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Orange-Sweet Aroma Reduces Stress During Numerical Tasks: A Physiological and Psychological Evaluation of Olfactory Cognition

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ABSTRACT

This study examines the stress-reducing effects of the aroma of Orange-Sweet essential oil (product name) from the perspective of olfactory cognition. The research is motivated by a significant social issue: stress can hinder individuals from working and disrupt their daily lives. This research aims to clarify, using aroma, whether aroma can reduce stress within this context. The experiment was conducted in two conditions: one with Orange-Sweet aroma at the perceptual threshold, and the other above the threshold. To evaluate the stress-reducing effects of the aroma in terms of olfactory cognition, we employed multiple physiological and psychological measures during stress induced by numerical tasks. Previous studies have failed to detect clear physiological changes associated with aroma factors. Therefore, we sought to explore the underlying mechanisms of aroma-induced stress reduction by introducing different physiological measures. The physiological measures included facial thermography and electroencephalography (EEG). The psychological measures included the short version of the Profile of Mood States 2 (POMS2), "*Jikakusho Shirabe*," and a Likert-scale survey assessing scent preference and intensity. From the EEG data, it was found that the Orange-Sweet aroma, at a concentration above the perceptual threshold, increased brain activity during a numerical task, leading to a state of concentration. From the psychological measures, we found that a weak aroma atthe perceptual threshold level inhibited the decline in "Vigor-Activity" on the POMS 2 and reduced "discomfort" in the "*Jikakusho Shirabe*". These findings suggest that even a weak aroma at the perceptual threshold may exert positive psychological effects, while a stronger aroma above the perceptual threshold may increase brain activity indicating a state of concentration. We plan to further examine the relationship between olfactory cognition and stress reduction effects using everyday relaxing aromas such as coffee and *igusa* (soft rush), within the same evaluation framework.

Keywords: Aroma, Olfactory cognition, Subjective rating, *Jikakusho Shirabe*, EEG, Facial thermography, POMS2

INTRODUCTION

The purpose of this study is to identify ways to reduce stress from the perspective of olfactory cognition. The number of patients with stress-related disorders is increasing (Ministry of Health, 2020), and it is inevitable that individuals and members of organizations face a variety of stresses. Various efforts and measures to avoid and reduce stress are necessary for people's well-being in daily social settings. Aromas are often used as an effective tool in psychotherapy and stress management, and making use of aromas in public and work environments is considered suitable for these environments as it typically does not interfere with the performance of duties. In practice, aromas below the perceptual threshold are sometimes diffused in commercial facilities.

However, the differences in effects between aromas presented at varying levels of olfactory cognition are not well understood. This study aims to examine these differences, specifically evaluating the stress reduction effects of Orange-sweet aroma. The experiment compares two conditions: an experimental condition (aroma above the perceptual threshold) and a control condition (aroma at the perceptual threshold).

The stress reduction effects are examined based on changes in physiological and psychological measures when a numerical computation is imposed as a stress task. Many previous studies have struggled to apply a consistent stress load across individuals due to differences in calculation ability. Therefore, this study will apply a unique stress task in which the numerical load is increased or decreased according to the individual's ability, ensuring that a consistent load is applied regardless of numerical speed. The results of this study will provide new insights into how differences in the olfactory cognition of Orange-sweet aroma contribute to stress reduction.

RELATED STUDIES

In our previous study on the relaxation effects of Orange-sweet aroma (Yamada, 2024), we compared stress measurements with and without the scent present at the perception threshold. Physiological measures (EDA, salivary amylase) and psychological measures (POMS2, *Jikakusho Shirabe*) were used. Orange-sweet aroma at the perception threshold showed potential for reducing the feeling of "discomfort" associated with stress from numerical tasks, as measured by the *Jikakusho Shirabe* questionnaire. No significant differences were found in other stress measures.

In research examining the stress reduction effect of lavender aroma (Hashizume, 2011), a seven-minute Kraepelin test and a three-minute mental arithmetic task in which participants had to keep subtracting seven from 1,000 were used as stress tests. During the task, participants were exposed to lavender scent under four conditions: 1) odorless, 2) weak, 3) medium, and 4) strong. The maximum improvement in stress was observed in condition 2), the weak aromatic condition (three microliters of lavender scent oil in a five-liter bag).

METHODS

Participants

Twenty university students (10 males and 10 females, mean age 22 years) who gave informed consent to participate in the experiment in accordance with the rules of the Ethics Committee of Chuo University. Participants were given a stress task where they were exposed to Orange-sweet aroma, known for its stress-reducing effects.

