{2}$$

$$\begin{aligned} &30^\circ \le \theta_1 \le 240^\circ \\ &0^\circ \le \theta_2 \le 30^\circ, 240^\circ \le \theta_2 \le 360^\circ \end{aligned} \tag{3}$$

Secondly, regarding C_i and DC_i, which are calculated from Equation (2), the ratio of comfort index (a_i) relative to the total number of plots for each minute starting after the presentation of the test sample until the end of

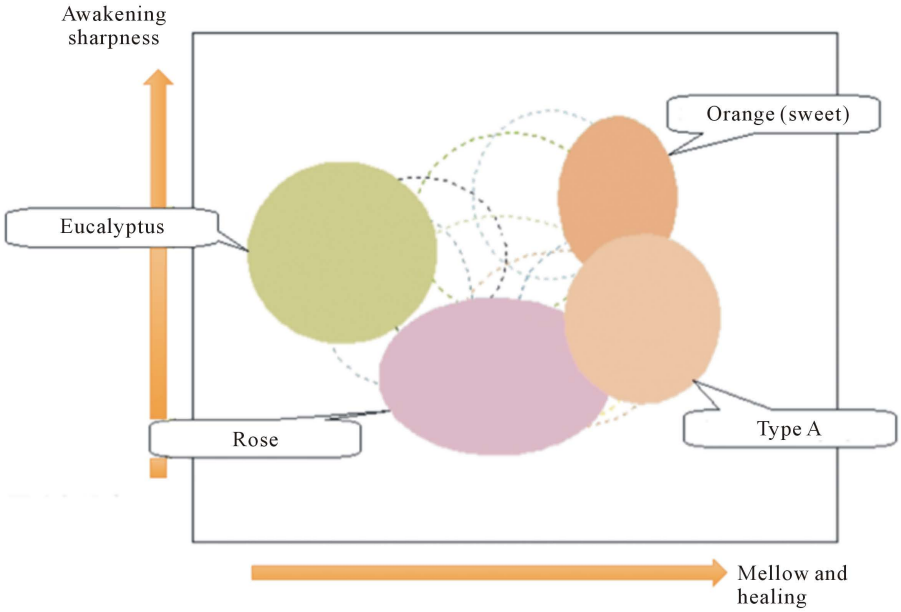

Figure 5. Picking up 4 kinds of fragrances. Four kinds of aromatic oil, Type A, Orange, eucalyptus and rose, are used based on aromatic image map.

