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Effects of Inhalation of Relaxing Essential Oils on Electroencephalogram Activity

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***Abstract*—The purpose of this study was to evaluate the effects of lavender (*Lavandula officinalis*) and bergamot (*Citrus bergamia, Risso*) essential oil inhalation on electroencephalogram (EEG) recordings. EEGs were recorded in 50 healthy participants. Twenty-five participants were assigned to the experimental group and twenty-five to the control group. Participants in the experimental group inhaled a mixture of 1 drop of lavender oil and 1 drop of bergamot oil were mixed in 20mL of distilled water for 5 min, using a nebulizer. Participants in the control group inhaled 2 drops of lavender oil were mixed in 20mL of distilled water for 5 min, using a nebulizer. EEGs were recorded using a quantitative 8-channel system, and data were analyzed using SPSS Win 18.0, including descriptive statistics and independent t-tests. The absolute theta power EEG spectrum at the right prefrontal lobe region significantly increased after essential oil inhalation in the experimental group compared to the control group. There were also significant differences in the relative fast and slow alpha power spectra after essential oil inhalation in the experimental group compared to the control group. Therefore, both physical and mental states became more stable and relaxed after inhalation of essential oil in the experimental group compared to the control group. A mixture of lavender and bergamot oil was more effective than lavender oil alone for sedation and relaxation, as well as for reducing anxiety and stress. In conclusion, these findings provide a scientific rationale for potential therapeutic interventions aiming to relieve anxiety and stress.**

***Index Terms*— Bergamot, Electroencephalogram, Lavender**

I. Introduction

Aromatherapy improves quality of life by increasing energy, as well as by promoting physical, mental, and psychological health using the therapeutic components of 100% natural essential oils that are extracted and refined from various plants [1-2]. Furthermore, aromatherapy is used as an intervention in various fields of study.

Previous studies have primarily investigated the abilities of *Lavandula officinalis* and *Citrus bergamia, Risso* oils to increase sedation and relaxation, as well as reduce anxiety and stress. These oils are readily available, which facilitates research on their effects.

The use of lavender oil originated in ancient Rome and Greece, and continues to be used till date [3]. Effects include sedation, analgesic effects, disinfection, and physiological balance. Some studies have also reported anesthetic effects of linalyl acetate and sedative effects of linalool, which are the main components of lavender [3-4]. Bergamot also reduces anxiety, symptoms of mild mood disorder, and cancer pain when used as aromatherapy [5]. Furthermore, bergamot does not activate the hypothalamus-pituitary-adrenal axis (HPA axis), owing to its ability to decrease the response of corticosterone, thereby contributing to reduced anxiety and stress [6].

Administration methods of aromatherapy include inhalation, lamp diffusion, topical application, bathing, massage, and footbaths. Aroma inhalation is a fast, convenient, and safe method [1]. The inhalation method uses a vaporizer or diffuser (nebulizer) [7]. In addition, the olfactory nerves are the only cranial nerves directly exposed to external stimuli, and they project directly to the cerebral cortex, thereby enabling strong stimulation [8]. During aroma inhalation, natural essential oils are volatilized to air, contact the cilia of nasal mucosa, affect the limbic system and hypothalamus via the olfactory nerves, produce sedative effects on the nervous and endocrine systems, and control physical and psychological changes. The transferred aroma particles then result in production of neurotransmitters such as dopamine and serotonin, which result in states such as sedation, relaxation, stimulation, and excitement. Furthermore, the olfactory nerve-limbic system axis can either strengthen cognitive functioning by stimulating the autonomic nervous system or reduce anxiety by promoting sedation and relaxation [1].

