THE INFLUENCE OF ODOR IN A TRAIN CARRIAGE TO INDUCE POSITIVE EMOTIONS IN RAILWAY USERS

(鉄道車両内の香りが利用者のポジティブ感情に与える影響)

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1. Introduction

1.1. Well-being in a rail transport system

Commuting related stress is a hot topic, especially in big cities such as Tokyo. According to 2016 data (Figure 1), people in big cities use trains more often. Over 60% use the train more than several times a month, 22.3% use it almost every day, and the average commute time in Tokyo is 102 minutes each day. The national average is 79 minutes. [1]

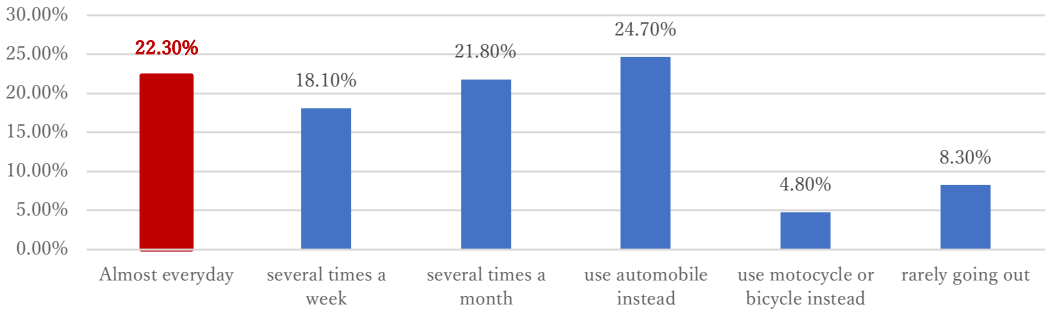

Figure 1. Frequency of using train and bus in Japan's big cities N=458
(Public Opinion Poll, 2016)

As people are using the rail transport system for these significant time durations we considered that more attention should be paid to their well-being. This could be influenced by many factors and in the PERMA model this is identified by five essential elements (Seligman, 2011), as shown in Figure 2 [2].

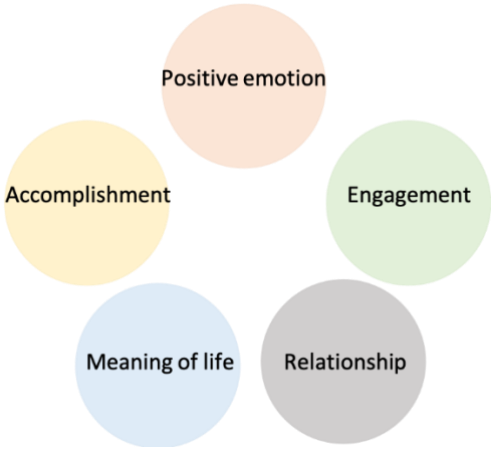

Figure 2. PERMA Model (Seligman, 2011)

Cohn and Fredrickson (2009) state that positive emotions are the good things that we feel, such as happiness, hope and joy, and research also suggests positive emotions are a key indicator of well-being [3]. Life satisfaction, resilience, mindfulness, social rewards, work outcomes, and physical health are all related to positive emotion as well. In addition, Diener (2000), also emphasized that experiencing positive emotions is a primary goal for individuals around the world [4]. Among the five essential elements in Figure 2 - P (Positive emotion), E (Engagement), R (Relationship), M (Meaning of life), A (Accomplishment) - P (Positive emotion) is most related to short-term experiences in our daily life that can significantly affect well-being.

The research project described here forms part of the Science & Technology + Art & Design Hybrid Innovation (STADHI) project at the Tokyo Institute of Technology, Japan. Nathan Cohen, an artist and researcher, initiated this collaborative research project in 2019, integrating olfaction with the railway system to enhance railway users' well-being, providing imaginative research ideas based on his experience of how odor influences people. With his knowledge of the olfactory field, supported by the public transport expertise of Shinya Hanaoka, we have been exploring possible connections between odor and well-being in the specific context of railway travel.

1.2. Previous odor research

Human beings have five senses, including vision, tactile, auditory, taste and olfaction. External information we receive through these senses cause many kinds of complex psychological and physical reactions that we have to the world around us. Among these, olfaction's influence has, historically, not been so intensively investigated.

However, in recent years, olfaction has started to become an increasing topic of interest in many research fields, in particular consumer related and marketing applications. Research shows that odor can create and arouse emotions [5], and also indicates that ambient odors are a critical factor that can drive purchase intentions [6].

Generally speaking, odor can influence people in many ways. Firstly, it can induce behavioral change - one experiment demonstrated that odor dispersed in a crowded room significantly increased the number of social interactions of the participants [7]. Another study in 2005 also shows that, although the participants are unaware of their

behavioral change, when they were exposed to the subtle ambient scent of an all-purpose cleaner, this induced them to keep the table they were eating at cleaner, with those subjected to the odor tidying up after themselves more frequently than those who were not. [8]

Secondly, emotional change can also occur because of the existence of odor. Kadohisa (2013) mentions that some odors can arouse emotion that leads to the recall of emotional memories, which are more vivid than with other senses. For example, many people can remember relating to certain images or episodes when they are exposed to the same odor as they had previously associated with that experience, even if this occurred a long time ago. Additionally, memory cues triggered by odor are more sensitive and emotional than those triggered by other senses [9-11].

In a study of environmental scents (Spangenberg, Crowley and Henderson, 1996), retailers succeeded in manipulating environmental perceptions using pleasant scents, especially ambient scents and scents that are not associated with a particular object, inducing customer interest and association with the store. Not only did this change the customers' perception of the store but also its products as well [12], the key here being that a person might identify the ambient odor generically with the store and its associated products collectively, not just with a specific product. This use of scent has also been shown to influence mood in a positive direction, with associations that result from this scent being perceived favorably. In terms of particular odors it was found by Spangenberg et al. (1996) that lemon had the strongest effect on positive emotions and energy, producing the best results in terms of perceived well-being. Measurements also show that mood is improved when there is the presence of pleasant ambient odor.

An experiment conducted in 1998, with 103 female university students, investigated the preference of odor and its psychological effects. It examined how the subject's mood changed before and after inhaling a preferred scent. From the results of SD method and Psychiatric Outpatient Mood Scales (POMS) analysis, reduction of tension and anxiety and increase in the clarity of thinking was demonstrated [13].

Thirdly, odors can influence psychological and physiological states. Since some odors can modulate emotion, the application of those odors for the treatment of particular psychological problems, such as reducing the effects of stress, is possible [14]. However, odor's influence not only exists by itself, but is also associated with many other factors,

such as colour, music, and other stimuli.

1.3. Odor used in public spaces

Emotional response can be triggered immediately by odor. When people sniff a preferred odor, their active and inactive sense of pleasant emotion is induced. Conversely, when encountering a dislikable smell, negative emotions can occur [15]. Therefore, the odor preference of individuals will also have significant influence upon the type and extent of emotion aroused.

Commercial applications of this principle might include encountering particular odors prepared for department store displays, or in up market hotel lobbies, where fragrances have been formulated for this purpose. In this way, besides appealing to our senses in other ways, the perhaps subtler sense of olfaction offers a more attractive way to communicate with consumers, a method termed “Olfactory Branding” [16].