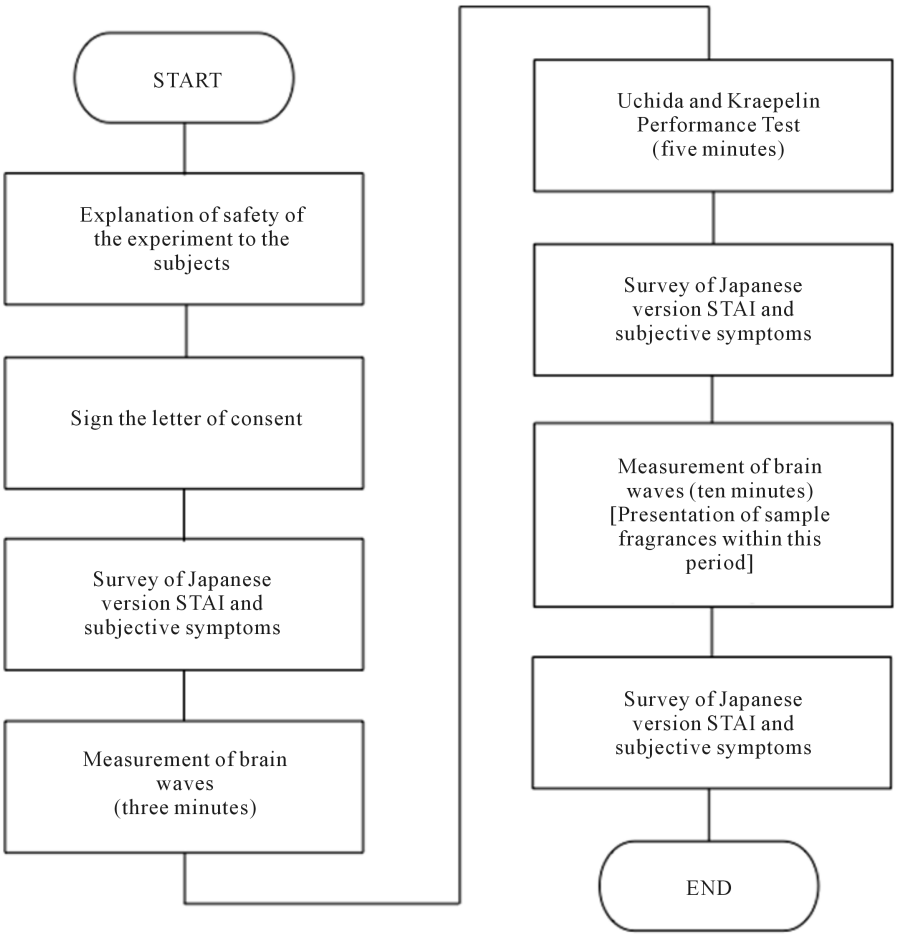

Figure 6. Flowchart of measuring brain wave experiment.

the experiment (i = 2, 3, ⋯, 9 [min]) is calculated by Equation (4). The ratio of comfort index (a_0) relative to total number of plots before the presentation of the test sample can be calculated using Equation (5).

$$a_i = \frac{C_i}{C_i + DC_i} \tag{4}$$

$$a_0 = \frac{C_0 + C_1}{C_0 + C_1 + DC_0 + DC_1} \tag{5}$$

Finally, regarding a_i and a_0, calculated separately using Equations (4) and (5), b_i as "stress recovery level" is calculated from Equation (6).

$$b_i = \frac{a_i}{a_0} \tag{6}$$

The standard condition for "Stress recovery level" is 100% immediately after the Uchida and Kraepelin Mental Test. If the stress recovery level is 100% or more, it indicates recovery from stress; and if it is 100% or less, it indicates increase of stress.

Figure 8 shows the average value and the standard deviation of "stress recovery level" of all subjects for each fragrance, at start and end of the experiment. As shown in **Figure 8**, Type A exceeds 100% among the four fragrances. This indicates recovery from stress. However, the remaining three fragrances are all less than 100%, that is, there is no indication of recovery from stress for them. The t test of "stress recovery level" for each of the

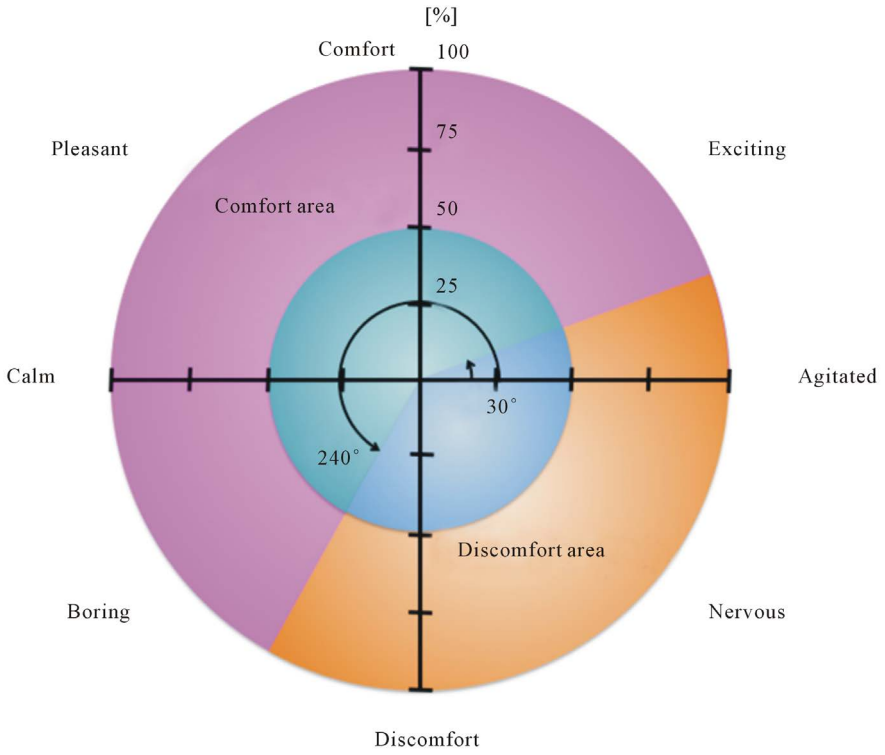

Figure 7. Comfort area and discomfort area.