The present study was designed to objectively identify differences between aromas with sedation and relaxation effects, using EEG of brain waves as indicators of aroma-induced central nervous system activity. EEG is an appropriate method to determine central nervous system activity, particularly of the cerebral cortex. Awake cerebral activity can be identified by the frequencies recorded during brain functions such as excitement, anxiety, and sedation [9]. EEG measures and amplifies electrical activity at the scalp, which results from activity of neurons in the cerebral cortex, and it is a relatively objective and noninvasive method that enables constant measurement [10]. Interpretation of the quantitative EEGs used in the present study was objective and easy because EEGs were classified by frequency, power values were obtained, and the signal was digitized [11]. In general, EEG signals are classified as delta waves (0.5–3 Hz), theta waves (4–7 Hz), alpha waves (8–12 Hz), beta waves (13–30 Hz), and gamma waves (>30 Hz). Frequencies lower than those representing alpha waves (delta and theta waves) are classified as slow waves. Beta waves, with frequencies higher than alpha waves, are classified as fast waves [12].

Mixtures of 2–3 aroma oils synergistically optimize therapeutic effects, although 1 essential oil can also be used [1]. Therefore, we applied an evidence-based approach by verifying, comparing, and analyzing EEG changes during inhalation of mixed essential oil aromas including lavender

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oil and bergamot oil, which are broadly used for their safe relaxation effects.

II. METHODS

A. Study design

A quasi-experimental design with a nonequivalent control group was used. The independent variable was inhalation of relaxing essential oils. The dependent variable was EEG activity.

B. Participants

Participants were recruited through a posting on the homepage of a hospital located in C city, explaining the purpose of the study. Informed consent was obtained prior to participation. Detailed inclusion criteria were as follows: 1) possessed understanding of the study purpose and consented to participate; 2) adults 20–64 years of age; 3) nonsmokers; 4) no history of using analgesics, sedatives, narcotics, or anticonvulsants; 5) no history of psychiatric disorders, alcoholism, drug abuse, seizures, or severe physical diseases; 6) able to communicate and no disabilities in vision, hearing, or speech; 7) no surgical history related to the nose and no olfactory abnormalities; and 8) tolerance to lavender and bergamot oil during the aroma preference test.

I used G*Power 3.1.2. software to determine that 21 participants per group were required for t-tests at a significance level of (α) = .05, statistical power (1-β) = .80, and effect size (d) = 0.80. A total of 60 participants were recruited in order to account for attrition, including 30 participants in the experimental group and 30 participants in the control group. Randomized group assignment was accomplished using a computer program. Data analyses included 25 participants in the experimental group and 25 participants in the control group. Five participants were excluded from each group due to inaccurate EEGs, excessive movement during testing, or opening eyes during testing.

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III. MEASURE

A. Electroencephalograms

EEGs, which are indicators of human cognitive physiology, measure the electrical activity produced by neurons of the cerebral cortex by detecting signal at the scalp. This signal is amplified and presented graphically with electrical potential on the vertical axis and time on the horizontal axis. EEG waves are classified as alpha (α), beta (β), theta (θ), and delta (δ) according to their frequency (11 Jin, 2011). In the present study, all participants relaxed for 10 min in a bright soundproofed room, in order to prevent influences from the outside environment. Measurements were performed using an 8-channel computerized digital EEG system (QEEQ-8 LXE3208, Laxtha, Daejeon, Republic of Korea). A total of 10 EEG electrodes were attached to each participant’s scalp, using the 10–20 international standard electrode adhesion method. Electrodes included 8 channels (Fp1, Fp2, F3, F4, T3, T4, P3, and P4), including at the left and right pre-frontal lobes (Fp1, Fp2), frontal lobes (F3, F4), temporal lobes (T3, T4), parietal lobes (P3, P4), 1 grounding electrode to the left earlobe (A1), and 1 standard electrode to the right earlobe (A2). EEG measurements were collected and analyzed using Telescan program and quantified using Laxtha’s Batch Processing program. Alpha (8–12 Hz) waves were analyzed as the relative power and theta (4–7 Hz) waves were analyzed as the absolute power, using the Telescan program.

