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Research Article

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Investigating the Psychological and Physiological Effects of Igusa (Juncus effusus L. var. decipiens "Suzukaze") Scent: A Pilot Study Using Igusa Water

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Abstract

Background: Tatami mats, an integral part of traditional Japanese architecture, are renowned for their distinctive scent primarily derived from rush (Juncus effusus L. var. decipiens) or igusa in Japanese. Although the aroma of tatami is deeply ingrained in Japanese culture, its potential psychological and physiological effects remain underexplored.

Methods: This study investigated the effects of igusa scent on mood, cognitive function, and behavior. The experiment was conducted in three stages to clarify its effects; 1. on brain activity when individuals inhaled a scent released from an inhaler in a small closed room, 2. on healthy subjects' moods in a normal living environment with a scent emitted by a diffuser, and 3. on the well-being of elderly individuals in a normal living environment using scents emitted by a diffuser. EEG monitor, visual stimuli tests, POMS mood test, 100 square calculation tests, and questionnaire were used for healthy individuals. MMSE test, DBD test, and CMAI test were used for individuals with dementia.

Results: Subsequent experiments involving healthy individuals and elderly participants in nursing homes revealed that igusa scent enhanced cognitive function, improved mood, and reduced behavioral symptoms, especially among elderly individuals with dementia.

Conclusions: The scent of igusa water demonstrated its effects regardless of preference. It can also be expected to have an effect through long-term exposure, even for those who do not perceive the scent.

Keywords: Igusa scent; Tatami; 1,8-cineole; Aromatherapy; Cognitive function;

List of Abbreviations

Cohen–Mansfield agitation inventory (CMAI)

Dementia behavior disturbance scale (DBD)

Electroencephalograph (EEG)

Gas chromatography-mass spectrometry (GC-MS)

Mini-mental state examination (MMSE)

Profile of mood states (POMS)

Total mood disturbance (TMD)

Volatile organic compounds (VOCs)

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Background

Tatami mats are traditional Japanese flooring mats made of rush (*Juncus effusus L. var. decipiens*), or *igusa* in Japanese (Figure 1). It has been reported that extracts from *Juncus effusus* have anti-inflammatory, antioxidant, and hemostatic effects, in addition to its protective nature against D-galactosamine-induced liver damage by decreasing oxidative stress [1].In Japan, tatami mats were initially used for aristocrats' seating and bedding during the 8th century, however in the later period, they were set from wall to wall and such a room became an essential element in Japanese architecture by the 16th century. Japanese rooms with *tatami* mats are characterized by their unique scent and appearance. The grassy scent of *tatami* mats, mainly from *igusa*, is highly regarded in Japanese culture and is often associated with a sense of comfort, relaxation, and nostalgia [2]. Although Western-style flooring is available in modern Japan, traditional Japanese rooms with tatami mats are still prevalent.

Figure 1: A typical example of a Japanese *tatami* room

To investigate the effects of the *tatami* mat scent, Sun et al. evaluated the effect of the scent of volatile organic compounds (VOCs) from *Juncus effusus L. var. decipiens Buchen*, dried *igusa,* and found an increase in alpha waves when subjects smelled the scent [3]. As the alpha band amplitude can be an indicator of the change in arousal level, this study showed that the scent of dried *igusa* has the effect of awakening the brain [4,5,6]. However, the specific effects of the scent of *igusa* on mood and behavior have not been conclusively proven. Moreover, the strength and quality of *tatami* mat's scent varies over time, yet it is not clear whether and how the effect of the scent changes over time.

As recent lifestyle changes have led to a significant decrease in Japanese-style rooms with *tatami* mats, there are fewer opportunities for exposure to the *tatami* scent in daily life, even in Japan. If the scent of *tatami* mats has psychological or physiological improvement effects, the application of the *igusa* scent in a portable form, such as an aroma diffuser would be advantageous. As a large portion of *igusa* is cut off during the manufacture of *tatami* mats, and the amount of discarded *igusa* is causing a serious environmental problem in Japan, the conversion of discarded *igusa* into value-added products is highly desirable, even from the environmental protection purposes. As *igusa* does not produce essential oils from distillation, this study used *Juncus effusus L. var. decipiens buchen hydrosol*, *igusa* water to verify the effect of *igusa* scent in a portable form, and not as traditional tatami mats.

Using *igusa* water manufactured by Daiichi Food Industry [7], made by distilling steam from boiling *igusa,* a rush cultivar (*Juncus effusus L. var. decipiens "Suzukaze"*), harvested in Yatsushiro, Kumamoto city, Japan. This study explored the scent effects of its VOCs on healthy young individuals and elderly individuals in nursing homes. The experiment was conducted in three stages to clarify its effects; 1. on brain activity when individuals inhaled a scent released from an inhaler in a small closed room, 2. on healthy subjects' moods in a normal living environment with a scent emitted by a diffuser, and 3. on the well-being of elderly individuals in a normal living environment using scents emitted by a diffuser. Prior to conducting the three experiments, a gas chromatography-mass spectrometry (GC-MS) analysis was performed using a 7890 A GC system (5975 C MSD) manufactured by Agilent Technologies with a thermal desorption unit to determine the VOCs in *igusa* water. The column used for analysis was VF-624MS (0.25 mm I.D. x60m, film thickness 1.4 µm). Column temperature was controlled as follows: 50°C (1 min) →160°C (15°C/min) → 250°C (5°C/min). Helium was used as the carrier gas at a flow rate of 1.5 mL/min, and the analysis mode was SCAN. The compounds were identified by Aroma Office Ver.5.0 with the NIST08MassSpectral Library Database. As a result of the analysis, the main VOCs detected in *igusa* water were Hexanal, D-Limonene, and 1,8-cineole (Figure 2).

