An Experimental Study of the Effect of Aroma on Brain Activity: Can We Relax by Just Smelling Aroma?

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Abstract

The present study investigated the relationship between olfactory stimulation and brain activity. In Experiment 1, points in a darts performance test and EEG were measured, comparing odor and control conditions, and the results showed a statistically significant increase in darts performance and in the power of brain waves. In Experiment 2, EEG was measured after a certain time interval. The relationships between aroma preference and the subjects' emotional state, and the influence of aroma on electrocortical activity, were also investigated. Alpha 2 dominated the electrocortical activity and beta levels decreased 12 to 18 minutes after aroma stimulation. The aroma preference and the subjects' emotional state were not found to have had a significant influence on the effectiveness of aroma. These findings suggest that aroma stimulation is an effective way to produce a UMB state, and is furthermore a very practical method for use in realistic settings.

Key Words : mental training, aroma, brain activity, five senses, peak performance

Introduction

Ichiro (Seattle Mariners) often refers to the need for psychological

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preparation and mental control in order to gain mastery over opposing pitchers. He has practiced such preparation prior to games, and uses special preparatory routines before all his at-bats, bending and stretching knees on his way to the batter's box, digging into the dirt, rounding his right arms, controlling his eyes, and cinching up his uniform with a predetermined gesture. His post game routine of cleaning his shoes and gloves is well-known as is his locker-room ritual of reflecting on and revisualizing all of his at-bats and fieldings of that night's game. All of these behaviors are methods to direct his mental condition toward peak performance.

Recently, a lot of athletes and coaches have become aware that psychological skills training (PST), which aims to control the internal environment, is necessary for peak performance. Toyoda (1998) claims that ideally athlete's psychological aspects, specifically his or her emotional and motivational states, should be controlled, and that the mental and physical states should be unified to ensure peak performance. The UMB (United Mind and Body) state is almost the same, psychologically, as the state of athletes who have achieved a peak performance state during competition(Toyoda, 1998; Williams, 1998). When mind and body are unified and harmonized, alpha waves become stronger and more predominant.

Numerous studies have shown the effects of olfactory stimulation in altering electrocortical activity (Brauchli, 1995). Van Toller et al. (1983) presented six odors on smelling strips and found that within 2.56 seconds there was a systematic increase of alpha power at the area right behind the central fissure and occipital region. They also reported a correlation between subjects' odor ratings and the electrocortical reactions. They found alternation in the alpha amplitudes in four domains, from anterior to the central fissure, correlating with subjective ratings.

However, reported results of odor presentation on frequency and spatial domains of ongoing EEG have been inconsistent. Schwartz et al. (1992) analyzed EEG data gained while subjects smelled three odors in flasks at supra-threshold and sub-threshold concentrations. When subjects detected the supra-threshold concentration, significant EEG alpha blocking was observed in anterior, central and posterior regions. When subjects smelled the sub-threshold concentration, significant alpha blocking was found in the central region and especially in the right hemisphere.

There can be several reasons to cause these inconsistencies namely; the compounds of aroma used, the way the aroma were presented, subjective ratings of aroma, and the subjects' emotional state as the aroma was presented. The following two experiments try to clarify the role of olfactory information in brain activity by measuring the electrocortical activity.

Experiment 1

There are two main variables which may have contributed to the inconsistent findings in previous studies of olfactory stimulation and brain activity. First, most of the previous research employed single vegetable -based scents such as lavender or lemon. Since the type of stimulation has a strong influence on results, the author applied another type of olfactory stimulation, using a compound of 180 vegetable essences. Secondly, many of the previous researches measured brain activity as subjects smelled the stimulations. Olfactory information is processed directly into the limbic system, so it may take time to alter electrocortical activities. We measured the frequency of EEG both during and immediately after stimulation.

Moreover, since the author aims to apply olfactory stimulation to athletic game preparation for relaxation/activation an experiment was also conducted on the change of athletic behavior with/without this aromatic stimulation.

Method

Subjects: 7 male college athletes were recruited. To reduce possible variability arising from sex differences in responding to the stimulus, only male subjects were examined.

Place: The experiment was carried out at a laboratory with temperature and humidity controlled.