B. Procedure

Data collection was performed from July 19 to July 27, 2014, and participants were advised about the study-related precautions prior to participation. The experiment was performed in the following series of steps: first, researcher preparation and research assistant training, second, participant preparation, third, pretest, fourth, intervention, and fifth, posttest.

Researcher preparation and research assistant training

The researcher and research assistants received approximately 5 h of training by a Laxtha representative regarding electrode locations, electrode adhesion, equipment operation, and use of the computer program. They also practiced EEG measurement techniques with 3 participants while under the supervision of the trainer, in order to enhance consistency and reliability.

Participant preparation

Participants were provided with a detailed explanation of the study purpose, methods, process, and time required, in order that they could give informed consent and cooperate with study instructions. They were instructed to wash their hair, avoid drinking stimulant-containing beverages such as coffee, and to eat prior to testing because fasting can alter EEG responses because of hypoglycemia. Additionally, participants were instructed to remove eyeglasses, earrings, and hairpins.

Pretest

The room for EEG measurements was maintained at 20–25°C and was soundproofed in order to minimize influences of the outside environment. Participants entered the room, had the EEG electrodes attached, and were instructed to relax with their eyes closed for 10 min prior to the start of EEG recordings.

Intervention

In order to administer the aroma using a nebulizer, 1 drop of lavender oil and 1 drop of bergamot oil were mixed in 20mL of distilled water for the experimental group. For the control group, 2 drops of lavender oil were mixed in 20mL of distilled water and diluted (10mL, 1 drop: 0.5%). In order to avoid the solution getting into participants’ eyes, they were instructed to inhale with their eyes closed. In addition, in order to avoid stimulation of the mucous membranes of the eyes and nose, participants were instructed to inhale for 5 min by deep inspiration while they were sitting comfortably and holding the nebulizer nodule with a distance of approximately 10 cm between their nose and the nebulizer nodule. Participants were blinded to their group status (experimental or control).

Posttest

EEGs were recorded a second time, with eyes closed, immediately after aroma inhalation. Following the measurements, participants completed a subjective aroma sensitivity evaluation survey. The room was sufficiently ventilated while participants rested after testing, in order to prevent contamination by the experimental aroma prior to testing the next participant. The entire control group was tested first, followed by testing the entire experimental group. All experimental processes and conditions were identical. Participants were instructed to drink water in order to facilitate excretion of the aromas absorbed into their bodies, and to rest while the aroma-induced relaxation subsided.

C. Ethical considerations

This study was approved by the institutional review board (IRB-12-016). Testing occurred following explanation of the study purpose and procedure, and written consent was obtained from each participant. Participants were informed that the inhaled aromas would be excreted in urine after drinking a cup of water. Aroma inhalation and EEG measurements are not harmful to the human body; however, participants were informed that relaxation might occur for a short period after aroma inhalation. In addition, participants were informed that the data would be used only for the study purpose, would be kept anonymous, and that withdrawal from study participation was always possible. The researcher gave to the participants as a gift after completion of the study.

D. Data analysis

Data were analyzed using SPSS 18.0 software. Descriptive analyses were used to assess the demographic characteristics of the study participants, and homogeneity of characteristics between the experimental group and the control group was analyzed using χ^2-tests or Fisher's exact tests. Kolmogorov-Smirnov tests determined that the data followed normal distributions, thereby the effect of the two groups was analyzed using independent t-test.

IV. RESULTS AND DISCUSSION

A. *Demographic characteristics of participants and homogeneity test*

There were 25 participants in the experimental group and 25 participants in the control group. Forty-five percent of participants in the experimental group and 20% of participants in the control group were >40 years of age. Ninety-two percent of the experimental group and 88% of the control group were right-handed. Sixty percent of participants in the experimental group and 68% of participants in the control group were university graduates or had higher education levels, and 96% of both the experimental and control groups had no chronic diseases. There were no statistically significant differences between groups for any demographic characteristics (Table 1).

Also there was no significant differences in the dependent variable between groups at pretest (Table 2).