Materials and Methods

Experiment 1. The effects on brain activity

The purpose of this study was to confirm the effect of *igusa* water on brain activity using an EEG monitoring and visual discrimination task. All participants (9 males, 8 females) were prohibited from consuming alcohol or medications one day before the experiment, and caffeine on the day of the experiment. For the experiment, a sound proofed room (1.2 m × 1.7 m × 2.0 m) equipped with an inhaler connected to Tenax glass tubes to provide the scent of *igusa* water from a diffuser was prepared (Figure 3 18). The CRT display was placed 114 cm from the subject's seat in the room. To clean the air in the room before the experiment, it was first ventilated using an exhaust fan and by opening the door 15 min before the

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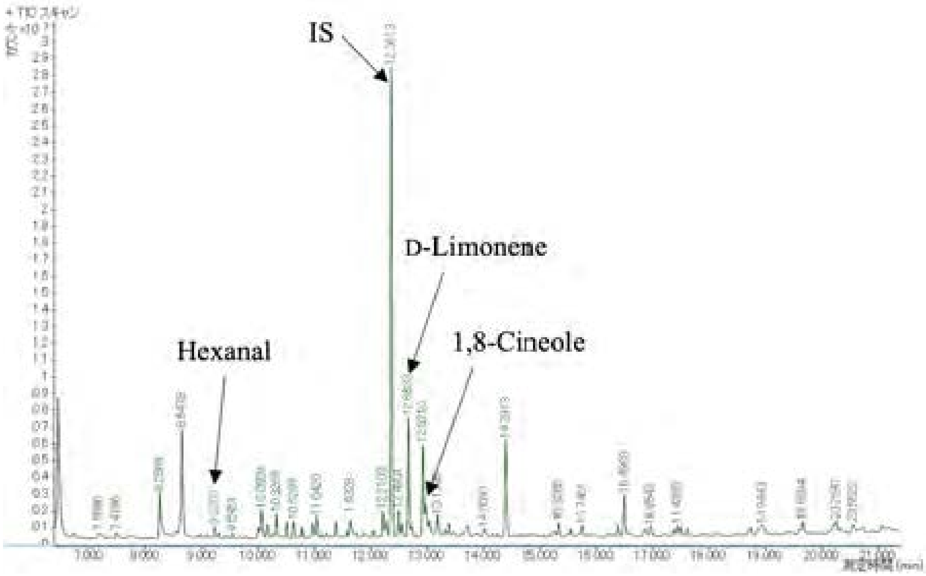

Figure 2: Volatile organic compounds (VOCs) of igusa water identified using chromatograms in the GS-MS analysis

experiment. Subsequently, the exhaust fan was stopped, and the door was closed for 30 min with a small fan circulating the air. The mini-pumps used to release the scent were activated 10 min before the participants entered the room and stopped after completion of their tasks. Each participant entered the experiment room after providing written informed consent, attached the EEG monitor, and played six sessions of 2.5 min visual stimuli tests while viewing the monitor and smelling the scent released from the inhaler.

Experiment 2. The effects to the mood of healthy individuals

The purpose of this experiment was to investigate the effect of *igusa* water's scent in a living room, using distilled water and 1,8-cineole as controls. The room used for the experiment was a regular classroom approximately 5 m × 6 m in size with windows (Figure 4 19). Two essential oil diffusers were used to diffuse the scent of 1,8-cineole, and two ultrasonic humidifiers were used to diffuse *igusa* water (diluted 10 times with distilled water), and distilled water respectively. The diffusing device was placed diagonally at a corner of the room (two devices in total). The room was ventilated prior to the experiment. Thirty minutes after the start of the experiment, the fan was turned off, windows were closed, and the diffusers were turned on. An air sample of 1.8-cineole was collected at the center of the room 30 min after diffusion with an air collection pump for 15 s and an air flow rate of 0.15 L/min, measuring 889.73 μg/m³. In contrast, the VOCs of air sample of *igusa* water were hexanal: 58.8 μg/m³, D-limonene: 83.2 μg/m³, and 1,8-cineole: 259.7 μg/m³.

Experiment 3. The effects to elderly individuals' well-being

The purpose of this study was to investigate the long-term exposure effects of *igusa* water on the elderly population. A diffuser or humidifier was placed near the bed and turned on for one hour at bedtime for seven consecutive nights. For 1,8-cineole diffusion, eight drops of 1,8-cineole were

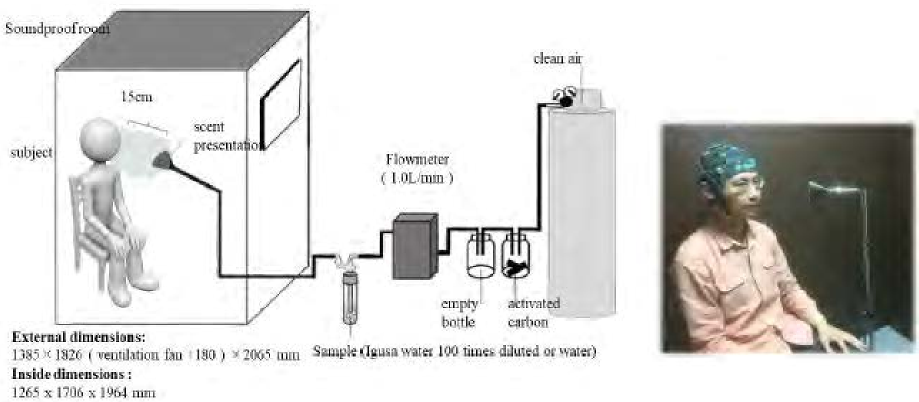

Figure 3: Experimental equipment and arrangement for Experiment 1

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Figure 4: A typical room used for Experiment 2

