Effects of Inhalation of Essential Oils on EEG Activity and Sensory Evaluation

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Abstract. The purpose of this study was to investigate EEG changes in subjects directly after inhalation of essential oils, and subsequently, to observe any effect on subjective evaluations. EEG and sensory evaluation were assessed in 13 healthy female subjects in four odor conditions. Four odor conditions (including lavender, chamomile, sandalwood and eugenol) were applied respectively for each subject in the experiment. The results were as follows. 1) Four basic factors were extracted from 22 adjective pairs by factor analysis of the sensory evaluation. The first factor was "comfortable feeling", the second "cheerful feeling", the third "natural feeling" and the fourth "feminine feeling". In the score of the first factor (comfortable feeling), the odors in order of high contribution are lavender, eugenol, chamomile and sandalwood. 2) Alpha 1 (8-10 Hz) of EEG at parietal and posterior temporal regions significantly decreased soon after the onset of inhalation of lavender oil (p<0.01). Significant changes of alpha 1 were also observed after inhalation of eugenol or chamomile. The change after inhalation of sandalwood was not significant. These results showed that alpha 1 activity significantly decreased under odor conditions in which subjects felt comfortable, and showed no significant change under odor conditions in which subjects felt uncomfortable. These results suggest a possible correlation between alpha 1 activity and subjective evaluation.


Keywords: odors, essential oils, EEG, sensory evaluation

Introduction

Fragrances, in the form of plant essential oils, have been used since ancient times as a medicinal treatment. This practice, more recently termed 'aromatherapy', has attracted much public attention (Tisserand, 1985). It is empirically known that fragrances affect our physical and mental conditions. As disorders attributable to mental stresses gradually come to pose a variety of serious problems in modern society, fragrances are increasingly expected to be useful for easily reducing the mental stresses that pervade in our daily lives.

Many attempts have been made in various research fields to clarify the physiological and psychological effects of odors (Hummel et al., 1992; Kobal et al., 1992; Lorig, 1989; Lorig et al., 1990; Lorig and Roberts, 1990; Našel et al., 1994; Sakuma et al., 1997; Sobel et al., 1998; Sugano, 1992). Further methods for identifying the sedating and exalting effects of odors have been discussed (Tisserand, 1985; Tori, 1986). However, the effects of odors are highly variable among individuals, and not constant even in a single individual. Therefore, it is appropriate to estimate these variables using various indices; more comprehensive evaluations, including types based on subjectivity, are required.

Evaluation techniques based on cerebral activities associated with sensory information processing are thought to be particularly important for evaluating the physiological effects of odors. However, such a technique has not yet been established; its relationship with subjective evaluation has not been clarified. The present study is focused on EEG changes during inhalation of essential oils, and the relationship of these changes to the corresponding subjective evaluations.

Method

Subjects

The subjects were 13 right-handed female students, ranging in age from 19 to 23 years (mean, 21 years). Subjects were screened for excessive nasal congestion,
EEG recording

EEG was recorded from 12 scalp positions of the international 10/20 system (F3, F4, C3, C4, P3, P4, O1, O2, F7, F8, T5 and T6; all referred to A1 + A2). EEG was amplified using multichannel biological amplifiers (Bio-Top 6R12-4, NEC Sanei Instrument) with a band-pass filtering between 0.1 and 32 Hz. EEG records contaminated by eye-blinks or motor artifacts were eliminated for each channel. EEG data were digitally filtered off-line to a 2–30 Hz bandwidth.

Odor administration

Four odors (three essential oils and eugenol) were applied in the experiment. The essential oils were lavender (LAVENDER ANGSTIFOLIA), sandalwood (SANRALUM ALBUM) and chamomile (CHAMAEMELUM NOBILE) (Pranalom Co.). Lavender, sandalwood and chamomile are all assumed to be sedative stimulants (Torii, 1986). Eugenol is a disinfectant. For each odor, the subjective intensity was established at an easily sensed olfactory level based on the preliminary investigation. After inhalation of each odor, the subjects were asked to mark the intensity scale of that odor from 0 (insensible level) to 26 (unbearable level) points. Odors were presented to each subject by means of a funnel-shaped supplier fixed on the chest, situated approximately 15 cm under the nose. The flowrate of the oil was set at 2000 ml/min.