Stimulus-odor: The stimulus-odor used here was a compound of 180 vegetable odors mixed, standardized and equalized in concentration, developed by F co Ltd. It was developed based on Indian medicine, aroma therapy, and Chinese herbal medicine.

Procedure: First, subjects were seated in a resting state with eyes closed for 3 min. Then they performed a task using darts. Afterward, they did the same tasks after aromatic stimulation. The odor was administered by first putting 2 mg of the compound on their hands. They then were instructed to rub their hands 15 times, cover their noses with both hands and breathe deeply 10 times (about 60 seconds)(odor condition 1). Then, they went back to a resting state (odor condition 2). In total, the odor condition was given for 3 min from when they started smelling. They performed the task with the darts again after odor stimulation.

Darts-performance task: The darts task was administered based on the international darts association rules. The darts board was set on the wall at a height of 173 cm from the ground to the center of the board, and a distance of 237 cm from the throwing line. Subjects were asked to throw 9 times in each condition.

Measuring and analyzing brain waves: EEGs of monopolar signals were measured using both earlobes as reference, and the power spectrum was transformed by Fast Furie Transformation (FFT). The five frequency bands of theta wave (4-8Hz), alpha1 wave (8-9Hz), alpha2 wave (9-12Hz), alpha3 wave (12-14Hz), and beta wave (14-30Hz) were classified from the power spectrum. The integral calculus value of the each frequency band was divided by total integral calculus values for construction values, and indicated the content of the each frequency band.

Results

The darts performance, here shown as the sum total of points from 9 throws, between control (no odor) and odor conditions was compared (Fig.1). Performance in odor condition was enhanced significantly (t=2.058, p<.05).

As the degree of concentration advanced, the total power of brain waves increased. Thus, the integral calculus values of odor sessions in each frequency band were compared to that of no-odor sessions (Fig.2, Fig.3).