used, which automatically stopped the aroma diffuser after approximately one hour. For *igusa* water diffusion, *igusa* water (diluted 10 times with distilled water) was used. An air sample of 1.8-cineole was collected at the center of the room 1 h after diffusion with an air collection pump for 15 s with an air flow rate of 0.15 L/min, measuring 1086.44 $\mu g/m^3$. In contrast, the sample of *igusa* water VOCs had hexanal: 47.2 $\mu g/m^3$, D-limonene: 99.9 $\mu g/m^3$ and 1.8-cineole: 393.7 $\mu g/m^3$.

Diffuser

For all experiments in this study, a 300 mL ultrasonic humidifier (Figure 5-A)22 was used to diffuse igusa water and distilled water, while an essential oil diffuser (Fig. 5-B)23 with a 2-min on, 1-min off cycle was used to diffuse 1,8-cineole.

Figure 5: Ultrasonic humidifier (A) and essential oil diffuser (B) used for experiments

Statistical analysis

In all results, the values are expressed as the means ± s.e.m. Paired t-tests with a Bonferroni collection were used to compare differences in each index between the conditions. Statistical significance was recognized when the p value was < 0.05, and the tendency was $p < 0.1$. All statistical analyses were performed using JASP 0.16.4 (JASP Team, 2022).

Results

Experiment 1. The effects on brain activity

Experiment 1 evaluated the effects of *igusa* water scent compared to that of distilled water (used as control), which has little odor. The experiment was conducted with nine healthy males and eight female young individuals using a questionnaire to assess mood and subjective impression of the scent. In addition, a visual stimuli test with an electroencephalograph (EEG) monitor was used to assess changes in work efficiency and brain waves caused by the scent. EEG is a non-invasive technique with excellent temporal resolution that is highly sensitive to fluctuations in human brain activity [8]. In the experiment, the subjects two sets of six sessions of visual stimuli tests, of 2.5 min each were performed on the subjects. One set smelled the scent of *igusa* water, and the other set smelled the scent of distilled water. Ultrasonic humidifiers were used to diffuse *igusa* water, which was diluted 100 times with distilled water and to diffuse distilled water. The VOC analysis conducted on samples collected from *igusa* water using an air collection pump for 15 s with an air flow rate of 0.15 L/min showed presence of Hexanal: 420 $\mu g/m^3$, D-Limonene: 661 $\mu g/m^3$, and 1,8-Cineol: 227 $\mu g/m^3$.

The visual stimuli test was conducted to assess the level of participants' focused attention to detail using a software "Presentation" by Neuro Behavioral System. In this test, three patterns of grayscale sinusoidal grating images – vertically straight pattern (T), tilted at 10 ° pattern (F), and tilted at 50 °pattern (I) appeared randomly on the screen. (T) appears with a probability of 15%, (F) with a probability of 70%, and (I) with a probability of 15%. The interstimulus intervals were also randomized between 850 and 1100 ms to make it difficult for the participants to anticipate. Participants were asked to press the button when (T) appeared (Figure 6). The task involved pressing a button accurately and quickly in response to (T). In addition to the visual stimuli test, a shortened version of the Profile Of Mood States (POMS) questionnaire was performed before and after the test, and a questionnaire survey was conducted to examine the impression of the scent after the test (Figure 7) [[9]. The POMS questionnaire categorizes mood into six dimensions: "tension," "depression," "anger," "fatigue," "confusion," and "vigor." In addition, scores of each dimension were calculated to indicate negative mood states.

Individuals recognized the scent of *igusa* water much stronger than that of the distilled water (2.00 ± 0.411 vs.0.824 ± 0.231, p = 0.048); however, preference for the scent of igusa water was lower than that of water (0.118 ± 0.169 vs. 0.412 ± 0.193, p = 0.289) (Figure 8). The results of the POMS questionnaire administered before and after the visual stimuli test did not show any significant differences compared to the distilled water condition. In contrast, toe results of the visual stimuli test, although no significant effect was found in the accuracy rate with the scent of *igusa* water (Figure 9), the

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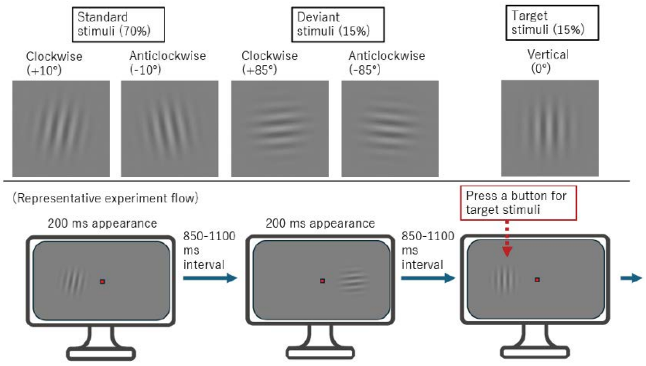