Procedure

Subjects individually entered the climatic chamber where the temperature was kept at 26°C, the relative humidity at 60% and illuminance at 20 lux. The subjects were instructed to sit quietly, close their eyes and to breathe normally during each condition. Then, an electrode cap was affixed to the head. For each condition, EEG was recorded during rest (30 sec) and administration of the odor (90 sec). The presentation order of odor stimuli was counterbalanced for each subject. After each condition, the subjects were asked to complete a questionnaire on sensory evaluation. The climatic chamber was ventilated during the interim time between conditions, which period was approximately 3 minutes.

Data analysis

EEG from each electrode was analyzed by using biomedical software packages (BIMTAS and ATAMAP, Kissei Comtec Instrument). Ten-second epochs of EEG activity were estimated by Fast Fourier Transform (FFT) for four frequency bands (4–8 (theta), 8–10 (alpha 1), 10–13 (alpha 2) and 13–30 (beta) Hz) for each electrode during inhalation of each odor. Each power during inhalation of odor was compared with the power obtained from the 30-second (rest condition) EEG data by calculating the paired t-values every 10 seconds (A total of 9 epochs). The t-map was constructed by using the t-values and the interpolated values. The t-map is one of the image processing techniques, known as ‘significance probability mapping’. For purposes of constructing the t-map, the lattice points were set up as shown in Fig. 1. In these lattice points, the values for the non-measurement points were calculated by the following equations:

\[
\begin{align*}
A: \, (Fp1 + F7)/4, & \quad B: \, (Fp1 + Fp2)/2, & \quad C: \, (Fp2 + F8)/4, \\
D: \, (T5 + O1)/4, & \quad E: \, (O1 + O2)/2, & \quad F: \, (T6 + O2)/4, \\
Fp1: \, (F3 + F7)/2, & \quad Fp2: \, (F4 + F8)/2, & \quad T3: \, (F7 + T5)/4, \\
T4: \, (F8 + T6)/2, & \quad Pz: \, (F3 + F4)/2, & \quad Cz: \, (C3 + C4)/2, \\
Pz: \, (P3 + P4)/2.
\end{align*}
\]

Then the t-map was constructed by using the following equation for interpolation:

\[
V (x, y) = \frac{\sum_{m=0}^{6} \sum_{n=0}^{6} f (m, n) \sin [\pi (x-m)] \cdot \sin [\pi (y-n)]}{\pi (x-m) \cdot \pi (y-n)}
\]

where \( f (m, n) \) is the value of the lattice point.

For purposes of sensory evaluation, 22 odor-related adjective pairs were selected on the basis of our previous data (Miyakazi et al., 1993). This scale was digitized with scores from 1 to 7. Using the average values, basic factors were extracted by means of factor analysis (principle
component method, varimax rotation). The factors whose eigenvalues were more than 1.0 were extracted.

**Results**

**Odor intensity**

The ratings of odor intensity showed no significant differences among odors.

**Sensory evaluation**

Four basic factors were extracted from the 22 adjective pairs. Three of the 22 adjective pairs were excluded because the eigenvalues were less than 1.0. The first factor was “comfortable feeling”, the second “cheerful feeling”, the third “natural feeling” and the fourth “feminine feeling” (Table 1). The accumulative contribution ratio was 80.3%. The first factor (comfortable feeling), which showed the highest contribution among the basic factors, included “Stimulating - Unstimulating”, “Pleasant- Unpleasant”, “Restful-Impatient” and so on (Table 1). Figure 2 indicates the score of the first factor. The odors in order of high score were lavender, chamomile, eugenol and sandalwood.