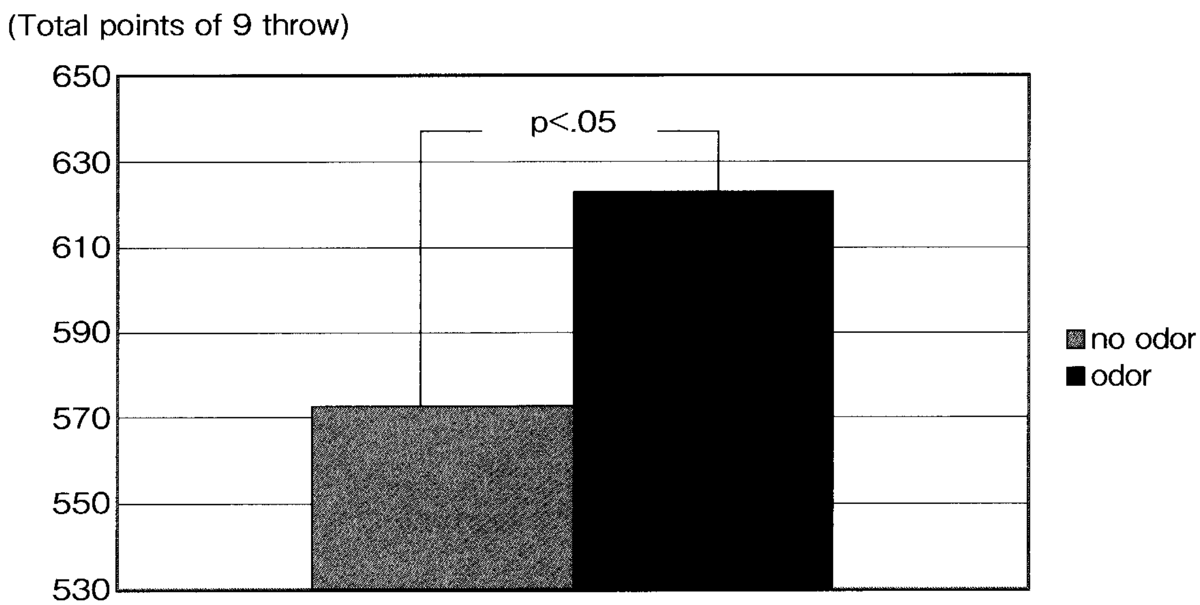

Fig.1 Increase in scores of darts task

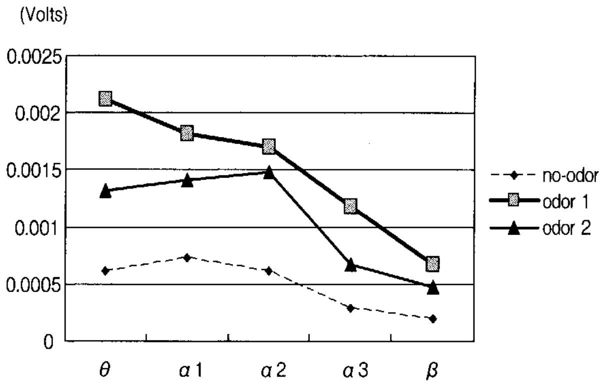

Fig.2 Increased power of brain waves(F3)

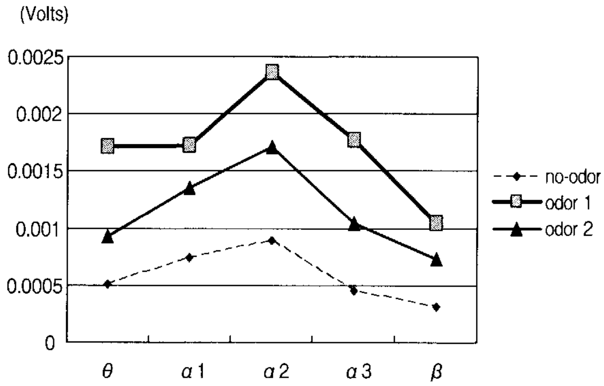

Fig.3 Increased power of brain waves (O1)

Brain waves contain a certain % of each frequency at any one time. The content of each frequency was examined, but the author did not find any significant differences (Fig.4).

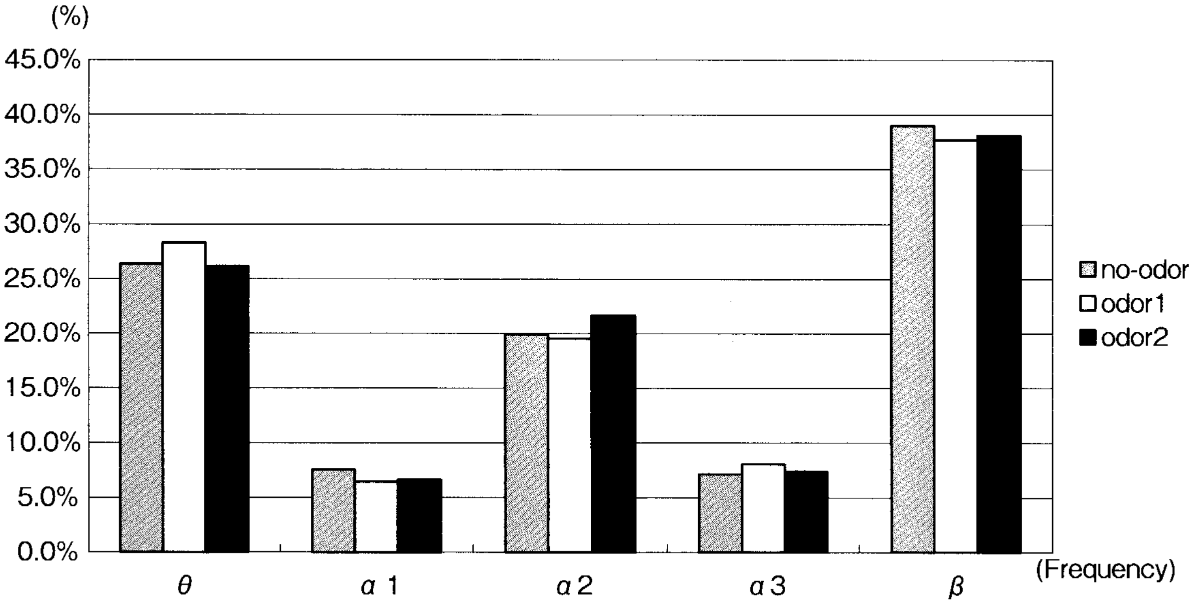

Fig.4 The content % of five frequencies (F3)

Discussion

Three main results were found in this experiment. 1) Odor stimulation significantly enhanced darts performance. 2) In odor condition, the power of brain waves was significantly increased. 3) There were no significant differences in the content of frequencies between conditions.