Odor, with its usefulness as a new method for differentiating brand image as well as creating new experience, is increasingly being applied in public spaces in recent years. Moreover, trials of applying odor in transport systems has also appeared in different countries around the world [17-19]. However, the different methods used to apply odor into train carriages or stations often lack published data relating to passenger feedback thereby preventing effective analysis. Without this it is not possible to gauge the particular advantages and disadvantages of applying odor in a public transport system. Besides this, research about applying odor in public spaces, and its’ connection with users’ feelings, is rarely conducted.

2. Objective

Through initial discussion we (Nathan Cohen, Shinya Hanaoka and myself) designed an experimental approach to find out the impact of odor on train travelers. We developed two hypotheses. First, that odor would induce positive emotion and alter people’s evaluation of the atmosphere in a train carriage setting. That is, a pleasant ambient odor will cause an increase in the pleasure score of the PAD model, while the arousal level of emotion will differ according to the arousal level of the odor.

According to prior research, odor can evoke physiological changes, especially emotion (Mikiko Kadohisa, 2013). This implies a likelihood that odor would alter how people perceive their environment to some extent, leading to our second hypothesis that different ambient odors could alter railway users' perception of the surroundings they are travelling in.

To establish the extent to which odor has impact at an individual level we also decided to ask those participating in the experiment about their cognition of odor, to confirm their impression of the intensity of the odor and to investigate whether any emotional change is affected by the odor we have added in comparison with the smell that originally existed inside the train carriage.

3. Methodology

3.1. Russell's Circumplex Model and SD method

For this experiment the railway users' positive emotion is measured by a questionnaire based on the PAD (Pleasure, Arousal, and Dominance) Scale [20]. Typically, the PAD scale consists of six pairs of adjectives expressing related emotions. As the outcomes of other research projects did not reveal an obvious influence in the Dominance section of the PAD scale, only the Pleasure and Arousal Scales were taken into consideration, providing the Russell's Circumplex Model shown in Figure 3. [21]

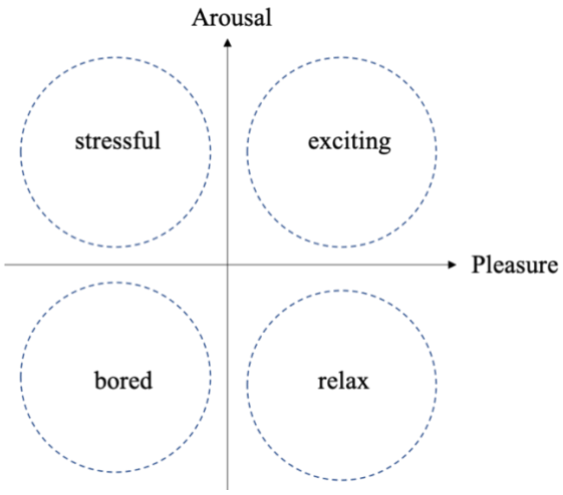

Figure 3. Russell's Circumplex Model

So for our research purposes we only applied word pairs in the corresponding Pleasure and Arousal parts of the scale. For the Pleasure scale: “unhappy-happy”, “annoyed-pleased”, “unsatisfied-satisfied”, “melancholic-contented”, “despair-hopeful”, “unpleasant-pleasant”. For the Arousal scale: “calm-excited”, “unaroused-aroused”, “dull-jittery”, “relaxed-stimulated”, “sleepy-wide awake”, “sluggish- frenzied”. Each pair of words was translated into corresponding Japanese word pairs to insure consistency for this experiment, with the translation based on a previous study by Ren (2018) [22].

Railway users’ perception of the surrounding environment was measured by the Semantic Differential (SD) method, which is generally applied in sociology and psychology experiments. The SD method allows participants to select their answer from adjective pairs with polarized meanings.

Twenty-five adjective pairs used for the SD method were selected by reviewing published research utilizing odor related SD method questionnaires and related adjectives [23-24].

Many of the adjective pairs were extracted from a study conducted in 1998, in which flowers (rose and fragrance on human beings) impact were analyzed by means of brain waves and the Semantic Differential (SD) method. The result of this experiment revealed that the presence of fragrance affects human being’s physiological aspect, and the presence of rose generated a higher score in factor analysis, suggesting that the flowers’ odor affects psychological response [23]. Therefore, we used the adjectives in this research which suggest change according to the presence of fragrance/odor, to apply to our experiment’s questionnaire content.

Research conducted in 2002 provides a short list of sense-descriptive adjectives for outlining olfactory properties of fragrances by means of factor analysis. The extent to which emotional reactions to fragrances have an effect on evaluating the fragrances with these adjectives was also investigated [24]. The resulting twenty-five adjective pairs are categorized in three groups: evaluation, potency, activity.

Typically PAD model and SD methods utilize numbered scales of five or seven for questionnaire responses. For the purposes of our train experiment, the time between answering questionnaires twice was only about 10 minutes, with emotional change difficult to measure. In case respondents might also remember their previous answers,

a Visual Analogue Scale (VAS) was applied for our questionnaire survey instead of a numbered scale. VAS are measures of subjective or behavioral experience (e.g., pain, physical exercise) and are typically presented as a 10cm line with descriptive anchor statements at each end, such as “no pain” to “extreme pain”. Questionnaire respondents place a vertical line through the point on the scale that best fits their experience at that moment. In previous odor related research, Visual Analogue scale reveals its advantage in measuring the level of recollection and pleasantness of odor [25]. For our experiment the VAS response line is from 0 to 100 measured in millimeters (it should be noted that there is no research to support that the Visual Analogue Scale is any more accurate when measured in centimeters than it is in millimeters, or that this would impact interpretation of the results) [26].

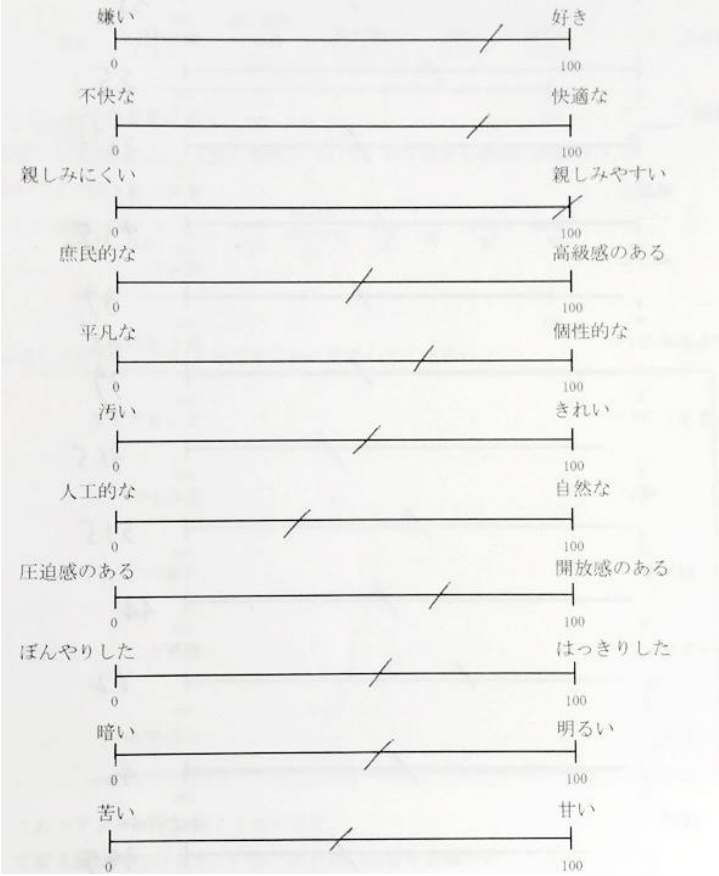

Figure 4. Example questionnaire responses using the VAS scale

The cognition level and pleasantness level are measured according to a scale applied in Osaka University research [27].