B. Data analysis for EEG

The theta wave absolute power spectrum (AT) appears during deep meditation and during the early stages of sleep. Also they are associated with deeply internalized and quiet physical states, emotion, and thought processes [12]. Theta waves increased in the right prefrontal lobe (Fp2), left frontal lobe (F3), right frontal lobe (F4), and right temporal lobe (T4) of the experimental group (lavender + bergamot inhalation group) following aroma inhalation; theta waves increased in the left temporal lobe (T3) of the control group (lavender inhalation group) following aroma inhalation. However, theta wave activity was significantly greater in the right prefrontal lobe (Fp2) of the experimental group compared to the control group ($t = -2.74$, $p = .009$). The experimental group experienced physical and mental relaxation, which was experienced as a more stable and comfortable condition compared to the control group after aroma inhalation.

The relative fast alpha power spectrum (RFA) occurs during relaxation [12]. The RFA increased in all recorded areas in the experimental group and decreased in the control group, following aroma inhalation. Differences in the RFA were statistically significant in the right frontal lobe (F4) ($t = -2.11$, $p = .040$) and the right parietal lobe (P4) ($t = -2.25$, $p = .030$) between the pretest and posttest recordings in the experimental group, but not in the control group. Therefore, participants in the experimental group were likely more internally relaxed, mentally comfortable, and subjectively stable compared to participants in the control group.

The slow alpha waves indicate brain activity associated with relaxation, falling asleep, or resting, active tasks are not necessarily stopped and may be maintained or resumed [12]. The relative slow alpha power spectrum (RSA) occurs during sleep or rest, and it increased in most recording areas of the experimental group compared to the control group. There were statistically significant differences between groups in the right prefrontal lobe (Fp2; $t = -2.08$, $p = .043$) and the left parietal lobe (P3; $t = -2.09$, $p = .042$). These results may indicate slow alpha wave increases related to relaxation, falling asleep, or resting following aroma inhalation in the experimental group compared to the control group (Table 3).

A limitation of this study is that the results may not be generalizable to populations with various health problems. In addition, I have not excluded the possibility that our results may be affected by psychological and environmental factors other than the aromas presented.

Further research is necessary in order to examine the effects aroma inhalation doses and time courses. Studies of the effects of aromatherapy in anxiety patients would also be beneficial.

Table 1. Homogeneity Test for General Characteristics of Participants (N=50)

. Characteristics	Categories	Experimental group (n=25)	Control group (n=25)	χ^2/t	*p*
		n(%)	n(%)		
Age (year)	20-29	5(20.0)	11(44.0)	5.19	.075
	30-39	8(32.0)	9(39.0)		
	=40-65	12(48.0)	5(20.0)		
Dominance*	Right-hander	23(92.0)	22(88.0)		1.000
	Ambidexterity	2(8.0)	3(12.0)		
Occupation	Yes	25(100)	25(100)		
Religion	Yes	10(40.0)	12(48.0)	0.33	.569
	No	15(60.0)	13(52.0)		
Education	≦High school	10(40.0)	8(32.0)	0.35	.556
	=College	15(60.0)	17(68.0)		
Chronic disease*	Yes	1(4.0)	1(4.0)		1.000
	No	24(96.0)	24(96.0)		

*Fisher's exact test.

Table 2. Homogeneity Test for Dependent Variables at Baseline (N=50)