**EEG data**

These results are expressed by the t-maps (Fig. 3). There were remarkable changes of alpha 1 during the inhalation of the essential oils. On the other hand, the power of alpha 2, theta and beta did not remarkably change. There were remarkable alpha 1 changes for 10 seconds after the beginning of inhalation of each odor. The changes of alpha 1 activity showed difference among the essential oils. Temporal changes were similar for each odor. The alpha 1-power on lavender significantly decreased from 0 to 10 seconds (P3, O1, O2, P3, P4, T5 and T6: p<0.01), and at 10–20 seconds (C3, F7, O1, P3 and T5: p<0.01) during inhalation. Then, alpha 1 power was found to return to the rest level at 20–30 seconds during inhalation, and significantly changed again at 30–40 seconds (O1 and P3: p<0.01) during inhalation, and

![Diagram](image)

**Table 1** Contribution of factors

<table>
<thead>
<tr>
<th>Adjective pairs</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
<th>Factor 4</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stimulating - Unstimulating</td>
<td>-0.888</td>
<td>0.240</td>
<td>-0.069</td>
<td>-0.085</td>
<td>Comfortable feeling</td>
</tr>
<tr>
<td>Pleasant - Unpleasant</td>
<td>0.827</td>
<td>0.218</td>
<td>0.130</td>
<td>0.280</td>
<td></td>
</tr>
<tr>
<td>Restful - Impatient</td>
<td>0.823</td>
<td>-0.005</td>
<td>0.093</td>
<td>0.328</td>
<td></td>
</tr>
<tr>
<td>Personal - Commonplace</td>
<td>-0.827</td>
<td>0.180</td>
<td>0.080</td>
<td>0.077</td>
<td></td>
</tr>
<tr>
<td>Exciting - Unexciting</td>
<td>-0.785</td>
<td>0.087</td>
<td>-0.223</td>
<td>0.019</td>
<td></td>
</tr>
<tr>
<td>Plain - Rich</td>
<td>0.758</td>
<td>0.142</td>
<td>-0.067</td>
<td>0.102</td>
<td></td>
</tr>
<tr>
<td>Agreeable - Disagreeable</td>
<td>0.750</td>
<td>0.347</td>
<td>0.230</td>
<td>0.199</td>
<td></td>
</tr>
<tr>
<td>Active - Gentle</td>
<td>-0.698</td>
<td>0.415</td>
<td>-0.003</td>
<td>-0.015</td>
<td></td>
</tr>
<tr>
<td>Refined - Unrefined</td>
<td>0.670</td>
<td>0.099</td>
<td>-0.075</td>
<td>0.455</td>
<td></td>
</tr>
<tr>
<td>Refreshing - Non-refreshing</td>
<td>0.655</td>
<td>-0.005</td>
<td>0.093</td>
<td>0.328</td>
<td></td>
</tr>
<tr>
<td>Solid-Soft</td>
<td>-0.623</td>
<td>0.069</td>
<td>0.077</td>
<td>-0.456</td>
<td></td>
</tr>
<tr>
<td>Cheerful - Gloomy</td>
<td>-0.025</td>
<td>0.831</td>
<td>-0.137</td>
<td>-0.085</td>
<td>Cheerful feeling</td>
</tr>
<tr>
<td>Dark - Light</td>
<td>-0.129</td>
<td>0.830</td>
<td>0.102</td>
<td>-0.266</td>
<td></td>
</tr>
<tr>
<td>Old-fashioned - New-fashioned</td>
<td>0.023</td>
<td>-0.108</td>
<td>0.848</td>
<td>0.295</td>
<td>Natural feeling</td>
</tr>
<tr>
<td>Urban - Rural</td>
<td>-0.201</td>
<td>0.150</td>
<td>-0.778</td>
<td>0.196</td>
<td></td>
</tr>
<tr>
<td>Natural - Artificial</td>
<td>0.221</td>
<td>0.225</td>
<td>0.704</td>
<td>0.175</td>
<td></td>
</tr>
<tr>
<td>Romantic - Unromantic</td>
<td>0.141</td>
<td>0.366</td>
<td>0.132</td>
<td>0.681</td>
<td>Feminine feeling</td>
</tr>
<tr>
<td>Feminine - Manly</td>
<td>0.497</td>
<td>0.017</td>
<td>-0.030</td>
<td>0.656</td>
<td></td>
</tr>
<tr>
<td>Delicate - Rough</td>
<td>0.494</td>
<td>-0.064</td>
<td>0.145</td>
<td>0.596</td>
<td></td>
</tr>
<tr>
<td>Eigen value</td>
<td>8.783</td>
<td>2.618</td>
<td>2.258</td>
<td>1.302</td>
<td></td>
</tr>
<tr>
<td>Contribution (%)</td>
<td>0.345</td>
<td>0.161</td>
<td>0.178</td>
<td>0.119</td>
<td></td>
</tr>
</tbody>
</table>