3.2. Odor stimuli used in this experiment

The odor stimuli in this experiment are lavender and lemon essential oils, manufactured by “Tree of Life”, which are also used in other odor related experiments.

Lavender is used as a sleep aid, with one study conducted by Hardy et al (1995) suggesting that the ambient odor of lavender can significantly enhance the amount of time asleep after withdrawal of medication for insomnia [28]. The healing effect of a lavender field located in a city park has also been verified according to a physiological test (blood pressure, pulse, and saliva amylase density) and psychological index (SD method) [29]. Lemon is a high arousal odor that has been used in experiments as a stimulus and has also been used for this purpose in research relating to environmental scent [12].

In our experiment, lemon and lavender are used as contrasting odors to investigate their high and low arousal influence on participants' emotional/pleasure responses. Lis-Balchin and Hart (2002) mention that, unlike the sedative properties of lavender, lemon oil has been described as activating, immune-modulatory, and mood enhancing [30]. Self-reported, unobtrusive mood measurements have provided strong evidence that lemon essential oil improves positive mood more significantly than water and lavender, regardless of expectations or prior experience of aromatherapy [31].

4. The Experiment

4.1. Isumi Railway Company

Following initial discussions, we have been able to work with the Isumi Railway Company in Chiba prefecture to conduct our experiment. This is a local Japanese ‘third quarter’ railway. Currently, not so many people are using Isumi Railway with the main users being local residents, high school students and tourists. The covid-19 pandemic has had a particularly negative impact on passenger numbers as might be expected. To attract more passengers, the Isumi Railway company is organizing different events, i.e. to celebrate local festivals and by providing special meals for group reservations.

4.2. Preparation of the preliminary test

Figure 5. The train carriage used for the preliminary test

One preliminary test was conducted a month before the main test in order to determine the proper intensity of odors to be applied in the main test and to confirm the content of the survey questionnaire. As there is no previous study that provides an indication for how to temporarily install odor equipment in a train carriage setting for the purposes of this type of experiment, we also wanted to test this. The preliminary experiment was conducted in the same train carriage as the main test, except the train was stationary at the station and not moving as with a normal train. The engine was kept on to mimic the conditions of the main test situation as far as was possible, allowing participants in this preliminary experiment to feel the fluctuations in the carriage produced by the train engine.

4.3. Results of the preliminary test

The preliminary test was conducted on the 2nd November, 2020. The questionnaire content and the odor intensity of the lavender and lemon odors were checked in this preliminary test, with 5 participants answering the same questionnaire survey 3 times in total.

Figure 6. Interior of the train carriage (right) showing location of fans (left) for the preliminary test

The information in Table 1 shows the results of the preliminary experiment which was conducted in 3 consecutive parts, with participants asked to complete a questionnaire for each part. For the first part of the experiment no odor was used, for the second lavender essential oil at 25% dilution strength, and for the third part lemon essential oil at 50%. From the responses received it was apparent that an odor intensity of 25% dilution was insufficient for everyone to detect the odor easily, so we increased the lemon essential oil odor intensity to 50% in the third test, with a corresponding increase in the lavender odor intensity to confirm participants detection and reaction to this relative to the 25% dilution.

	1st	2nd	3rd	Confirmation of fragrance concentration
Fragrance	none	lavender	lemon	lavender
Concentration	none	25%	50%	50%
Comment from participants	Odor of the train carriage	Quite light	Appropriate	No uncomfortable feelings

Table 1. Information derived from questionnaire results for the preliminary train carriage odor test

The odor intensity that participants felt is shown in figure 7. Except for the first test (the ambient smell of the train carriage itself), the intensity of the lavender and lemon odors is set at a level that is just barely detectable.

Regarding the pleasantness scores shown in Figure 8, the 3 tests all show that the odor is responded to by the participants as being at a “quite pleasant” level, meeting with our anticipation. Though the difference between lavender and lemon odors is notable, this may be due to the limited number of participants in the preliminary experiment.

It is also interesting to note a gender difference in response to the ambient train carriage smell, with female participants noting this more than the their male counterparts, causing a greater impact in their responses to the no odor, first part of the test. This may explain the reason for the odor intensity of the first test being recorded as much higher and in the “easily detectable” range in Figure 7.

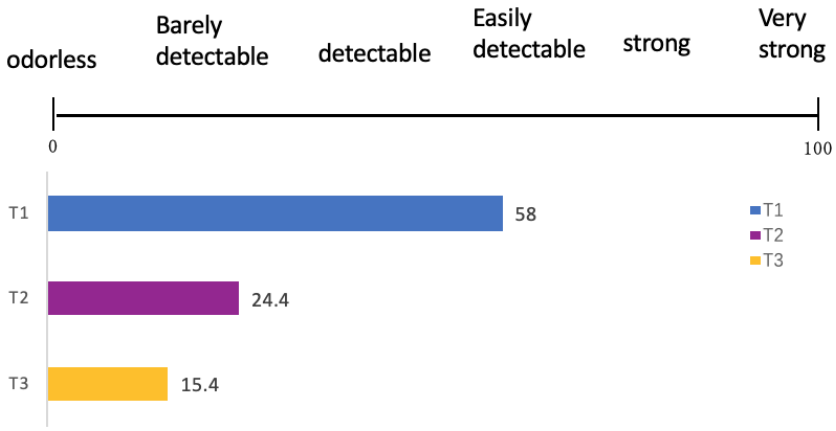

Figure 7. Result of odor intensity

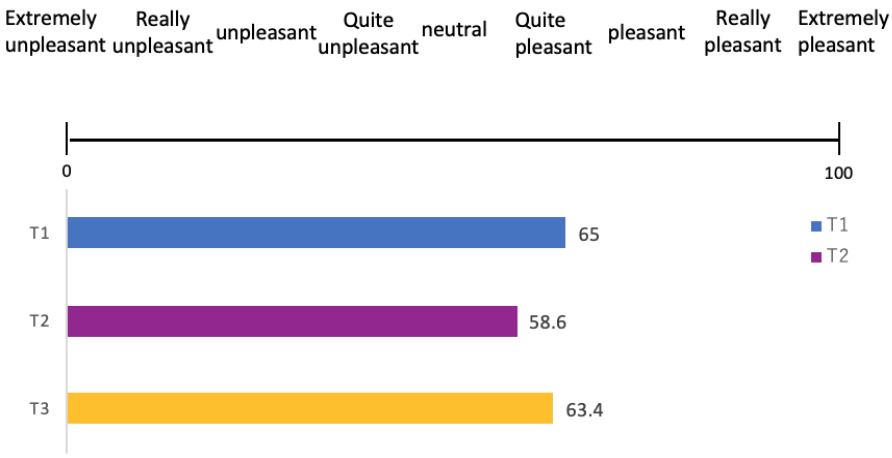

Figure 8. Results of the preliminary test participants responses to odors pleasantness

Another result of this preliminary test was that participants feedback suggested alternative wording would be necessary for some of the response options, which were subsequently revised for the main test questionnaire.