Measures

Physiological and psychological measures were taken during the task to examine stress changes. Physiological measures included facial thermography and electroencephalography (EEG). Psychological measures involved two subjective evaluation questionnaires: the Profile of Mood States Second Edition (POMS2, short version for adults), the Japanese Evaluation Questionnaire for Subjective Symptoms of Work-Related Fatigue called "*Jikakusho Shirabe*," and a Likert scale questionnaire assessing scent preference and intensity.

Procedure

Experimental participants first receive an explanation of the experiment and fill out a questionnaire on psychological measures. After that, the participants practice answering the stress task for 40 seconds to familiarize themselves with its operation. Participants answer the stress task using a monitor and a numeric keypad. After that, they enter the experimental booth. Crucially, participants are not informed about the presence of an aroma. Inside the booth, the participants rest for 3.25 minutes and then perform the stress task for 6.5 minutes, as in the practice session, with the participants instructed to "work to get a higher score." After the stress task, participants rest for 3.25 minutes again and a questionnaire is given.

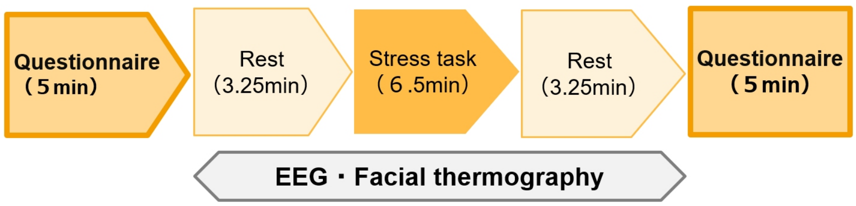

Figure 1: Experimental procedure.

The experiment was conducted on two separate days to compare two scent conditions: one at the Orange-sweet aroma perceptual threshold (control condition) and one above the perceptual threshold (experimental condition). The second experiment was conducted at the same time of day as the first, within one week of the first experiment. To avoid order effects, the conditions were counterbalanced: half of the participants received the control condition on day one and the experimental condition on day two, while the other half received the conditions in the reverse order. To control the scent conditions, participants were asked not to use perfume, hand cream, or other odorous substances on the day of the experiment.

Diffusion of Aroma and Its amount

The scent of Orange-sweet was generated by a nebulizer-type aroma diffuser using essential oil (Carris Seijo, lot number: ASC PGS10K3) extracted from the peel. The diffuser was placed out of sight, at a distance of three meters from the participants. As a preliminary investigation to determine the threshold of aroma perception, we asked four people, who were different from the experimental participants, to evaluate the strength of the scent in the experimental booth using a six-step scent strength rating questionnaire. Based on the results of the preliminary study, the 'at perceptual threshold' condition was defined as follows: the essential oil was diluted to one-sixth strength (1:5 ratio) with unscented MCT oil, and this mixture was diffused using a cycle of a 5-second spray followed by a 60-second stop. The ventilation fan was turned off when the scent was introduced, and the room was filled with the prescribed concentration of the scent when the participants entered the experimental room.

Stress Task

The stress task is a subtraction task in which seven is continuously subtracted from 1000. The default answer time is five seconds per question, with a shorter answer time for each correct answer and a longer answer time for each incorrect answer. Specifically, the goal is to achieve a 50% correct response rate using the up-and-down method. The up-and-down method is a psychological measurement method in which stimuli are continuously adjusted in response to the participants' responses (Kingdom & Prins, 2010). The response time of the next question decreases by a factor of 0.9 when the correct answer is given, while the response time increases by a factor of 1.11 when the time runs out or when the wrong answer is given. The stress task is created using a Python program, and the graphical user interface (GUI) is created using the Tkinter toolkit and displayed on a monitor.

Physiological Measures

Physiological measures were recorded using facial thermography from a Boson camera module and a MUSE 4-channel wearable EEG. It is known that among facial thermal images, nasal temperature, in particular, decreases with stress. Regarding EEG, alpha (α) waves do not merely indicate a state of brain calmness, but rather play a role in actively suppressing unnecessary information processing, while an increase in beta (β) waves is associated with attention and working memory.