Figure 6: Visual test process

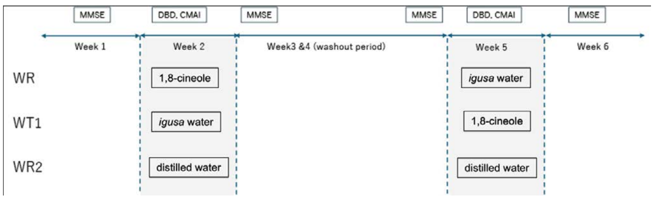

Figure 7: Experimental procedure of Experiment 1

reaction time was significantly faster with the scent of *igusa* water than that of the distilled water in session 3 (510.44 ± 16.35 msec vs. 561.82 ± 16.40, p = 0.01). Furthermore, EEG monitoring during the visual stimuli task displayed that gamma power during the task with the scent of *igusa* water was significantly larger than the distilled water (46.80 ± 16.08 vs. 39.34 ± 17.02, p = 0.016) (Figure 10). Gamma waves are known to appear during a state of high arousal (emotional and cognitive processing), and it can be said that the scent of *igusa* water enhance es sensory and cognitive processing functions [10].

Experiment 2. Effects to healthy individuals' mood

Experiment 2 examined the effects of the *igusa* water scent emitted by a diffuser in a normal living environment on 40 healthy young college students (20 males and 20 females, with an average age of 21.3 years). In addition to distilled water, 1,8-cineole was used as a control, which has been confirmed to have an arousing effect in previous studies [11].

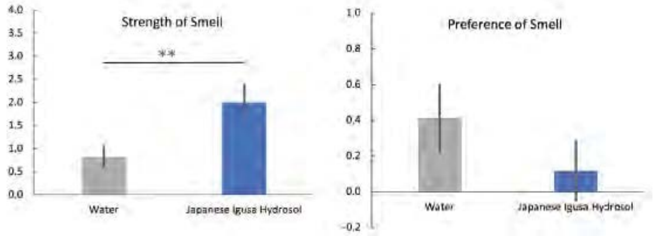

Figure 8: Results of evaluation for the strength (left) and preference (right) of the scent

The scent of 1,8-cineole is described as a fresh, with slightly minty aroma, and is often used in aromatherapy for its relaxing properties. The participants were randomly divided into two groups, A and B, for a single-blind experiment in three environments: a room with the scents of distilled water, 1,8-cineole, and *igusa* water. Both groups performed the experiment once a day using one scent. Experiments with different scents were performed at least three days apart. Both groups undertook the experiment in a room with the scent of distilled water first, subsequently followed by group A undertaking the experiment in a room with the scent of *igusa* water first, and group B undertaking the experiment in a room with the scent of 1,8-cineole first.

The experiment used 1) a survey to evaluate the preference for the scent on a 5-point scale, measuring the liking or disliking of the scent, 2) a shortened version of the POMS questionnaire to measure mood changes, and 3) 100 square calculation tests to measure the change in mood owing to the scent. This was an arithmetic task involving single-digit additions to a 10 × 10 grid within a limited time of 1 min. In addition, the number of correct answers were also recorded (Figure 11). In one experiment, the participants first completed the POMS questionnaire and 100 square calculation tests in a room with open windows that did not diffuse any scent. After completing the tests, they moved to the next room, where the scent was diffused. After they sat down and had a quiet time of 3 min, they completed a questionnaire about their scent preference, a calculation test, and a POMS questionnaire (Figure 12).

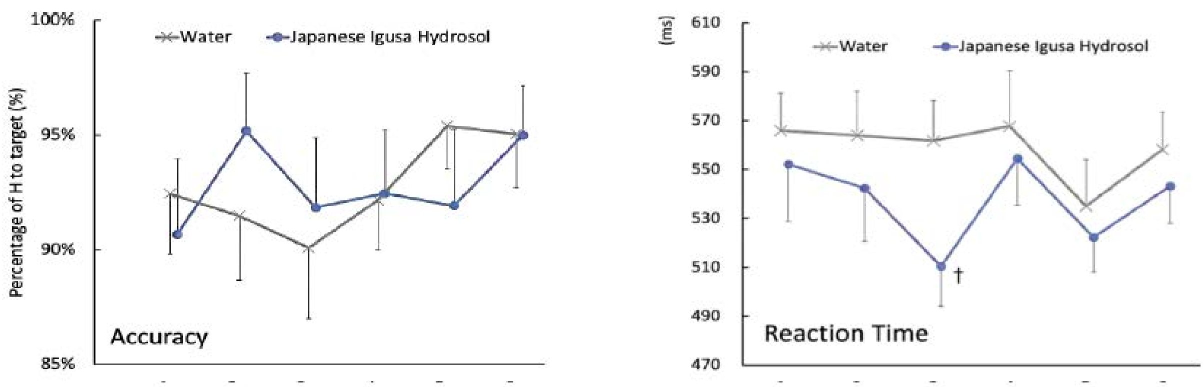

Figure 9: Results of visual tests: accuracy (left) and preference (right)

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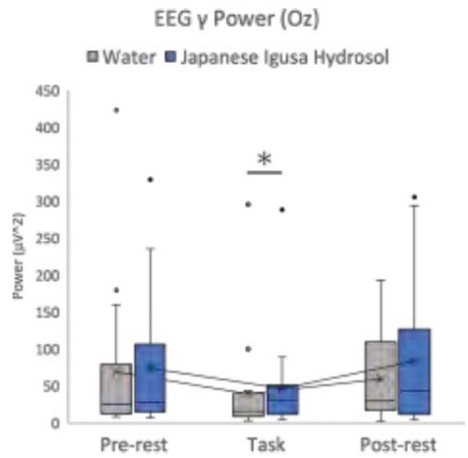

Figure 10: Changes of EEG gamma power in the visual tests

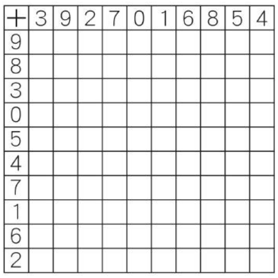

Figure 11: A sample of 100 square test.