Darts performance requires fine motor control and a high level of concentration. Aromatic stimulation, which raised the power of brain waves, contributed to an enhanced physical and mental environment for the athletic performance. This shows that the aroma used in the experiment could be effective as a part of game preparation routines.

The content, however, did not change even after odorous inhalation. By producing a UMB state, or peak performance psychological state, the content of alpha wave, especially alpha2 wave, tends to increase, and the percentage of beta waves should be lower. As noted earlier, olfactory stimulation is processed through the limbic system, in which emotions, the autonomic nervous system, and hormone secretions are controlled. Since the limbic system is under the neocortical level of the brain, it takes time to alter electrocortical activities, which are measured over the thick neocortical layer and hard skull.

Moreover, the hedonic qualities of stimulation are said to affect brain activity (Brauchli, P., 1995). Because all the subjects were male, gender -specific influential variables might be experienced to aromatic stimulation, leading to a lower estimation of reference, and, as a result, an unchanged percentage of each frequency.

Experiment 2

Aromatic stimulation enhanced motor performance and the level of brain activity, but the wavelength content, which is considered the key component in producing a UMB state, was not changed in Experiment1. It is possible that time after stimulation, preference of aroma, and the subject's emotional state produced variations in the effects of odorous stimulation.

The purpose of Experiment 2 was 1) to assess the influence on electrocortical activity at certain intervals after aroma presentation, 2) to describe the change of aroma effect as time passed, 3) to assess the relationship between aroma preference and electrocortical activity, and 4) to assess the relationship between aroma and the emotional state at the time of aroma presentation, and how this influences to electrocortical reaction to aroma presentation.

Method

Subjects: 29 male college soccer players. For the purpose of reducing surplus variables, only male subjects were recruited.

Place: The experiment took place at a laboratory in which temperature and humidity were controlled between 18-22℃ and 40-60% respectively.

Stimulus odor: The compound was the same as used in Experiment 1.

Procedure: To create the aroma condition, 2 mg of aroma was administered on the palm, and then subjects were instructed to rub their hands about 15 times in order to reduce the effect of the alcoholic ingredients through evaporation. They then covered their noses with both hands, inhaled, and lowered their hands as they exhaled. As they were presented the olfactory stimulation, subjects were asked to perform diaphragmatic breathing for 3 minutes. Right after the administration of aroma, subjects completed a Profile of Mood State (POMS) test, which took about 8 minutes. 10 minutes after administration of the aroma, EEG was recorded for 3 minutes (10-13 minutes after the aroma administration), and another 3 minutes after a 5 minute break (18-21 minutes after the aroma administration). After the second EEG recording, the pleasantness of the aroma was rated on a five point scale.

In the control (no-odor) condition, subjects followed the same procedure as in the odor condition, except that distilled water was used instead of the aroma, and the estimation of aroma pleasantness was not carried out.

EEG measure: EEGs of monopolar signals were recorded, with both earlobes used as reference, from 8 electrodes (F3, F4, C3, C4, P1, P2, O1, and O2) based on international 10-20 methods. The EEG signals were transformed by the Fast Furie Transformation (FFT) and the power spectrum was calculated. Two frequencies of alpha2 (9-12 Hz) and beta (14-25 Hz) were classified from the power spectrum for the analysis of EEG.

Result

The comparison between odor and control conditions of the percentage change in integral values from 10 to 20 minutes after stimulation was conducted. The result revealed statistically significant differences in both alpha 2 ($t=6.04$, $p<.01$) and beta ($t=4.96$, $p<.01$) (Fig.5).