For the preliminary test one diffuser and two circulators were used to disperse odors evenly and rapidly into the train carriage. These were positioned centrally in the train passageway (see Figure 6 (left)). However, for the main test where we would need to disperse the odor during the journey in a more discrete way, we realized that it would not be appropriate for the equipment to be displayed so obviously. Another problem we found during the preliminary test is that using only one diffuser required it be placed centrally in the train carriage, or the odor would not diffuse as evenly as required. In addition, we conducted the preliminary test on a stationary train, but for the main test there would be greater exchange of air from the circulatory system in the train ceiling and drafts through windows and doors, allowing for faster air circulation overall when the train is moving. Consequently, we improved the setting of the experiment by including an additional diffuser, with all of the equipment installed more discretely under the seats for the main test in the moving train carriage.

4.4. Preparation for the Main test

For the main test, we used the improved questionnaire and the experiment settings described, with the fans and odor diffusers in Figure 9 located at the front and rear end of the train carriage and kept running for the duration of the experiment. As it was also necessary that participants would not be forewarned about the particular odors they

would be experiencing during the experiment, it was decided that should some express curiosity about the presence of the fans, the explanation to be given would be that they were there to increase the air circulation within the train carriage.

Figure 9. Main test train carriage setting showing more discrete location of odor diffuser and fan

4.5. Main test participants

The Main test was conducted on 2nd of December, 2020. 23 undergraduate and graduate participants (Male: 14, Female: 9), average age 24.4 years (SD=2.6), were recruited from the Tokyo Institute of Technology. None of participants had difficulty with their sense of smell or any medical conditions or allergies. The study was approved by the Ethical Committee of Tokyo Institute of Technology (2020208). After receiving an introduction to the experiment, participants signed the consent form in compliance with the University guidelines governing Human Subjects Research Ethics Review.

The experiment was conducted in a reserved train carriage, so only the participants and those overseeing the tests were present. In transit the doors of the train did not open during the process, to maintain odor intensity.

Figure 10 is a photograph taken during one part of the experiment. Participants were seated separately in compliance with Japanese government guidelines for travel on public transport during the Covid-19 pandemic. This was to address “the Three Cs”: “Crowded places”, “Close-contact settings” and “Confined and enclosed spaces”. The participants were also asked to avoid speaking during the experiment, and wore face masks except during the short duration of the experiment.

Figure 10. View of the participants in the train carriage during the Main test.

4.6. The Main test procedure

Figure 11. Map of the Isumi Railway in Chiba, Japan

For the experiment the 23 participants were divided into two groups: Group Lavender and Group Lemon. Each group followed the time schedule shown in Table 2, with Group Lavender embarking the train at Otaki station. After 10 minutes to adapt to the surrounding environment they were asked to complete the questionnaire for the first time. Following this the odor diffuser was switched on dispersing the lavender odor to the train carriage.

Again, the participants had about 10 minutes to sense the environment before answering the questionnaires a second time. Group Lemon started from Ohara station with the time schedule shown in Table 2, the procedure followed being the same as Group Lavender but dispersing the Lemon odor.

Otaki station	Group lavender →				Ohara station
	11:25 Start	11:30~11:40 Questionnaire	11:40 Disperse Odor 1	11:50~12:00 Questionnaire	12:00 Arrive
	13:00 Arrive	12:50~13:00 questionnaire	12:40 Disperse Odor 2	12:30~12:40 Questionnaire	12:23 Start
	← Group lemon				

Table 2. Main experiment schedule

5. Results and Discussion

5.1. Odor using habits

The first part of the questionnaire enquires about participants' odor using habits, so this can be analyzed in relation to the answers given to other sections of the questionnaire. Participants were asked about what habitual use they might make of three kinds of products: perfume, fragrance / aroma diffuser, and fabric softener with fragrance. These products typically incorporate a pleasant odor as an important element of their function and are intended to enhance user value. Although odor preference differs from one person to another, a habit of using these products can influence participants' perception of olfaction in their daily lives, hence the need to ask these questions at the outset.

The results shown in Figure 12 indicate that the participants of this experiment do not use perfume much, with more than half of the male participants not using it at all.

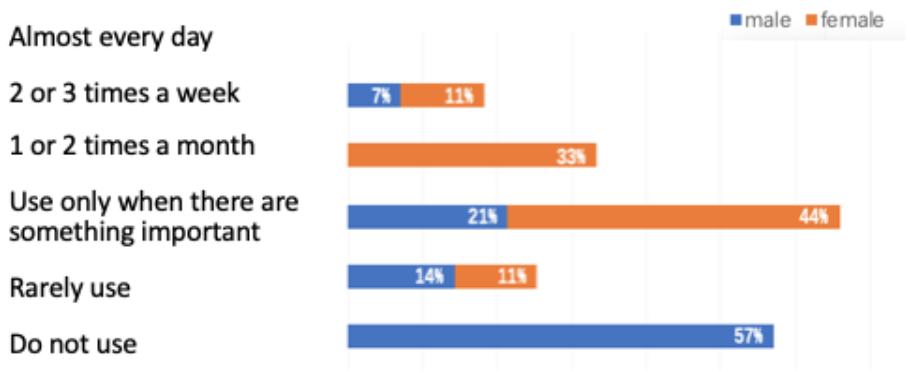

Figure 12. Main experiment participants perfume using habits

The participants' habit of using fragrance or aroma diffusers is shown in Figure 13, indicating that 36% of the male and 66% female have a habit of using these products, a significant increase in percentage compared with using perfume.

As fragrance and aroma diffusers typically release less intense, pleasant scents within a limited space there may be an incentive for people to include these odors in their daily lives, with the emphasis being on a controlled dispersal of odor.

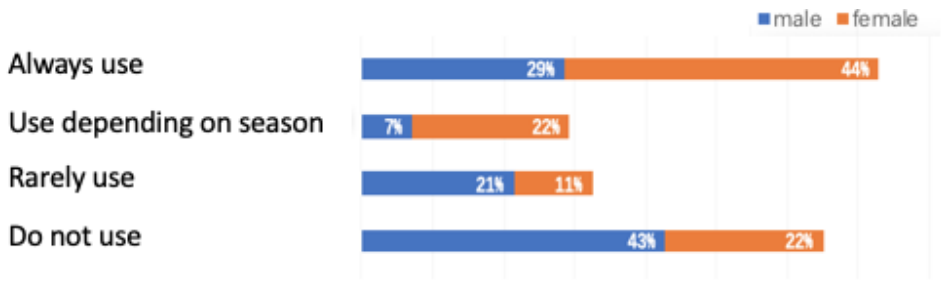

Figure 13. Main experiment participants use of fragrance or aroma diffusers

We also asked about participants' habit of using fabric softener, which is more generally used in daily life. The results in Figure 14 show that women's habit of using fabric softener is greater than male participants, with the considerable difference of 78% to 7%. From this result, we can infer that female participants are more likely to buy odor related cleaning products for clothes, with the lighter the odor the using percentage rising accordingly.