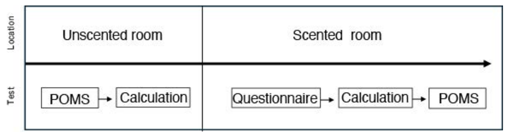

Figure 12: Experimental procedure of Experiment 2.

Figure 13 presents the results of the questionnaire regarding scent preferences. Approximately 45% of participants very liked (18%) or liked (27%) the scent of 1,8-cineole, whereas none very liked (14 %) the scent of igusa water. In contrast, 15% of the participants very disliked (11%) or disliked (4%) the scent of 1,8-cineole, whereas 48% of the participants very disliked (9%) or disliked (39%) the scent of igusa water. The smell of *igusa* water reminded the participants of old barns, countryside, and grass, and was less favored than 1,8-cineole. The results of the 100 square calculation tests displayed that the average score significantly improved after exposure to 1,8-cineole (p=0.0046). In particular, all participants who answered that they disliked the *igusa* water scent performed worse in the 100 square calculation tests after exposure to the scent. However, despite the lower scent preference, *igusa* water demonstrated better results in the total mood disturbance (TMD) evaluation of the POMS questionnaire. The TMD was calculated by summing the scores of the first five subscales (tension-anxiety, depression-dejection, anger-hostility, fatigue-inertia, and confusion-bewilderment) and subtracting the vigor-activity score. TMD provides an overall measure of mood disturbance, with higher scores indicating greater negative affect. The results of TMD in this experiment indicated that the scent of *igusa* water had a greater mood-enhancing effect than 1,8-cineole among young individuals.

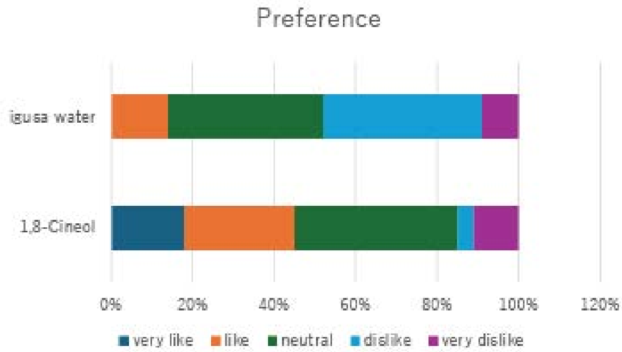

Figure 13: Preference of the scent of *igusa* water.

Experiment 3. The effects to the elderly subjects' well-being

Experiment 3 was conducted with the residents of two nursing homes, WR (Wakaba Residence) [12] and WT (Wakaba Terrace), [13] in Sasebo City, Nagasaki Prefecture, Japan. 34 participants (WR: 11 females, 3 males; WT1:10 females; WT2:10 females) were recruited from residents who had mini-mental state examination (MMSE) scores between 10 and 27. The average age of participants was 92 years. Distilled water and 1,8-cineole were used as control. The experiment involved exposing the participants to one of the scents for 1 h before bedtime for seven consecutive days. As the participants' room doors were closed at bedtime, the scent components diffused by the diffuser lingered in the room while the participants were sleeping. All participants lived in a single room (approximately 3 m x 5 m) furnished with a bed, bedside table, closet, and a shelf (Figure 14). Temperature was controlled with air conditioning, and the windows were typically kept closed.

Figure 14: An example of a typical participant's room.

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The MMSE, dementia behavior disturbance scale (DBD), and Cohen–Mansfield agitation inventory (CMAI) were used as indicators to measure cognitive abilities and behavioral observations [14,15,16,17]. The MMSE is a questionnaire used to assess cognitive impairment by examining functions such as attention, calculation, recall, and language. It consists of 11 questions measuring cognitive ability. The DBD is a scale comprising 28 items that caregivers use to assess behavioral symptoms. The CMAI is a scale divided into aggressive behavior (11 items) and non-aggressive behavior (11 items), totaling 22 items, in which caregivers assess behavioral symptoms. The duration of the experiment was 6 weeks. The participants were exposed to scents for seven days during the 2nd and 5th week. The WT2 participants were exposed to the scent of distilled water for both weeks; while WT1 participants were exposed to *igusa* water during week 2 and 1,8-cineole during week 5; whereas WR participants were exposed to the scent of 1,8-cineole during week 2 and *igusa* water during week 5 (Figure15). None of the participants recognized the scents; however, all caregivers perceived the scents of 1,8-cineole and *igusa* water. During the 6 weeks of the experiment, four MMES tests were performed: week1 (before the first scent test), week 3 (after the first scent test), week 4 (before the second scent test), and week 6 (after the second scent test). Evaluation of DBD and CMAI was performed daily between 2 PM and 5 PM during weeks 2 and 5 respectively.