Using the results of one-way analysis of variance (ANOVA) repeated measures, the time after stimulation as an independent variable and the average amplitude as a dependent variable, both alpha 2 and beta were shown to have significantly changed(alpha2; $F=12.95$, $p<.01$, beta; $F=14.00$, $p<.01$). The results of Fisher's least significant difference (LSD) indicated increased alpha 2 and decreased beta power from 12 to 18 minutes after stimulation (Fig.6).

To investigate the influence of aroma pleasantness, subjects were divided into two groups (11 subjects in each group), according to their subjective ratings of pleasantness of the aroma. Subjects who rated the aroma very pleasant were labeled as "pleasant group", and those who rated it neutral or unpleasant were labeled as the "unpleasant group".

As shown in Tab.1, using aroma pleasantness and aroma stimulation as independent variables and the changed percentage of power as a dependent variable, a two-way ANOVA randomized block design was conducted and the result showed no substantial effect of aroma pleasantness and

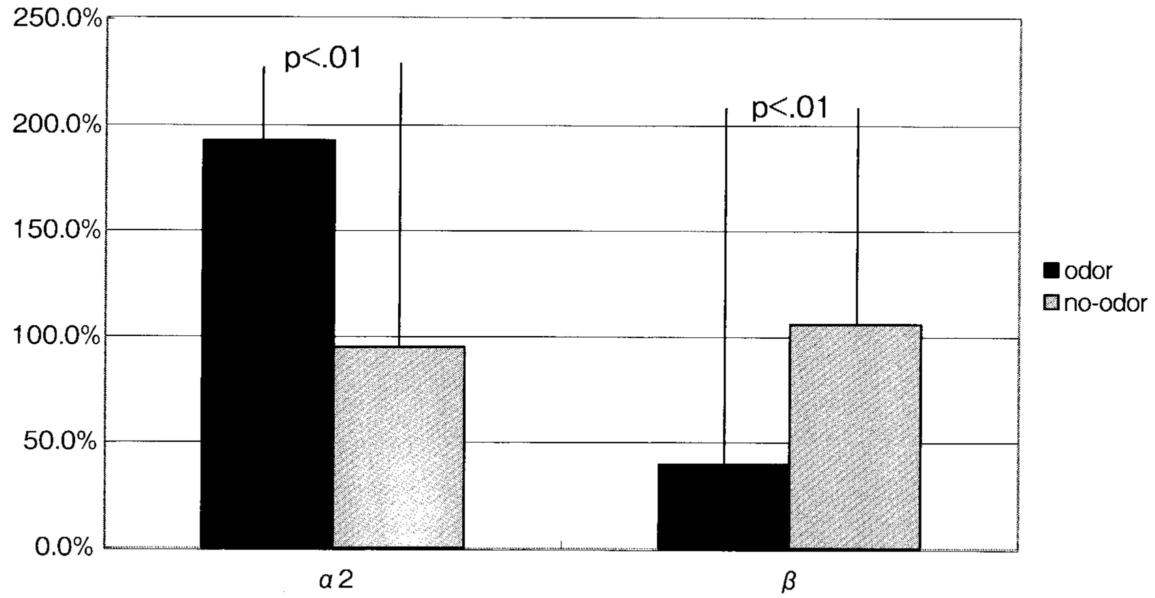

Fig.5 The comparison of % change of integral values from 10 to 20 minutes after aroma stimulation (F3)