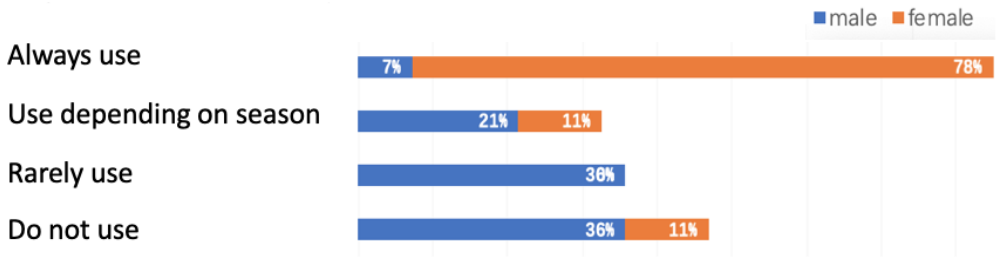

Figure 14. Main experiment participants habit of using fragranced fabric softener

From this, we can draw the conclusion that female participants' habit of using odor in daily life is greater than for the male participants, which verifies previous studies [28], with use frequency also affected by odor concentration.

5.2. Russell's Circumplex Model results

After analyzing the results of the first part of the questionnaire, measuring the degree to which an odor induces emotional change in a participating passenger, we arrived at the results in Table 3.

During the analysis, one participant's data was excluded because of their significant difference in arousal level (a change of more than 50 points). This may be the result of

this participant becoming very sleepy during the experiment and not because of the odor stimulus. Therefore, we excluded this individual's data and then conducted the t test analysis for Group Lavender and Group Lemon.

				A					B				
				Mean		SD		t test	Mean		SD		t test
				No odor	Lavender	No odor	Lavender		No odor	Lemon	No odor	Lemon	
Pleasure	1	Unhappy	Happy	69.2	71.5	15.2	13.4		71.8	75.3	12.8	12.5	
	2	**Annoyed**	**Pleased**	67.3	72.7	12.7	14.5	*(+)	63.0	75.25	13.9	13.2	**(+)
	3	**Unsatisfied**	**Satisfied**	69.6	75.3	17.5	16.9		64.4	76.7	15.8	12.3	*(+)
	4	**Melancholic**	**Contented**	58.9	69.3	17.6	15.5	*(+)	61.9	75	13.3	12.4	**(+)
	5	Despairing	Hopeful	65.4	65.4	16.0	13.4		66.9	70.05	14.6	12.2	
	6	**Bored**	**Relaxed**	70.6	76.1	16.1	14.9		74.4	81.35	13.8	9.2	
Arousal	7	**Calm**	**Excited**	48.0	36.3	19.0	15.1	*(-)	44.9	35.3	26.8	23.1	
	8	**Sleepy**	**Wide awake**	60.0	42.5	26.7	27.9	*(-)	58.9	35.1	20.8	26.8	**(-)
	9	**Dull**	**Jittery**	56.5	43.6	15.2	18.0	*(-)	53.5	38.05	15.2	21.7	*(-)
	10	**Sluggish**	**Frenzied**	54.5	42.5	18.6	16.8	*(-)	51.9	36.3	19.2	21.8	**(-)
	11	Unroused	Aroused	59.0	51.6	18.4	15.6		59.5	55.9	16.3	18.5	
	12	Relaxed	Stimulated	38.1	33.9	17.8	18.2		38.7	29.7	13.5	18.5	

(significance codes *$* p < 0.05, ** p < 0.01$*)

Table 3. Main test results of the Russell's Circumplex Model

This table shows the results of both Group Lavender and Group Lemon, including every word pair of the pleasure arousal scales. The data includes the mean value, standard deviation, and results of the t-test.

Two word pairs of the pleasure scales in Group Lavender and three in Group Lemon show significant difference, compared with the no odor results. This means that for these the participants are feeling more "pleased" and "contented", while Group Lemon also feel more "satisfied".

In the arousal scales four word pairs in group Lavender and three in Group Lemon show significant difference, indicating that the participants felt more "sleepy", "dull" and "sluggish" in both groups, and also more "calm" in Group Lavender as well. Before the experiment we had anticipated that the Lemon odor would arouse participants' attention leading to a higher arousal level. However, this data reveals a different story, that in the context of the train journey it actually makes the participating passengers less aroused.

One possible explanation for this result is that the fluctuating movements of the train indices drowsiness. In a study conducted in 2008, researchers investigated the

relationship between sleepiness and vibrations on several trains, with the potential to induce drowsiness in each of the trains surveyed defined by the ratio of sleeping passengers. According to the vibration analyses, the results suggest that vibrations with a frequency of 1 to 2 Hz could more readily induce passengers' sleeping behavior [32]. Another reason for the lower arousal level may be that the participants tended to relax more when they sensed the odor, as they were told that there will be an odor test.

We calculated the pleasure and arousal scores for Groups Lavender and Lemon, shown in Figures 15 and 16 respectively, indicating emotional change according to the Russell's Circumplex Model. In this way we could compare the difference between Group Lavender and Group Lemon's data in four areas: stressful, exciting, boring, relaxing. This shows that for Group Lavender, when the lavender odor is detected, the clusters of dots representing users responses shift from the upper left to a more lower right position, which is from the more stressful and boring to the more excited and relaxing areas.

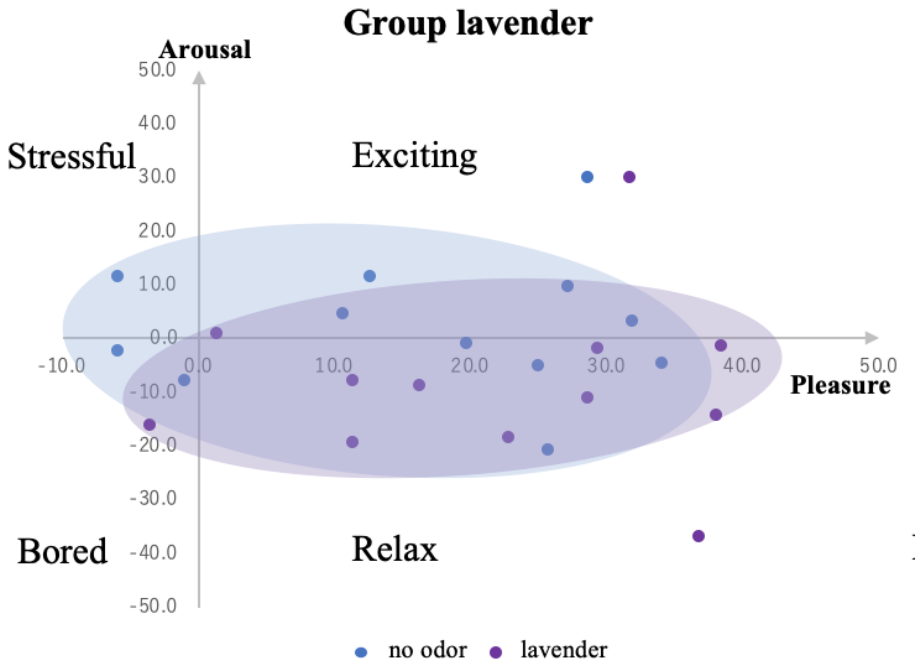

Figure 15. Group Lavender's result

For Group Lemon, when the odor was detected the dots shift from left to right, indicating greater change in the pleasure axis.