![Diagram](image)

**Fig. 2** Average scores of the first factor (Comfortable feeling) in factor analysis by inhalation of essential oils. N=13. Bars are standard errors.
thereafter (40–50 sec: C3, C4, F4, F8, O1, O2, P3, P4 and T5, p<0.01; 50–60 sec: O1, O2 and P3, p<0.01; 60–80 sec: T5, p<0.01). These significant decreases (the red areas in Fig. 3) were greatest over the parietal and posterior temporal regions.

During the first 10-second period after the beginning of odor inhalation, there were significant decreases of alpha 1 power in the left parietal regions (lavender: p<0.01, eugenol: p<0.01, chamomile: p<0.01) and the left posterior temporal regions (lavender: p<0.05, eugenol: p<0.01) during the inhalation of these oils. On the other hand, such changes were not observed for sandalwood. For each odor, the t-maps of alpha 1 power are presented in Fig. 4.

**Correlation between alpha 1 activity and sensory evaluation**

Significant decrease of alpha 1 was observed for three odors (lavender, eugenol, and chamomile) (i.e., all odors except sandalwood) during the first 10-second period of inhalation (Fig. 5). For relative value of the alpha power to 100% in the resting condition, the alpha 1 power decreased 19.70% for lavender, 14.74% for eugenol and 16.81% for chamomile (p<0.05). The significant decrease was persistent during the period in which lavender was presented. On the other hand, the decrease was not persistent for the other odors. For lavender, chamomile and eugenol, subjects estimated the duration of exposure as comfortable (Fig. 2). Alpha 1 showed no significant change for sandalwood, which was estimated as uncomfortable (Fig. 2). Thus, those odors that subjects felt comfortable while inhaling tended to correspond to decreases in alpha 1 activity.

To confirm the above finding, we divided the subjects into a “pleasantness” and an “unpleasantness”, based on their preference (Fig. 6). The preference ranges from 1, very pleasant to 7, very unpleasant on subjective evaluation. The preference score on pleasant group (pleasantness) was from 1 to 3. The preference score on unpleasant group (unpleasantness) was from 4 to 7. The alpha 1 power decreased in the pleasant group for 10 seconds after the inhalation of lavender, chamomile or eugenol. In this group, the positions showing significant alpha 1-decrease included F3, O1, O2, P3, P4, T5 and T6 (p<0.01) for lavender; F3, T6 (p<0.01), C3, C4, O1, P3 and P4 (p<0.05) for chamomile; and F7, O1, P3, T5 (p<0.01), C3, F8 and O2 (p<0.05) for eugenol. However, in the unpleasant group, the positions showing significant decrease (the red areas in Fig. 6) included only T5
Fig. 4 The t-map of the distribution of alpha 1 activity for 10 s after odor stimulation. This t-map was constructed by interpolation. The red area indicates a significant decrease of alpha 1 compared with its level during the resting condition. The changes in alpha 1 were observed during inhalation of lavender, eugenol and chamomile.

Fig. 5 Changes in alpha 1 at P3. P3 was one of the regions where EEG changed significantly. N=13. Bars are standard errors. *: p<0.05; Significant difference from the resting condition. The odor conditions in which subjects felt comfortable were characterized decrease in alpha 1 activity.

(p<0.01) for lavender and F8 (p<0.01) and O1 (p<0.05) for eugenol. In the case of sandalwood, the significant decrease of alpha 1 was not observed in either group.

Discussion

In this study, we found significant changes in alpha 1 activity during the inhalation of essential oils. The alpha activity usually corresponded to some sensory stimulation in addition to the olfactory stimulation (Lorig and Isaac, 1983; Motokizawa and Furuya, 1973). The signal itself was a form of sensory stimulation that immediately blocked further alpha activity. Lorig (1989) referred to topographical maps that may clearly show differences that are obscure in a table of EEG values. Regarding EEG changes during stimulation or a task condition, as compared with changes during a rest condition, significant probability mapping (Duffy et al., 1981) such as t-map is often used. By using t-maps of alpha 1, we obtained several types of patterns corresponding to each odor.