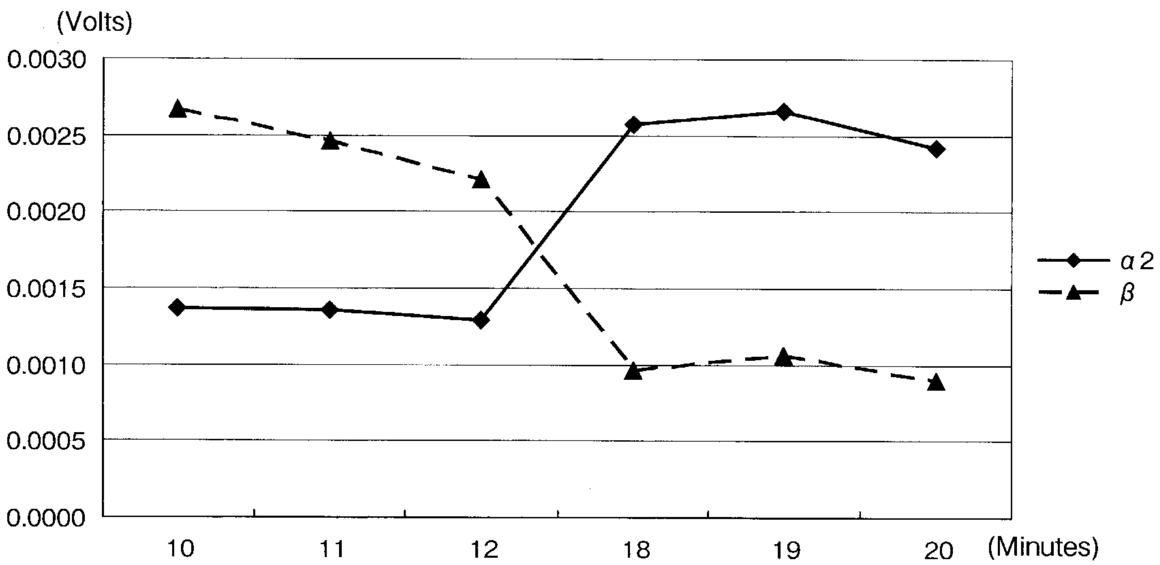

Fig.6 The comparison of average amplitudes (F3)

no interaction effect for alpha 2. At F3, C3, C4, P1, P2, and O1, the main effect of the aroma stimulation was found and the result of Fisher's LSD demonstrated that alpha 2 power was significantly enhanced (Tab.1).

For beta at F3, C3, C4, P1, P2, and O2, power was decreased significantly by aroma administration. Moreover, there was an interaction effect at O1 and O2, indicating, at O1, decreased beta power in the aroma condition for

Tab.1 The changed % of alpha 2 amplitude from 10 to 20 minutes after aroma stimulation

	Factor A (aroma)		Factor B (pleasantness)				
	aroma (%)	no-aroma(%)	pleasant (%)	unpleasant (%)	F value (A)	F value (B)	A×B
F3	194 (53.9)	96 (66.8)	154 (60.4)	136 (91.5)	26.893 **	0.929	0.249
F4	232 (149.9)	178 (183.2)	211 (128.0)	199 (202.6)	1.056	0.048	0.309
C3	202 (190.0)	92 (60.7)	165 (203.1)	129 (61.7)	6.252 *	0.676	0.115
C4	187 (46.6)	86 (35.3)	144 (68.2)	130 (61.0)	60.750 **	1.122	0.031
P3	218 (80.8)	83 (31.7)	147 (85.1)	154 (96.9)	48.703 **	0.133	0.070
P4	228 (70.7)	86 (32.0)	166 (88.4)	148 (90.4)	70.123 **	1.162	0.544
O1	242 (170.4)	85 (29.0)	158 (99.8)	168 (179.4)	16.583 **	0.066	0.169
O2	185 (101.4)	84 (43.0)	137 (81.1)	133 (103.0)	16.840 **	0.033	0.154

n=22 **; p<.01 *; p<.05

the "pleasant group" and increased beta in the no-odor condition for the "unpleasant group", and at O2 slightly decreased beta power for the " pleasant group" and significantly decreased beta(Tab.2).

To assess the influence of emotional states on the effects of aroma stimulation, the subjects were divided into two groups, a high T-A (Tension and Anxiety in POMS) level group and a low T-A group. 11 subjects, those who rated more than 50, were classified in the high T-A group and the 11 subjects who reported a T-A of less than 40 were classified in the low T-A

Tab.2 The changed % of beta amplitude from 10 to 20 minutes after aroma stimulation