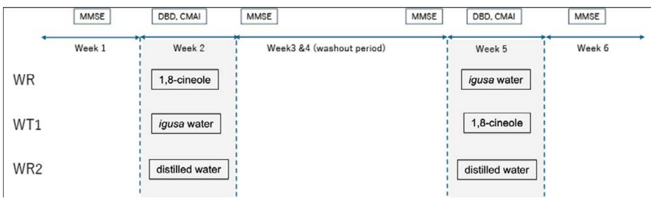

Figure 15: Experimental procedure of Experiment 3.

The effects on cognitive function

Figure 16 illustrates the changes in the normalized average MMSE scores of the three groups of participants (WR, WT1, and WT2) before and after the two exposure sessions. Although scent was not perceived by any participant, the MMSE score improved during the scent exposure periods. The effect of the scents is evident from the results that the average MMSE of WR and WT1 participants increased during the period of exposure and decreased during the 2 weeks of washout period. Although the caregivers preferred the smell of 1,8-cineol, the scent of igusa water had a more positive impact on the MMSE results compared to that of the scent of 1,8-cineole. The WR participants showed significantly improved MMSE scores with the scent of 1,8-cineole (p=0.02) and igusa water (p=0.001), while W1 participants showed a trend of improvement with the scents of igusa water (p=0.34) and 1,8-cineole (p=0.33). No significant change was observed in the MMSE scores of WT2 participants exposed to the scent of distilled water.

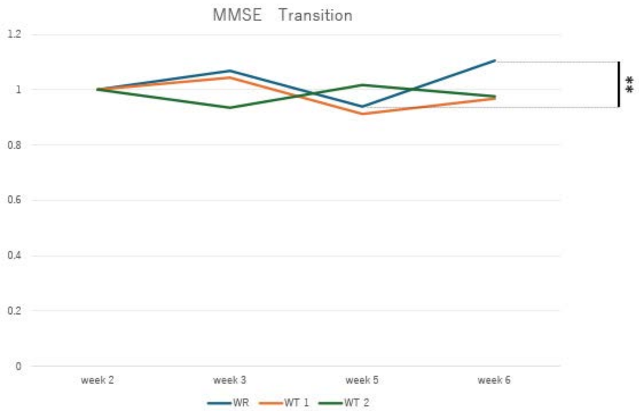

Figure 16: Normalized average MMSE between week 2 and week 6.

The effects on behavior

Figure 17 shows the average DBD and CMAI scores on day 1 (blue) and day 7 (red) of scent exposure. An increase in the values indicated an increase in behavioral issues. Comparing the results of days 1 and 7 of scent exposure, there was no significant change in the case of water; however, there was a significant improvement in DBD and CMAI for both *igusa* water (DBD, p=0.0005; CMAI, p=0.002) and 1,8-cineole (DBD, p=0.025; CMAI, p=0.013). In addition, the degree of improvement was greater for *igusa* water than for 1,8-cineole. While considering the details of the improvements, there was a particular improvement in items such as "trying to go to a different place," "repeating the same actions," "repeating the same words," "urinary incontinence," and "fecal incontinence." According to caregivers' records, there was an increase in requests from participants to use the toilet during the exposure period to *igusa* water and 1,8-cineole. These improvements could be because the scent had an effect on awakening the participants' consciousness.

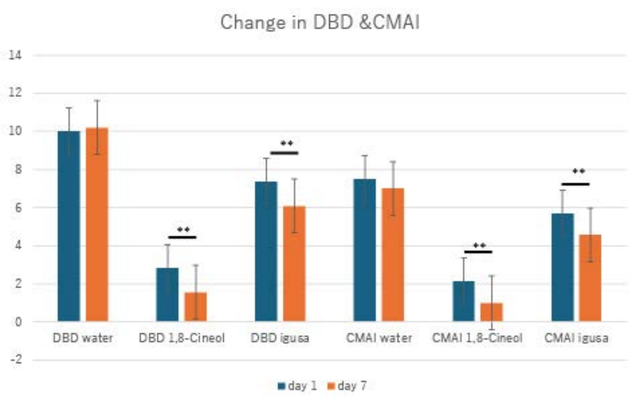

Figure 17: Change in DBD and CMAI between day1 and day 7.

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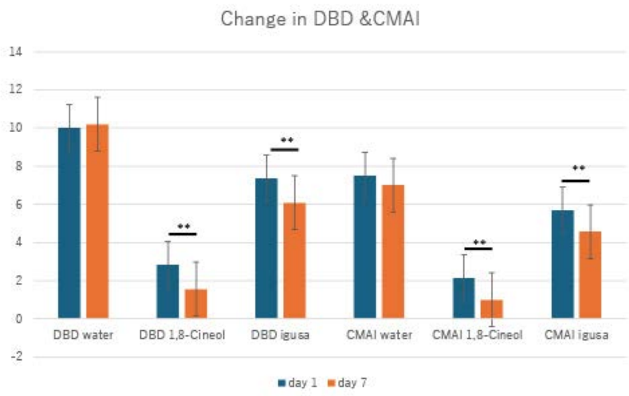

Figure 18: Preference of the scent of new *igusa* water.