As to effects of odor on EEG activity, several studies have revealed an increase of alpha or theta rhythms during the presentation of odor (Sawada et al., 1992; Van Toller et al., 1993). However, Brauchili et al. (1995) reported that
Fig. 6 The t-map of the distribution of alpha 1 activity on pleasantness and unpleasantness. This t-map was constructed by interpolation. The red area indicates a significant decrease of alpha 1 compared with its level during the resting condition. Pleasant group: Lavender n=8, Chamomile n=5, Eugenol n=7 and Sandalwood n=5. The average for the pleasant group was 6.25 (± SD=1.5). Unpleasant group: Lavender n=5, Chamomile n=8, Eugenol n=6 and Sandalwood n=8. The average for the unpleasant group was 6.75 (± SD=1.5).

the sedative effects of some odors remain unclear; an increase in alpha rhythm may be such an effect. In the present study, alpha 1 showed significant decrease with no difference of beta and theta band during the presentation of a comfortable or pleasant odor. Therefore, the data obtained in the present study also bring into question the interpretation of more alpha activity in response to relaxation. Suppression of alpha 1 at some scalp electrodes
indicates the neural activity around the brain regions under them (Kikuchi, 1996). These findings are in agreement with data reported on other sensory stimuli, namely, that the alpha rhythm is suppressed during visual stimulation (Michel et al., 1994) or during acoustic stimulation (Kaufman et al., 1992). Therefore, it is suggested that the decreases in alpha rhythm during inhalation of odor reflect local activity related to the olfactory information processes in the brain.

Alpha 1 changes were mainly observed in the parietal and posterior temporal regions. These regions are related to integrative sensory information processing, including that of olfactory sensation. Based on this result, more complicated and integrative neuronal activities related to odors considered to occur in these regions. In addition, it is supposed that these regions have some relationship to emotions or experience, and that this emotional or experimental information is related to memory. Moreover, a relationship with memory has been suggested. Ehrlichman and Halpern (1988) reported that a significantly greater percentage of memories were categorized as happy by subjects in the pleasant odor condition as compared with those memories categorized by subjects in the unpleasant odor condition. The activities found in the present study may be related to these processes.

Alpha 1 decreased when the odors that subjects had evaluated as comfortable were inhaled. However, alpha 1 did not change when the odor that subjects had evaluated as uncomfortable was inhaled. These results suggest that there may be some correlation between alpha 1 activity and subjective evaluation. Furthermore, the decrease of alpha 1 power was observed in the pleasant group for three odors, including lavender, eugenol and chamomile (i.e., excepting sandalwood), when the subjects were divided into a pleasant group and an unpleasant group according to their preference of odors. The degree of alpha 1 decrease corresponds to a decrease of pleasantness or comfort; the subject’s preference (pleasant-unpleasant) of odors showed a high contribution in the first “comfortable feeling” factor (Fig. 6). Brauchli et al. (1995) suggested that olfactory stimulation by an unpleasant odor leads to a stronger cortical deactivation than does such stimulation by a pleasant odor. We expected the effects of odors in relation to positive or comfortable feelings. Therefore, the power of alpha 1 is thought to be one of the most useful indices of the comfortable or uncomfortable feelings of subjects.

Schifman et al. (1994) found that the use of fragrance can improve the overall mood of women at mid-life. In that study, feelings of tension, depression and confusion were significantly alleviated in the presence of pleasant odors. Conclusively, it is important that we make aromatherapeutic use of odors in consideration of the physical and subjective effects, in order to bring our physical and mental conditions to be comfortable.

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References


Kobal G, Hummel T, Toller SV (1992) Differences in human chemosensory evoked potentials to olfactory and somatosensory chemical stimuli presented to left and right nostrils. Chem Senses 17: 233-244


Lorig TS, Herman KB, Schwartz GE, Cain WS (1990) EEG activity during administration of low-concentration odors. Bulletin of the Psychonomic Society 28: 405-408


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