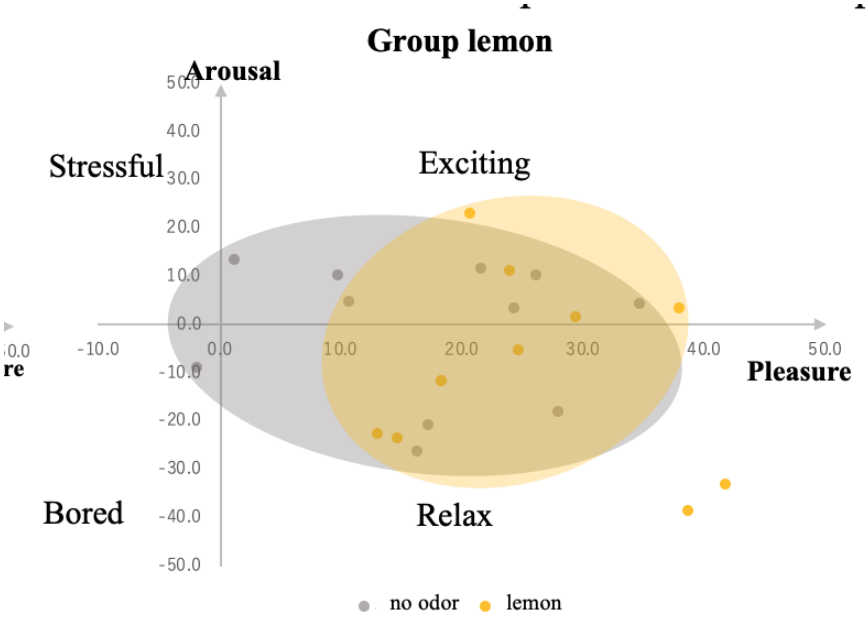

Figure 16. Group Lemon's result

Where dots sit outside the accumulations this may be the result of a contrast between some participants perceptions compared with the larger group as a whole.

We also examined the change of pleasure and arousal scores by conducting a t-test between each group. Table 4 shows the data and result of the t-test, with the pleasure scores of Groups Lavender and Lemon revealing significant difference. While the arousal score of Group Lavender indicates variation, that of Group Lemon's arousal score reveals no significant difference.

	A no odor	A Lavender	p value	B no odor	B lemon	p value
Mean of Pleasure	66.8	71.7	0.035	66.9	75.4	0.013
Mean of Arousal	52.7	41.7	0.001	48.7	40.5	0.086

Table 4. Result of pleasure score and arousal score

5.3. SD method results

Figure 17 shows the result of the SD method, indicating the degree to which passengers' perceptions of the train carriage changed because of the odor stimuli. This figure shows both the SD profile and the result of the t-test.

From these results, we can detect that several of the 25 adjective pairs showed significant difference, indicating that perception of the train carriage environment is affected by odor stimuli.

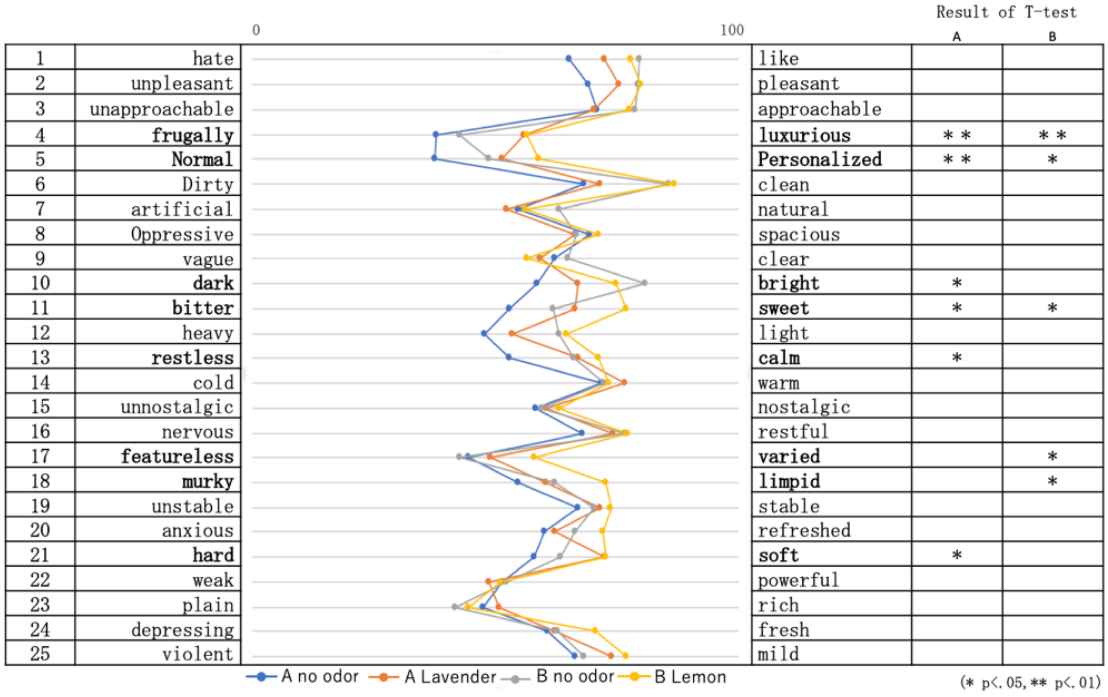

Figure 17. Combined results of the SD profile and t-test

Table 5 includes the adjective pairs showing the most significant variance. Among these, both lavender and lemon odors have an increased influence indicated by the responses given to the pairs: "Frugally-Luxurious", "Normal-Personalized", "Dark-Bright", and "Bitter-Sweet". We can also infer that, according to each odor's characteristics, passengers' perceptions of the train carriage atmosphere also changed; "restless-calm" and "hard-soft" is possibly influenced by lavender odor's sedative characteristic, while responses to "featureless-varied" and "murky-limpid" are effected more by the lemon odor.

			Group lavender	Group lemon	Possible explanation
1	frugally	luxurious	↑	↑	
2	normal	personalized	↑	↑	
3	dark	bright	↑	↑	
4	bitter	sweet	↑	↑	
5	restless	calm	↑		Lavender's influence
6	featureless	varied		↑	Lemon is more recognizable
7	murky	limpid		↑	Lemon's influence
8	hard	soft	↑		Lavender's influence

Table 5. Result of SD method

5.4. Odor cognition in the Main test

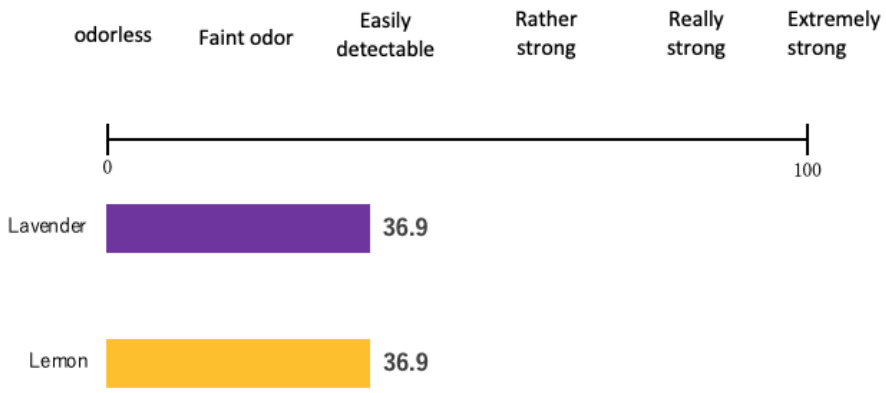

Figure 18. Result of odor intensity

The odor intensity that participants felt is shown in Figure 18, indicating this to be at a level that was 'easily detectable'. (Only 1 of the 23 participants could not detect the odor.)