Psychological Measures

Psychological measures used in this study included scent intensity on a six-point scent intensity scale, room scent preference, the Profile of Mood States, 2nd Edition (POMS2) short version for adults, and the Japanese evaluation questionnaire for subjective symptoms of work-related fatigue, *Jikakusho Shirabe*. The scent intensity scale is a six-point scale ranging from no scent to strong scent in a room. Room scent preference was rated on a seven-point scale from very disliked to very liked. The POMS2 short version is a rapid assessment of fluctuating and transient emotions (Heuchert, 2015). The *Jikakusho Shirabe*, aims to capture changes in work-related fatigue over time and investigate fatigue after stressful tasks (Japan Society for Occupational Health, Working Group for Occupational Fatigue, 2002).

RESULTS

Physiological Measures

For EEG, data from 16 participants were used, excluding 4 participants who had incomplete measurements. To reduce noise in the data obtained, a moving average with a window size of 5 was applied. Figure 2 shows the four recorded channels. T-tests were conducted between conditions for alpha and beta waves, respectively.

As shown in Figure 3, alpha waves in the prefrontal cortex (AF7, AF8) significantly increased during the experimental condition compared to the control condition. As shown in Figure 4, beta waves significantly increased in the prefrontal cortex (AF8) and the temporoparietal region (TP10) during the experimental condition compared to the control condition.

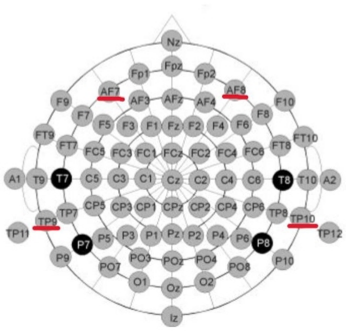

Figure 2: The extended 10–20 system.

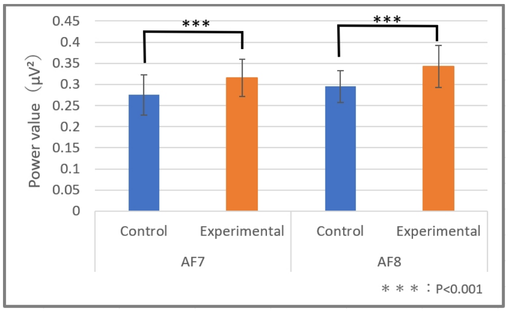

Figure 3: Comparison of alpha waves control condition and experimental condition.

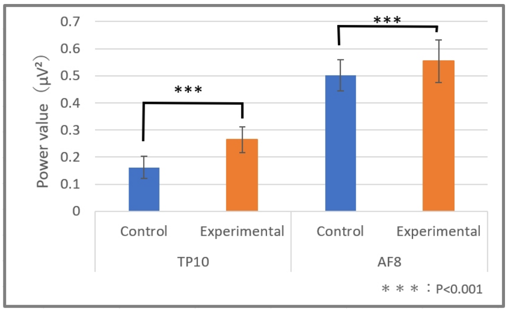

Figure 4: Comparison of beta waves control condition and experimental condition.

For facial thermography, data from 18 participants were used, excluding 2 participants who had incomplete measurements. We focused on nasal temperature, which is reported to decrease due to stress. The mean temperature during the first 1-minute rest period was used as a baseline, and the mean temperature difference was calculated every 30 seconds. Figure 5 shows the changes in the mean nasal temperature for all participants. In both conditions, it significantly decreased at the start of the task and significantly increased at the end of the task.

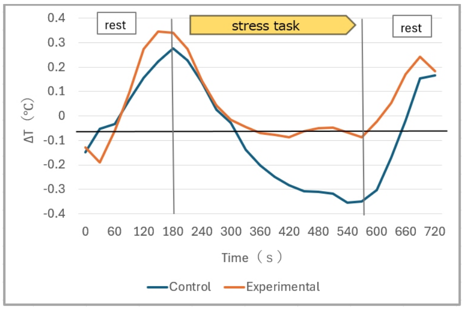

Figure 5: Comparison of nasal temperature control condition and experimental condition.

Psychological Measures

A t-test was applied to the results of response times and related scores for the subtraction tasks on two sets of data: one control condition and the other experimental condition. However, no significant differences were found in the number of responses, percentage of correct responses, mean time to answer, or scores.

A two-way ANOVA was conducted considering two factors: control condition or experimental condition and the timing of the implementation of the stress task (before and after the task). As shown in Figure 6, in one of the scales of the shortened version of POMS2, "Vigor-Activity" significantly decreased after the task in the experimental condition ($p = 0.014$). In contrast, no significant change in "Vigor-Activity" was observed in the control condition.