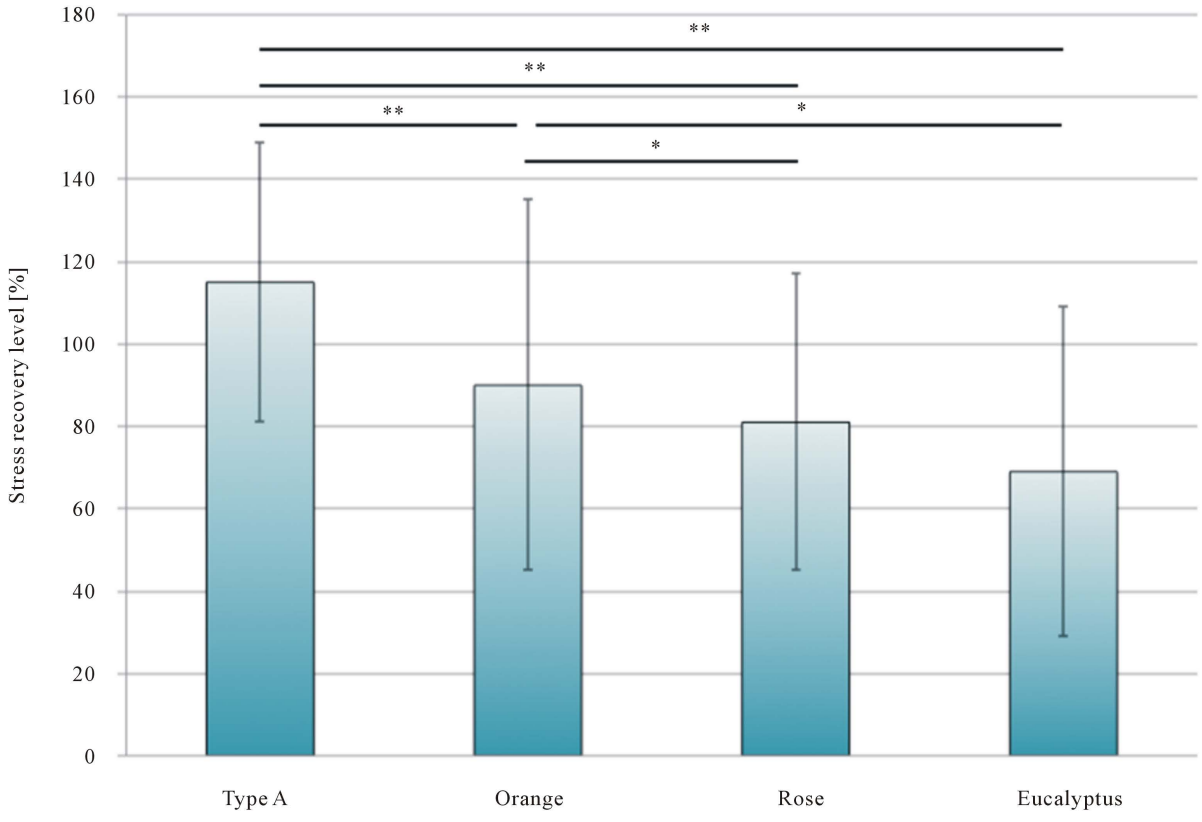

Figure 8. Recovery from stress (**: $p < 0.01$, *: $p < 0.05$). Type A shows this aromatic oil is most effective to stress recovery. On the other hand, Eucalyptus shows this aromatic oil is ineffective to stress recovery.

four fragrances shows that the stress recovery ratio of Type A is high compared to the remaining three fragrances at the significance level of 1%. Moreover, it was clarified that the stress recovery ratio of orange (sweet) is high compared to rose and eucalyptus at significance level of 5%.

2.2.3. Consideration Based on Experiment Result

From the "Stress Recovery Level" shown in **Figure 9**, the value of Pleasure Time is the highest. It is statistically significant, and it is found that it has the effect of recovering from stress. It was also found that other three fragrances, orange (sweet), rose and eucalyptus, have no stress recovery efficacy.

In addition, since the recovery from stress is assumed to be accomplished by the effect of "healing", the result of recovery level and the distribution of the Aromatic Image Map shown in **Figure 4** were compared. From the Aromatic Image Map, it was clear that the "fragrance" samples that contribute to stress recovery are located on the right side, and similar tendency is observed from the result of the "Stress recovery level."

Moreover, based on the position of the Aromatic Image Map and the experiment result, it is assumed that the Type C, which is closely positioned to Type A, has the similar stress recovery effect. This fragrance is estimated to contribute to the enhancement of comfort of the vehicle interior.