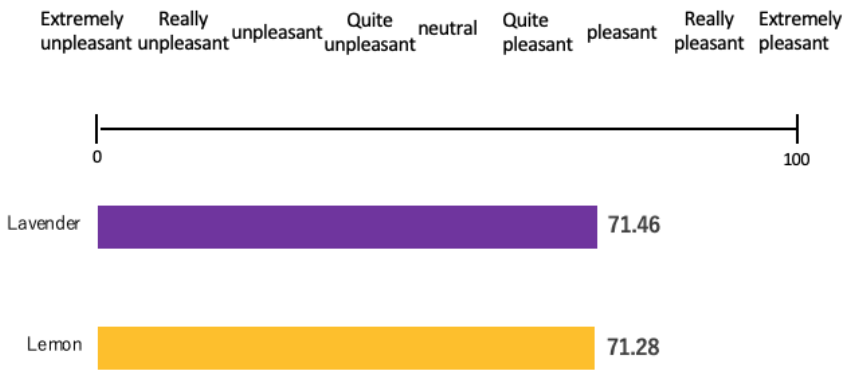

Figure 19. Result of participants' perceptions of odor pleasantness

Figure 19 reveals the participants' 'pleasantness' perceptions of the odors indicating both lavender and lemon to be between "quite pleasant" and "pleasant" with little difference between the two.

5.5. Participants comments

Table 6 charts some keywords from participants' comments during the 'No odor', 'Lavender' and 'Lemon' odor tests. For 'no odor', individual differences are evident, with one respondent noting the smell of other people, two others (from Group Lemon) mentioned a faint natural smell (possibly faint traces of the lavender odor from the earlier test), and another participant (from Group Lavender) saying they could not detect any odor at all. Given that all participants were informed that the test included an experiment about odor this may have made them more attuned to their perception of the odor within the train carriage prior to completing the questionnaires.

No odor		Lavender	Lemon
A little unpleasant because of smell of people	Feeling of participants	Relax, pleasant, feeling good, refresh, do not feel uncomfortable	Relax, calm, stimulate nose, better feeling, comfortable, sleepy
Two mentioned a faint natural smell	Kinds of odor	Grapefruit, fruit, adhesive, orange, grass smell, lavender (two)	Cookie, citrus(three), orange, lemon (one)
One didn't feel any odor during the whole experiment	Description of odor	Sweet, soft, warm	Sweet, warm(two), fresh, light
	Other	Easily to feel Car sick	Good odor but do not match with scenery outside Remind of the **vegetable flowers** of Isumi railway

Table 6. Example of participants comments

For Lavender and Lemon the comments are categorized by the participants' feelings, the kinds of odor they sensed, their description of it, and other thoughts. Commenting on the lavender odor participants noted that they felt relaxed, pleasant, feeling good, refreshed, and did not feel uncomfortable.

The lemon odor was responded to as causing feelings of inducing a 'better feeling', being relaxed, sleepy, calm, comfortable and nose stimulating. In this 'feeling' section most comments in both groups were quite similar in sentiment despite the different odor stimuli, although Group Lemon did include the comment about the odor inducing a 'sleepy' feeling. (There is a possibility that as this was a test held later in the day this may have contributed to this particular response.)

In relation to the 'kinds of odor', in Group Lavender only two participants correctly identified the odor used for the test, with others in the group offering several alternative suggestions. By contrast, in Group Lemon five participants recognized it as citrus, orange or lemon odor. This result suggests that lemon or citrus odor is easier for the participants to correctly identify. Citrus odors appear frequently in our daily lives (both as natural and synthetic smells) so it is possible that the participants are more familiar with it than the lavender odor. However, lavender is quite commonly applied in air fresheners and cosmetic products, the latter being used more often by women. For this experiment there was a lower ratio of women participants which may also explain why the level of recognition for the lavender odor was not higher.

The descriptions of the odors, both for lavender and lemon, include "warm" and "sweet". It is possible that, given the temperature difference of the train carriage interior compared with the temperature outside, this may have influenced this choice of description, although it is also possible that this term may be associated with feelings of well-being induced by odors that are generally perceive to be pleasant within an environmental context. In the case of lavender, the word "soft" is also used, while for lemon the terms "fresh" and "light" are chosen to describe the odor.

Another comment by one participant mentions 'motion sickness' and another notes that the odor inside the rain carriage does not the scenery visible through the windows. For motion sickness, there is a study that explores this in the context of odor. This found that there is currently a lack of evidence to demonstrate a causal link, although there was an impact on olfactory perception noted through a nauseogenic test, which showed that

odor pleasantness changed [33]. Visually induced motion sickness, however, was found to be potentially reduced by pleasant odor [34]. The relationship between olfactory perception, olfactory sensibility, and motion sickness is still waiting to be clarified.

The comment noting a disconnect between the odor and the scenery along the Isumi railway, might suggest connections between color/visual stimuli and odor (and thus in commercial contexts, associations with brand imagery), but this is also speculative and requires further investigation.

6. Conclusions

6.1. Conclusions

From the evidence above it is possible to draw the conclusion that pleasant odors inside train carriage could affect railway users' emotions. Both lavender and lemon ambient odors increased railway users' pleasure levels. Interestingly arousal levels are reduced despite thus use of one high arousal odor (lemon) and one low arousal odor (lavender) for the train carriage tests. Participants sense of the atmosphere within the train carriage was affected by odor stimuli in relation to aspects of their psychological responses, feelings and perception of the odor properties.

6.2. Considerations

The results of this experiment must be read in relation to the limitations that prevailed at the time of the tests, such as temperature difference, adaptation effects, and the limited sample number. During this study, experimentation with fewer participants was required due to the Covid-19 pandemic situation. All participants traveled by bus to the railway station, and as they were inside the same train carriage for the tests, had to maintain social distancing, thereby limiting the numbers who could participate. Since both groups of participants experienced the process from no odor to with odor an adaptation effect should also be taken into account, and considered when designing future related experiments.

REFERENCES

[1] Public Opinion Poll. 2016. Public Opinion Poll on Public Transportation. Cabinet Office, Government of Japan. https://survey.gov-online.go.jp/h28/h28-kotsu/2-1.html

[2] Seligman, M. (2011). Flourish: A visionary new understanding of happiness and well-being. NY: Free Press.

[3] Cohn, M., & Fredrickson, B. (2009). Positive emotions. In S. J. Lopez & C. R. Snyder (Eds.), Oxford handbook of positive psychology (2nd ed., pp. 13–24). NY: Oxford University Press.

[4] Diener, E. (2000). Subjective well-being: The science of happiness and a proposal for a national index. American Psychologist, 55(1), 34–43. doi:10.1037/0003-066X.55.1.34.

[5] Warm, J.S., W.N. Dember, and R. Parasuraman. (1990) Effects of olfactory stimulation on performance and stress in a visual sustained attention task. Journal of the Society of Cosmetic Chemists, 42: p. 199-210.

[6] Chebat, J.-C. and R. Michon. (2003) Impact of ambient odors on mall shoppers' emotions, cognition and spending--A test of competitive causal theories. Journal of Business Research, 56: p. 529-539.

[7] Dina Marie V. Zemke, Stowe Shoemaker, Scent across a crowded room: Exploring the effect of ambient scent on social interactions, International Journal of Hospitality Management, Volume 26, Issue 4, 2007, Pages 927-940, ISSN 0278-4319, https://doi.org/10.1016/j.ijhm.2006.10.009.