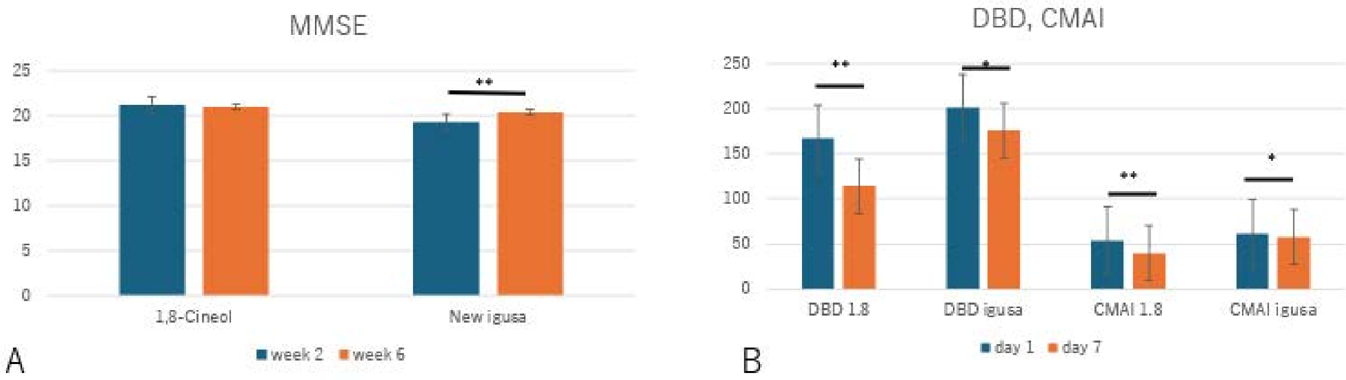

Figure 19: Change in MMSE between week 2 and week 6 (A) change in DBD and CMAI (B).

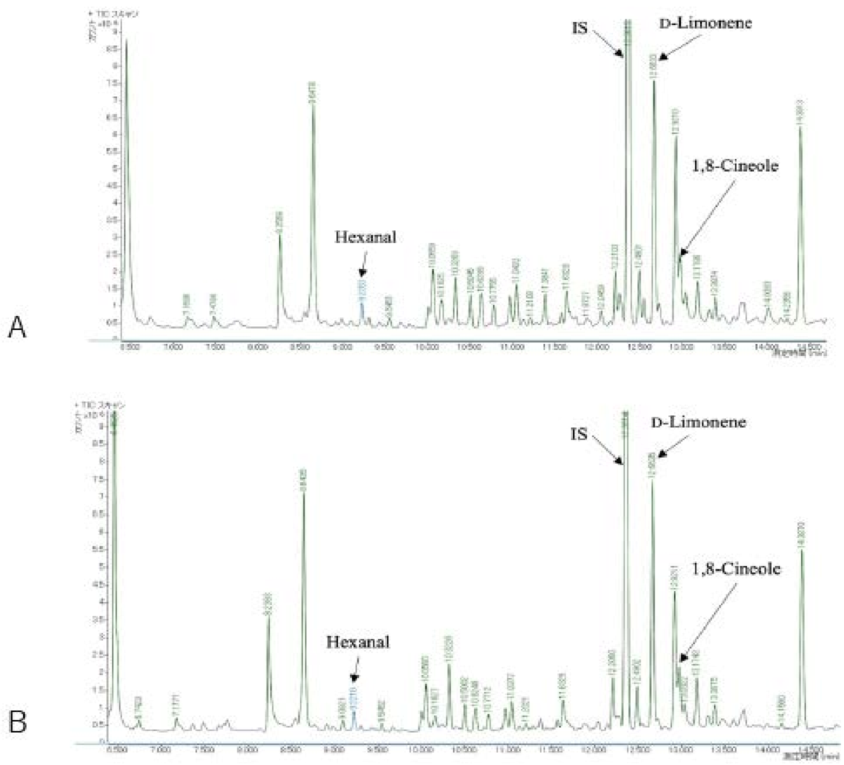

Figure 20: Chromatograms of the air from old igusa water (A) and new igusa water(B).

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Discussion

As the Japanese usually favor the scent of new *tatami*, many participants disliked the scent of *igusa* water used for this experiment as it smelled like old *tatami* mats. Despite its unpopularity, Experiment 1 confirmed that the scent of *igusa* water triggered gamma waves in the brain. Experiment 3 displayed that the scent of *igusa* water improved the DBD, CMAI, and MMSE scores in elderly participants, although they were unaware of the scent. These results suggest that regardless of the perception of the scent, the scent of *igusa* water has awakening effects. These effects helped improve the cognitive function and behavioral symptoms of elderly participants with dementia and reduced the physical and psychological burden on caregivers. However, Experiment 2 found that the results of the 100 square calculation tests worsened for participants who found the scent unpleasant.

Generally, individual preferences for scents influence the effectiveness of aromatherapy, and it is important to consider individual preferences for scents for optimal effectiveness [18]. If the scent of *igusa* water had been pleasant, better effects could be expected. Therefore, Daiichi Food Company was requested to revise its manufacturing methods to improve its scent. After months of trial and error, a new *igusa* water was prepared by steaming *igusa* instead of boiling it. With this new *igusa* water, Experiment 2 included 40 healthy participants (20 males, 20 females), and Experiment 3 included 29 participants from the same nursing home (13 females from WR, 1 male from WR, and 15 females from WT) with an average age of 93 years. Distilled water was not used, however only 1,8-cineole was used as the control.

The scent of the new igusa water was similar to the scent of new tatami mats. The results of the survey evaluating the preference for the scent on a 5-point scale, measuring the liking or disliking of the scent, showed that the preference for the scent of new *igusa* water was not significantly different from that of 1,8-cineole (Figure 18). Although the results cannot be directly compared between the new *igusa* water and old *igusa* water as the subjects who participated in the experiment were different, none of the participants very liked, and only 14% of participants liked the scent of old *igusa* water, while 9% of participants very liked and 18% liked the new *igusa* water. However, the average accuracy rate of the 100-square calculation task significantly improved after exposure to 1,8-cineole (p=0.047), whereas the accuracy rate after the exposure to the new *igusa* water significantly decreased (p=0.015). In contrast, in the POMS mood test, TMD significantly improved with both scents (1,8-cineole, p=0.002; new igusa water, p=0.03). Therefore, although the impression rating of the scent of *igusa* water improved, the results of the 100-square calculation task and POMS did not improve.