3. Conclusions

In this paper, at first the creation of the Aromatic Image Map, which is based on a questionnaire survey, is explained. Based on the results of the Aromatic Image Map, the preference for a certain fragrance is determined by components such as "mellow" and "healing." The "sharpness" of fragrance seldom affects preference, and it is found that it has a functional aspect. According to the Aromatic Image Map, developed aromatic oil for vehicle is a fragrance that is generally well liked. People's preference for Type A, in particular, is very high, and it is proved that it contributes to enhance comfort of the vehicle interior.

Next, in order to quantitatively validate the result of the Aromatic Image Map, the effect of fragrance is examined by using brain wave measurement as a quantitative approach. Judging from the index of "stress recovery level", the value of Type A is the highest. This fact proves that recovery from stress is possible by this fragrance. The order of the test score below the Type A is orange (sweet), rose and eucalyptus. But stress recovery effect is not observed with these three fragrances. This result indicates the validity of the Aromatic Image Map. In particular from the point of view of recovery from stress, it is estimated that Type A contributes to the enhancement of comfort of the vehicle interior.

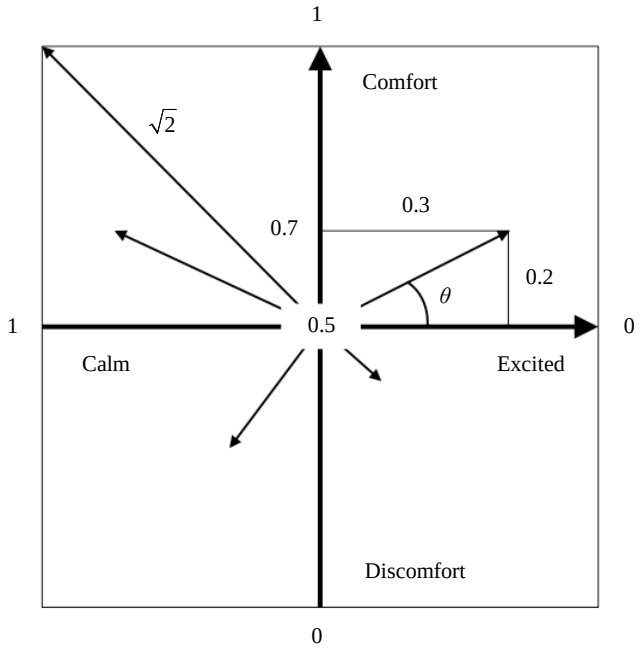

Figure 9. How to decide the direction and level of comfort.

4. Issues and Prospects

Human olfactory sense adapts quickly, so further detailed study is required with regard to the method and time of presentation of fragrance. Specially, in view of the limited space within the vehicle interior, future studies regarding the issue of remaining smell and its method of elimination are required.

Despite the above-mentioned remained issues with regard to smell, the following points can be looked over from our research.

First of all, a more comfortable vehicle interior can be produced by providing a fragrance with a high "mellow and healing" effect for luxury oriented models, and a fragrance with a high "sharp awakening" effect for sport oriented models.

The next step is the application of "fragrance" to warning systems. For instance, when the driver is under a reduced arousal level, a fragrance with high awakening effect that is "sharp enough so as to awaken him/her" may be used. On the other hand, when the driver is excessively tense, presenting a fragrance that is "mellow and healing" to the driver may be effective.

We are sure that the Aromatic Image Map is very effective with regard to a more detailed study of these fragrances.

5. Afterword

Needless to say, comfort is dependent on sensibility. The "pleasure of driving" from the aspect of "driving performance" largely depends on the function of perception, tactile and auditory senses such as "feeling of expected cornering of oneself", "feeling of expected acceleration of oneself" and "comfortable engine sound."

However, when considering comfort in general, true comfort cannot be achieved by pursuing only the aspect of driving performance. It is important to know how comfortable the driver feels in the private space of the vehicle interior.

At this time, in addition to the sensory, tactile and auditory senses, we think that the comfort of the driver can be further enhanced by considering the olfactory sense.

Looking from the viewpoint of HMI (Human Machine Interface), it is desirable that the warning system is in the harmony with the sensitivity of the driver without giving an unpleasant feeling to the driver. Apart from conventional warning systems, the utilization of the sense of smell as a "driver-harmonious" warning system is worthy of consideration.