Variables	Experimental group (n=25)	Control group (n=25)	t	*p*
	M±SD	M±SD		
Absolute Theta (AT) power spectrum				
AT_Fp1	20.68±19.21	22.11±12.12	0.32	.754
AT_Fp2	16.53±14.29	22.37±12.83	1.52	.135
AT_F3	20.33±18.90	23.18±17.21	0.56	.580
AT_F4	21.67±21.11	23.92±20.91	0.38	.707
AT_T3	14.41±14.55	21.48±22.61	1.32	.196
AT_T4	8.53±6.66	7.79±5.34	-0.43	.666
AT_P3	15.71±11.95	19.07±21.30	0.69	.496
AT_P4	14.10±10.44	20.48±19.86	1.42	.163
Relative fast Alpha (RFA) power spectrum				
RFA_Fp1	0.07±0.05	0.08±0.09	0.60	.554
RFA_Fp2	0.07±0.05	0.09±0.10	0.85	.402
RFA_F3	0.09±0.06	0.10±0.11	0.53	.598
RFA_F4	0.08±0.05	0.10±0.10	1.03	.309
RFA_T3	0.07±0.03	0.07±0.07	-0.16	.875
RFA_T4	0.08±0.04	0.08±0.04	0.02	.985
RFA_P3	0.15±0.13	0.17±0.17	0.42	.680
RFA_P4	0.14±0.11	0.19±0.19	1.26	.217
Relative slow Alpha (RSA) power spectrum				
RSA_Fp1	0.40±0.20	0.32±0.15	-1.61	.114

RSA_Fp2	0.42±0.21	0.32±0.16	-1.97	.055
RSA_F3	0.43±0.19	0.35±0.17	-1.59	.118
RSA_F4	0.40±0.20	0.35±0.15	-0.99	.326
RSA_T3	0.27±0.16	0.16±0.10	-3.01	.051
RSA_T4	0.33±0.17	0.26±0.14	-1.57	.124
RSA_P3	0.44±0.22	0.40±0.23	-0.67	.506
RSA_P4	0.45±0.22	0.41±0.22	-0.65	.518

Fp1=Left prefrontal; Fp2=Right prefrontal; F3=Left frontal; F4=Right frontal; T3=Left temporal; T4=Right temporal; P3=Left parietal; P4=Right parietal.

Table 3. Changes of Outcome Variables between the Experimental and Control Group (N=50)

Dependent variables	Pre-test	Post-test	Difference	t	*p*
	M±SD	M±SD	M±SD		
Absolute Theta (AT) power spectrum					
AT_Fp1					
Exp.	20.68±19.21	17.16±15.08	-3.52±9.54	-0.79	.433
Cont.	22.11±12.12	16.35±8.540	-5.75±10.42		
AT_Fp2					
Exp.	16.53±14.29	16.81±15.28	0.28±8.33	-2.74	.009
Cont.	22.37±12.83	16.24±8.87	-6.13±8.18		
AT_F3					
Exp.	20.33±18.90	21.38±18.22	1.05±8.59	-0.62	.538
Cont.	23.18±17.21	22.47±13.28	-0.71±11.28		
AT_F4					
Exp.	21.67±21.11	24.76±22.45	3.10±14.34	-1.63	.109
Cont.	23.92±20.91	20.71±12.80	-3.21±12.92		
AT_T3					
Exp.	14.40±14.54	13.52±11.88	-0.88±6.06	0.64	.527
Cont.	21.48±22.61	26.05±34.72	4.57±42.02		
AT_T4					
Exp.	8.53±6.66	9.63±11.47	1.10±9.59	-0.78	.441
Cont.	7.79±5.34	7.31±4.34	-0.48±3.35		
AT_P3					
Exp.	15.71±11.95	15.70±14.77	-0.01±9.69	-1.13	.265
Cont.	19.06±21.30	15.95±13.17	-3.12±9.79		
AT_P4					
Exp.	14.10±10.44	13.21±10.55	-0.89±5.93	-0.70	.489
Cont.	20.48±19.86	17.60±13.11	-2.88±12.96		
Relative fast Alpha (RFA) power spectrum					
RFA_Fp1					
Exp.	0.07±0.05	0.08±0.04	0.01±0.03	-1.34	.186
Cont.	0.08±0.09	0.08±0.08	-0.00±0.04		
RFA_Fp2					