[8] Holland, Rob W., et al. “Smells like Clean Spirit: Nonconscious Effects of Scent on Cognition and Behavior.” Psychological Science, vol. 16, no. 9, 2005, pp. 689–693. JSTOR, www.jstor.org/stable/40064295. Accessed 9 Jan. 2021.

[9] Herz, R.S. (1998) Are odors the best cues to memory? A cross-modal comparison of associative memory stimuli., in Olfaction and taste XII: An international symposium (Annals of the New York Academy of Sciences) New York Academy of Sciences.: New York. p. 670-674. [10] Herz, R.S. and G.C. Cupchik. (1995) The emotional distinctiveness of odor-evoked memories. Chemical Senses, 20: p. 517-528.

[11] Herz, R.S., et al. (2003) Neuroimaging evidence for the emotional potency of odor-evoked memory Neuropsychologia, 42: p. 371-378.

[12] Spangenberg, E., Crowley, A., & Henderson, P. (1996). Improving the store environment: Do olfactory cues affect evaluations and behaviors? Journal of Marketing, 60(2), 67-80.

[13] Masanori Nagai, Maki Wada, Akiko Tanaka, Akiko Yoshizaki, Yae Hasebe, 13 Comfortable scent and its physiological effects, JAPANESE JOURNAL OF BIOMETEOROLOGY, 1998, Volume 35, Issue 3, Pages S49, Released October 13, 2010, Online ISSN 1347-7617, Print ISSN 0389-1313, https://doi.org/10.11227/seikisho1966.35.3_S49.

[14] Kadohisa Mikiko. (2013) Effects of odor on emotion, with implications. Frontiers in Systems Neuroscience. 7: p.66. https://www.frontiersin.org/article/10.3389/fnsys.2013.00066. ISSN=1662-5137, DOI=10.3389/fnsys.2013.00066.

[15] Eriko Kawamoto, Ayumi Anan, Satoko Cho, Investigation on the Effects of Smell on Daily Life. Japanese journal of applied psychology. 0387-4605. 2013-07 39.1.25-32. https://ci.nii.ac.jp/naid/40019785142/en/

[16] Chatterjee, Shuvam. (2015). Olfactory branding: A new trend for defining brands through smell -a case of ITC Sonar Hotel in Kolkata, India. International Journal of Trade and Global Markets. 8. 196. 10.1504/IJTGM.2015.071603.

[17] Metro combatting smelly train cars with new deodorizers. Apr 26, 2017.https://la.curbed.com/2017/4/26/15441580/metro-train-car-smell-subway-red-purple-line.

[18] Passengers incensed: Vienna adds perfumed trains to €1 a day travel。 Fri 19 Jul 2019 12.35 BSTLast modified on Mon 22 Jul 2019.https://www.theguardian.com/world/2019/jul/19/vienna-trials-perfumed-subway-trains-passengers-incensed-austria-u-bahn.

[19] Exterion Media UK launched new scented posters on London Underground…that smell like strawberries!.https://www.exterionmedia.com/group/news/exterion-media-uk-launched-new-scented-posters-on-london-underground-that-smell-like-strawberries

[20] A. Mehrabian, and J.A. Russell; An approach to environmental psychology, Journal of Marketing, 46(2), pp.86-91, 1974.

[21] Russell, J. A. (1980). A circumplex model of affect. Journal of Personality and Social Psychology, 39(6), 1161–1178.

[22]任 曼菲，井上　哲浩 (2018) 製品動画とオンラインにおける衝動購買の関係について

[23] 浅海 英記, 仁科 弘重, 難波 亮子, 増井 典良, 橋本 康, 観葉植物の印象の評価, および, 観葉植物を配置した室内の居住者心理の SD 法による評定, 植物工場学会誌, 1995, 7 巻, 1 号, p. 34-45.

[24] 樋口 貴広, 庄司 健, 畑山 俊輝, 香りを記述する感覚形容語の心理学的検討, 感情心理学研究, 2001-2002, 8 巻, 2 号, p. 45-59.

[25]*Kohsuke Yamamoto, Takefumi Kobayashi, Tatsu Kobayakawa, Odor identification ability, odor imagery ability, subjective well-being, and autobiographical memory in elderly people, The Proceedings of the Annual Convention of the Japanese Psychological Association, 2019, Volume 83, The 83rd Annual Convention of the Japanese Psychological Association, Session ID 1A-054, Pages 1A-054, Released September 26, 2020, Online ISSN 2433-7609, https://doi.org/10.4992/pacjpa.83.0_1A-054

[26] Dale A. Halfaker, Steven T. Akeson, Danielle R. Hathcock, Curtis Mattson, Ted L. Wunderlich, 3 - Psychological Aspects of Pain, Editor(s): Ted A. Lennard, Stevan Walkowski, Aneesh K. Singla, David G. Vivian,Pain Procedures in Clinical Practice (Third Edition),Hanley & Belfus,2011,Pages 13-22,ISBN 9781416037798, https://doi.org/10.1016/B978-1-4160-3779-8.10003-X.

[27]松尾 真臣, 山中 俊夫, 甲谷 寿史, 冨田 武志 (2001): 建築材料から発生するにおいの主観評価 : (その 3)臭気濃度とにおいの強さ、快適性、嗜好性、容認

性に与える影響，日本建築学会大会学術講演梗概集, D-2, pp 957-958.

[28] Hardy M, Kirk-Smith MD, Stretch DD. Replacement of drug treatment for insomnia by ambient odor. Lancet. 1995; 346:701.

[29] Yutaka IWASAKI, Satoshi YAMAMOTO, Mayuko ISHI, Mikio WATANABE, Study on physiology and psychological effect of lawn ground and lavender field in city park, Journal of the Japanese Society of Revegetation Technology, 2007, Volume 33, Issue 1, Pages 116-121, Released February 12, 2008, Online ISSN 1884-3670, Print ISSN 0916-7439, https://doi.org/10.7211/jjsrt.33.116.

[30] Lis-Balchin M, Hart S. Chemical profiles of lavender oils and pharmacology. In: Lis-Balchin M, editor. Lavender: The Genus Lavandula. Taylor and Francis; New York: 2002. pp. 243–250.

[31] Kiecolt-Glaser JK, Graham JE, Malarkey WB, Porter K, Lemeshow S, Glaser R. Olfactory influences on mood and autonomic, endocrine, and immune function. Psychoneuroendocrinology. 2008;33(3):328-339. doi: 10.1016/j.psyneuen.2007.11.015

[32] 木村 仁, 遠藤 真美, 小関 道彦, 伊能 教夫, 誘眠効果をもたらす機械的環境の研究，日本機械学会論文集 C 編, 2008, 74 巻, 740 号, p. 806-813.

[33] A.C. Paillard, M. Lamôré, O. Etard, J.-L. Millot, L. Jacquot, P. Denise, G. Quarck, Is there a relationship between odors and motion sickness?, Neuroscience Letters, Volume 566, 2014, Pages 326-330, ISSN 0304-3940, https://doi.org/10.1016/j.neulet.2014.02.049.

[34]Keshavarz B, Stelzmann D, Paillard A, Hecht H. Visually induced motion sickness can be alleviated by pleasant odors. Exp Brain Res. 2015 May;233(5):1353-64. doi: 10.1007/s00221-015-4209-9. Epub 2015 Jan 30. PMID: 25633319.

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