Some people may drive for a change, when there is something they don't feel contented in their daily lives. Even in such moments, the driver will not feel uncomfortable, because added value for driving such as "fun" and "comfort" will make him/her feel pleasant and comfortable. The study of "fragrance" will certainly contribute to create such a value added for driving.

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Appendix

W. Heller proposed a two dimensional model of emotion [9], in which in addition to the differences of right and left in the activity of the forehead, which reflect dimension of values, fluctuation of arousal level of the autonomic nerve in the rear part of the top of the head is considered. The basic concept is that the foundation of the expression of emotional experience is related not only to the emotional character (comfort and discomfort) but to the components of arousal (high and low).

According to Yoshida, the declination of the frequency fluctuation spectrum of the α-wave in the left forehead corresponds to the condition of the mood, whereas that in the right forehead corresponds to the arousal condition. Regarding the relation of fluctuation spectrum of α-wave and mood/arousal feeling in the left and right forehead, he studied by establishing a hypothesis that "The condition of mood is reflected in frequency rhythm of the brain waves in the left forehead. The frequency rhythm of the brain waves in the left forehead gets close to absolute value of 1 (*i.e.* 1/f) as the comfortable mood grows, and it gets close to 0 as the comfortable mood declines. On the other hand, the arousal feeling corresponds to the frequency rhythm of the brain wave in the right forehead, and that inclination gets close to zero as arousal feeling grows."

Based on this assumption, we decided to get the level of comfort and fragrance by inclination (absolute value) of frequency fluctuation spectrum in the right and left forehead. The absolute value of the fluctuation spectrum that was estimated using the linear regression formula was almost from the value of −1 to 0, and the absolute value of the inclination was newly expressed as degree of rhythm. In case the absolute value of inclination is actually bigger than 1, we will set expediential 1, and determine the degree of rhythm within the range of 1 from 0. In this way, the level of comfort is converted to numerical values operationally by objective indexes of brain wave. The calculation formula is as follows:

1) Calculation method of the direction of comfort feeling Angle

$$\theta[\mathrm{deg}] = \left(\arctan \frac{\mathrm{Fp1}_{slope} - 0.5}{0.5 - \mathrm{Fp2}_{slope}} \right) \times \frac{180}{\pi} \tag{a}$$

where,

$\mathrm{Fp1}_{slope}$: Level of inclination of frequency fluctuation in left forehead (absolute value)

$\mathrm{Fp2}_{slope}$: Level of inclination of frequency fluctuation in right forehead (absolute value)

Level of inclination (absolute value) 0.5 indicates that the level of inclination is at the middle of 0 and 1 (**Figure 9**).

Relative to θ that is calculated using formula (a), the defined θ' by following formula (b) will be the angle to be used to determine the direction of comfort feeling.

$$\begin{aligned} \theta' &= \theta + 180 \quad 0.5 - \mathrm{Fp2}_{slope} < 0 \\ \theta' &= \theta \qquad\quad 0.5 - \mathrm{Fp2}_{slope} > 0 \end{aligned} \tag{b}$$

According to Yoshida, the constant 0.5 in formula (1) is based on the experiment result that have been done so far. The inclination of the right forehead (Fp2) in comparison to the left forehead (Fp1) is relatively large in resting condition. However, it has been confirmed that both portions are almost close to 0.5 in the degree of rhythm. For this reason, 0.5 is used as standard in calculating the angle.

2) Method to determine the level of comfort

$$\text{Level of comfort F[\%]} = \left\{ \sqrt{\frac{\left(\mathrm{Fp1}_{slope}\right)^2 + \left(\mathrm{Fp2}_{slope}\right)^2}{2}} \right\} \times 100 \tag{c}$$

The level of comfort is a quantitative value based on brain waves of comfort feeling. In case the degree of rhythm 1 for right and left forehead (Fp1 and Fp2), this indicates a very good condition in which the feeling is calm. The scalar amount at this moment is $\sqrt{2}$ as 100% comfort level, the level of comfort is determined in a ratio with a value of the level of comfort calculated from the degree of rhythm that was actually achieved.

Since the position and the amount of the level of comfort can be determined by formulas of angle calculation and level calculation, the evaluation based on the measurement of the periodic rhythm of the brain waves en-

ables us to know whether the subject is comfortable as result of easygoing or relaxed condition, and how much the level of comfort is [8].

Based on this theory, the level of comfort is calculated from the level of the inclination of the right and left brain that was measured by HSK Center Rhythm Monitor System SLIM.