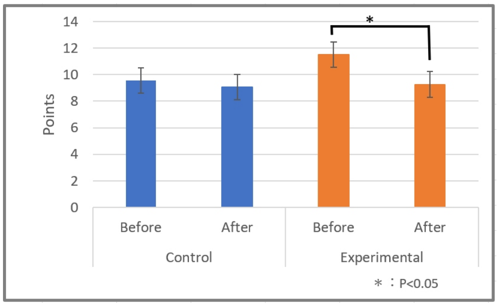

Figure 6: Comparison of "Vigor-Activity" scale values of the POMS2 short version control condition and experimental condition, before and after the task.

Multiple comparisons (Figure 7) revealed a significant increase in the "discomfort" scale of the "*Jikakusho Shirabe*" between pre-task and post-task in the experimental condition ($p = 0.04$, significant at the 5% level). In contrast, no significant change in "discomfort" was observed in the control condition.

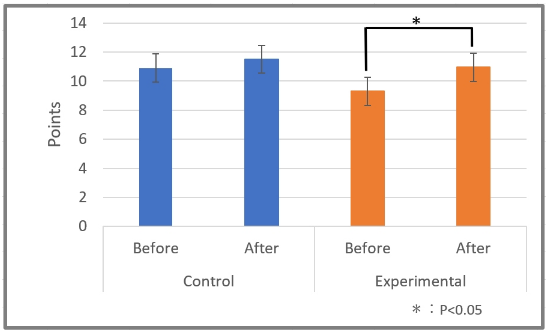

Figure 7: Comparison of "discomfort" scale values of "*Jikakusho Shirabe*" control condition and experimental condition, before and after the task.

DISCUSSION

Physiological Measures

The significant increase in alpha waves in the frontal and parietal regions during the calculation task is considered to play a role in actively suppressing irrelevant information processing, rather than merely indicating a calm state of the brain (Ole, 2010). The results of this study may reflect efficient brain activity under the stronger, above perceptual threshold Orange-sweet aroma, where the brain actively suppressed irrelevant sensory information and distracting thoughts to maintain concentration on the stress task.

The increase in beta waves suggests the involvement of attention and working memory (Serena, 2023). The results of this study suggest that participants may have maintained attention on the information necessary for calculation, or held the answers in memory while calculating under the stronger, above perceptual threshold Orange-sweet aroma.

The changes in nasal temperature indicated an increase in stress due to the stress task and recovery during the rest period.

Psychological Measures

Since no differences were observed in the results of the numerical task as a stress task, it is likely that the aroma did not affect performance measures such as speed and accuracy.

Based on the results for "Vigor-Activity," a significant decrease was observed in the experimental condition, while no significant change was seen in the control condition. This suggests that the control condition (aroma at the perceptual threshold) helped maintain a state of refreshment (characterized by high levels of energy, liveliness, and vitality), preventing the decline observed in the experimental condition.

Similarly, regarding physical "discomfort," an increase was observed in the experimental condition, while no significant change was seen in the control condition. This suggests the possibility that physical "discomfort" was prevented from increasing in the control condition (aroma at the perceptual threshold).

CONCLUSION

The findings of this study suggest that sweet orange aroma may exert dual effects depending on its concentration. There is a possibility that an aroma at the perceptual threshold induced a pharmacological relaxation effect. In contrast, a supra-threshold (perceivable) aroma may activate brain activity during the stress task, potentially assisting the brain's concentration on the calculation work.

At first glance, there appears to be a discrepancy between physiological and psychological results. Rather, it reveals the dual role of the aroma, suggesting the necessity of selectively using different concentrations of Orange-Sweet aroma depending on the work environment and the desired objective.

This suggests the optimal concentration depends on the goal. For example, our results imply that an Orange-sweet aroma at the perceptual threshold (a weak scent) should be used for situations requiring a refreshment effect, such as during rest periods. In contrast, a supra-threshold Orange-sweet aroma (a stronger scent) should be used during tasks that require enhanced concentration or working memory support. It should be noted, however, that these findings apply specifically to Orange-Sweet, and it is possible that the effects differ depending on the type of scent.

For future research, we plan to conduct a comparative analysis to verify the changes in each metric resulting from the odor stimulus alone and the stress task alone. Furthermore, future studies should investigate how individual differences in aroma selection and participant factors—such as scent preference, coffee drinking frequency, and olfactory sensitivity, which were used for classification in this study—modulate these effects.

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