Exp.	0.07±0.05	0.08±0.04	0.01±0.04	-1.76	.085
Cont.	0.09±0.10	0.08±0.08	-0.01±0.04		
RFA_F3					
Exp.	0.09±0.06	0.10±0.05	0.02±0.05	-1.24	.222
Cont.	0.10±0.11	0.10±0.08	-0.00±0.06		
RFA_F4					
Exp.	0.08±0.05	0.10±0.06	0.02±0.05	-2.11	.040
Cont.	0.10±0.10	0.09±0.07	-0.01±0.05		
RFA_T3					
Exp.	0.07±0.03	0.10±0.04	0.03±0.04	-1.86	.068
Cont.	0.07±0.07	0.07±0.03	-0.00±0.06		
RFA_T4					
Exp.	0.08±0.04	0.10±0.05	0.02±0.04	-1.76	.085
Cont.	0.08±0.04	0.08±0.03	-0.00±0.04		
RFA_P3					
Exp.	0.15±0.13	0.17±0.12	0.02±0.09	-1.40	.169
Cont.	0.17±0.17	0.15±0.14	-0.02±0.11		
RFA_P4					
Exp.	0.14±0.11	0.16±0.11	0.03±0.10	-2.25	.030
Cont.	0.19±0.18	0.14±0.15	-0.05±0.15		
Relative slow Alpha (RSA) power spectrum					
RSA_Fp1					
Exp.	0.40±0.20	0.34±0.17	-0.06±0.08	1.00	.322
Cont.	0.32±0.15	0.29±0.14	-0.03±0.11		
RSA_Fp2					
Exp.	0.42±0.21	0.34±0.18	-0.08±0.12	2.08	.043
Cont.	0.32±0.16	0.31±0.17	-0.01±0.12		
RSA_F3					
Exp.	0.43±0.19	0.36±0.17	-0.07±0.11	0.91	.366
Cont.	0.35±0.17	0.31±0.17	-0.04±0.12		
RSA_F4					
Exp.	0.40±0.20	0.33±0.17	-0.07±0.12	1.06	.295
Cont.	0.35±0.15	0.32±0.16	-0.03±0.12		
RSA_T3					
Exp.	0.27±0.16	0.25±0.12	-0.02±0.11	1.36	.180
Cont.	0.16±0.10	0.18±0.09	0.02±0.10		
RSA_T4					
Exp.	0.33±0.17	0.29±0.14	-0.04±0.10	1.36	.181
Cont.	0.26±0.14	0.26±0.15	-0.00±0.09		
RSA_P3					
Exp.	0.44±0.22	0.36±0.17	-0.08±0.13	2.09	.042

Cont.	0.40±0.23	0.40±0.22	0.01±0.16		
RSA_P4					
Exp.	0.45±0.22	0.36±0.17	-0.09±0.13	1.73	.091
Cont.	0.41±0.22	0.39±0.24	-0.02±0.16		

Exp.=Experimental group (n=25), Cont.=Control group (n=25); Fp1=Left prefrontal; Fp2=Right prefrontal; F3=Left frontal; F4=Right frontal; T3=Left temporal; T4=Right temporal; P3=Left parietal; P4=Right parietal.

CONCLUSION

Lavender and bergamot essential oils are used for a wide range of cosmetic and therapeutic purposes. Mixtures of 2–3 aromas optimize synergistic therapeutic effects, although 1 essential oil can also be used [1]. The present study found significant alpha and theta wave changes, based on EEG analyses, resulting from inhalation of combined lavender and bergamot oil aromas.

This study revealed that physical and mental states became more stable, comfortable, and relaxed after essential oil aroma inhalation by the experimental group compared to the control group. Therefore, a mixture of lavender and bergamot at a 1:1 ratio is more effective for increasing sedation and relaxation, as well as for reducing anxiety and stress, compared to lavender alone. The results of this study provide preliminary scientific evidence regarding the possibility that mixtures of aromatherapy oils can be applied as complementary medicine for people with anxiety and stress.

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