In nursing homes, as in the previous experiment, the elderly participants did not recognize either scent; however, the caregivers sensed both scents. However, there were no complaints from caregivers about the scent of the new *igusa* water. Figure19-A illustrates the average MMSE scores on days 1 and 7 after one week of exposure to the two scents. The MMSE score of the participants significantly improved with the scent of new *igusa* water (p=0.04), however it was not the case with the scent of 1,8-cineole. Positive effects on behavior (DBD and CMAI) were also observed for the two scents, as in the previous experiment. However, where significant improvements in the behavior of DBD (p=0.0001) and CMAI (p=0.003) were observed with 1,8-cineole, and only a trend toward improvement in DBD (p=0.3) and CMAI (p=0.1) was observed with new igusa water (Figure 19-B). As both 1,8-cineole and old igusa water significantly improved both DBD and CMAI, the effect of new igusa water on 1,8-cineole was not as good as that of the old igusa water on 1,8-cineole despite a better preference for the scent.

Figure 20 displays the chromatograms of air captured from the old and new *igusa* waters. The main VOCs in both air types were identified as hexanal, D-limonene, and 1,8-cineole with similar peaks [19]. Although the composition of VOCs between the old and new *igusa* waters are similar, the results of the VOC analysis that was collected from the old *igusa* water with an air collection pump for 15 s and an air flow rate of 0.15 L/min, included hexanal: 420 μg/m^3, D-limonene: 661 μg/m^3, and 1,8-cineol: 227 μg/m^3. However, the results of the new *igusa* water showed the presence of hexanal: 266 μg/m^3, D-limonene: 430 μg/m^3, and 1,8-cineol: 115 μg/m^3. As the new *igusa* water had approximately 63% hexanal, 65% D-limonene, and 50% 1,8-cineole compared to the old igusa water, the reason for the sensory difference in the scent of the old and new *igusa* water could be owing to the differences in the concentration of the components. Many participants felt that the scent of the new *igusa* water was better because it had a lower concentration of VOCs. Furthermore, there are limitations and challenges in identifying VOCs with GC-MS analysis. Although GC-MS analysis is a powerful technique for identifying and quantifying compounds in air, as *igusa* water contains a wide range of compounds, both organic and inorganic, some components may be undetectable in the analysis process. Humans are sensitive to scents and can judge whether the scents are different depending on the concentration including undetected microscopic elements of VOCs, even if the main components of the VOCs are the same.

Conclusion

In research on the relationship between scent preferences and relaxing effects, Akiyoshi stated that some aromas affect mood depending on the degree of preference, whereas others affect mood regardless of the degree of preference [20]. Although the scents of the old and new *igusa* water were recognized differently, the proportion of the main VOCs was similar, and similar effects were obtained regardless of the

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degree of preference. Whether the scent represented a new or an old tatami, the scent of *igusa* water improved the mood of both healthy young people who could detect the scents well as well as elderly people who could not detect the scents. Although the quality of the scent of *tatami* varied with age, it is generally considered to offer a sense of security. This study confirms this empirically cultivated perception. The scent of *igusa* water demonstrated its effects regardless of preference, however it can also be expected to have an effect through long-term exposure, even for those who do not perceive the scent [21].

If the scent of *igusa* could be used in a variety of places, including residences, offices, hospitals, and nursing homes, it would help to improve the quality of daily life. In particular, its effects on improvements in peripheral behavior could lead to reduced mental burden on caregivers and enhancement in quality of care. However, further research is required before *igusa* water can be used in practical applications. First, it is important to further investigate the effects of each VOC as well as the effects based on different distributions of VOCs, as well as the appropriate concentration and time of exposure. Second, the quality of aroma water can vary greatly depending on the quality of the plant and the extraction techniques used. It is necessary to continue trial and error to determine the best manufacturing method to obtain favorable and effective scents. Third, although this study was conducted with Japanese subjects who know the culture of *tatami* mats, further research is needed to determine whether the effects of the scent of *igusa* water depend on the cultural background.

Declarations

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Author contributions

1. Designed the study, directed the projects, and wrote the manuscript.
2. Arranged and supervised the experiments at Wakaba Terrace and Wakaba Residence.
3. Planned the protocol for the EEG experiment, conducted data analysis, and summarized the data.
4. Conducted data analysis.
5. Conducted GC-MS analysis.
6. Conducted data analysis.
7. Conducted GC-MS analysis.
8. Designed the study and directed the project.

Ethical Approval

Experiment 1 was approved by Kyushu University Ethics Review Committee in accordance with the Declaration of Helsinki (approval #83, 2021/08/06), Experiment 2 and Experiment 3 were approved by Nagasaki University Ethics Review Committee in accordance with the Declaration of Helsinki (approval #R4-1, 2021/06/27, approval #R4-2, 2021/07/17).

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Data Availability Statement: The data from human experiments that support the findings of this study are not publicly available as they contain information that could compromise the privacy of research participants. Available data is provided within the manuscript.

Consent to Publish Statement

The image clipping used in Figure 18 obtained the consent for publication.

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