	Factor A (aroma)		Factor B (pleasantness)				
	aroma (%)	no-aroma(%)	pleasant (%)	unpleasant (%)	F value (A)	F value (B)	A×B
F3	36.1 (9.69)	110.7 (77.92)	81.7 (86.69)	65.1 (36.06)	19.273 **	0.954	1.689025964
F4	73 (74.0)	271.8 (553.59)	128.8 (116.74)	215.9 (560.61)	2.596	0.498	0.460744789
C3	52.2 (63.04)	105.4 (91.66)	95.7 (113.21)	61.9 (20.07)	4.858 *	1.964	0.533583272
C4	39.2 (10.14)	97.3 (72.66)	78.3 (80.44)	58.1 (19.80)	13.931 **	1.687	2.845937547
P3	50.5 (30.96)	97.0 (71.89)	78.6 (78.28)	68.9 (32.09)	7.471 **	0.328	2.118649713
P4	51.1 (14.89)	98.1 (60.03)	79.0 (67.38)	70.2 (18.74)	12.546 **	0.437	3.04133381
O1	113.0 (147.34)	100.3 (41.74)	89.5 (49.17)	123.8 (143.28)	0.156	1.134	4.277 *
O2	59.2 (21.49)	106.2 (80.70)	92.9 (85.33)	72.5 (24.34)	7.279 *	1.368	4.478 *

n=22 **; p<.01 *; p<.05

group. EEG data were analyzed using two-way ANOVA (2 × 2), with the level of T-A and aroma stimulation used as independent variables and the changed percentage of power as a dependent variable. The results showed no substantial effect of emotional states and no interaction effect for either frequency.

Discussion

The present experiment addressed the questions of how aroma stimulation effects change over time and whether the preferences of aroma or emotional states change the effects of the aroma. Alpha 2 power was enhanced and beta power decreased as time passed, especially between 12 and 18 minutes from the end of aroma administration. This result indicates that a certain time interval is needed to alter the content of frequencies. As anticipated, the route of olfactory information can contribute to the result, meaning that it takes time to ascend, through electrocortical alternation, from the limbic system to the neocortical layer.

Another main finding was that emotional state did not influence the effect of olfactory stimulation. In preparing for athletic games/competitions, players' level of emotional arousal may vary, but you do not have to consider such differences. Similarly, aroma preference is not related to reactions in brain activity, at least for the aroma used in this experiment, so that practitioners do not have to consider those individual differences in terms of using the aroma for relaxation.

The result showed that the reaction of the occipital region differed depending on the aroma preference; beta power decreased for the preferred group, but it was enhanced for unpreferred group. The result has suggested the possibility of subjective judgment influencing occipital region, but since there have been inconsistent findings in terms of what regions react to olfactory stimulation, further studies should be conducted to clarify this matter.

Conclusion

The present study examined the influence of olfactory stimulation on electrocortical activities. The following results were found during the two experiments.

- Darts performance was enhanced significantly by aroma stimulation.
- Electrocortical activity was significantly altered during aroma presence, but only in power/integral values, not in its content.
- After a certain interval, the electrocortical activity was dominated by alpha 2 and beta power was decreased significantly.
- Brain activity alternation apparently occurred between 12 and 18 minutes after aroma administration.
- Aroma preference and the subjects' emotional state at the time of stimulation did not influence the effect of the aroma in general.
- The occipital region reaction to the aroma differed depending on subjective preference.

Psychological skills training or mental training tries to promote self-control through applications of various psychological techniques, such as breathing, mental imagery, and self-talk. Most skills aim to manage tension or emotional states. One finding of this study was that aromatic stimulation can be as much a part of mental training in generating a UMB state, or peak performance producing psychological states as the above-mentioned techniques. Aroma is far easier to apply from purely practical standpoint because mere exposure is not very difficult and does not require much time to create the desired outcomes.

In further studies, cognitive aspects of aroma's effect, and the duration of its effects need to be considered. Athletic skills contain such cognitive aspects as selective reaction and strategy selection. There is little scientific research which inquires into the relationship of such cognitive aspects and olfactory stimulation. This study suggests that the alpha wave enhancing effect of aroma persists for 20 minutes or more. The effective duration, however, is not yet known. It will be possible to use aroma to train athletes more effectively if these questions are answered.

As mentioned at the beginning of this study, the nature of the aromatic compound may also be a factor contributing to changes in electrocortical activity. Since this study used one aroma essence which includes 180 vegetable essences, the influence of the various constituents could not be examined directly. Therefore, in further studies, the differences between aromas with single compound essences and with various compound essences should also be investigated.

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付　　記

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