Effects of Inhaling Essential Oil on Decreasing Mental Fatigue: A Physiological Indices Study

Shyh-Yueh Cheng

Department of Occupational Safety and Health
Chia-Nan University of Pharmacy and Science
Tainan, Taiwan 717, ROC

ABSTRACT

Essential oil inhalation is one of the important aromatherapy. Essential oils are always used to dispel fatigue by officer workers. Owing to lack of objective measured data of the effect on decreasing fatigue for essential oil, the reliability of subjective experiment from questionnaire has always been challenged. The purpose of this study is to evaluate the effect on decreasing mental fatigue for inhaling essential oil by using physiological indices including Electroencephalogram (EEG) and heart rate variability (HRV). The basic and ratio indices of EEG power reflecting the drowsiness and relaxation levels, and the variety of HRV reflecting the condition of mental workload were used to evaluate the effect on decreasing mental fatigue substantially for inhaling essential oil. Twenty college students aged from twenty to twenty-five years old recruited for subjects participated the experimental test. Before experimental test, the subjects must fill in NASA-TLX self-evaluation inventory and measured their EEGs and heart rate variability (HRV) for five minutes. The subjects undertook their school courses about four hours and then inhaled essential oil. The study found that EEG power ratio indices (+)/ decreased and / increased after inhaling essential oil. It demonstrated that the subjects inhaled essential oil would facilitate their relaxation obviously. The result of heart rate variability showed that low-frequency component LF decreased, high-frequency component HF increased and LH/HF decreased obviously after inhaling essential oil. For NASA-TLX rating scales measurement, the participants subjectively felt more relaxed. It revealed that the subjects had remarkable effect to decreasing mental fatigue after inhaling essential oil. To summarize as mentioned above, our study found that essential oil had obvious effect on decreasing mental fatigue and facilitating relaxation.

Keywords: Essential Oils, EEG, Heart Rate Variability, mental fatigue, relaxation level

INTRODUCTION

In our competition society, what we concern is efficiency. Life step becomes faster gradually. Either official business at workplace or private business at home, to face the stress is become a part of our lives. Stress, especially mental stress may result in bother of anxiety and emotionality. Mental stress from workplace would cause physical and mental harm, even increase the probability of the accident. Lin & Hwang (1992) addressed workers' physical and mental stresses usually arise from the task demands at workplace. As the performance of the worker could not consist with the request of the tasks, the workplace would bring stress to him. The stress employee encounters at workplace may essentially endanger his/her health, moreover, induce the human error causing an accident. The research reported there was 70% - 90% system failure resulted from directly or indirectly human error due to the work stress (Lin & Hwang, 1992). As human errors attributable to mental stresses gradually come to pose a variety of serious problems in workplaces, some stress reliefs, e.g. fragrance therapies, 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 fragrances (odors) (Hummel et al., 1992; Kobal et al., 1992; Sakuma et al., 1997; Sobel et al., 1998; Sugano, 1992). However, the effects of fragrances 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 fragrances. However, such a technique has not yet been established; its relationship with subjective evaluation has not been clarified. In this study, we attempted to evaluate the effect on decreasing mental fatigue for fragrances derived from essential oil by using physiological indices including electroencephalography (EEG) and heart rate variability (HRV).

Electroencephalography is the neurophysiologic measurement of the electrical activity of the brain by recording from electrodes placed on the scalp. Electrode placement is accomplished by measuring the scalp. Electrode locations and names are specified by the International 10–20 system. This system ensures a system of placement that is reliable and reproducible. The resulting traces are known as an electroencephalogram and represent an electrical signal (postsynaptic potentials) from a large number of neurons. These are sometimes called brainwaves, though this use is discouraged (Cobb, 1983), because the brain does not broadcast electrical waves. The EEG is a brain function test, but in clinical use it is a “gross correlate of brain activity” (Ebersole, 2002). The EEG is frequently used in experimentation because the process is non-invasive to the research subject. The subject does not need to make a decision or behavioral action in order to log data, and it can detect covert responses to stimuli, such as calculation. The EEG is capable of detecting changes in electrical activity in the brain on a millisecond-level.

One of the most widely researched areas of heart-related measures in mental condition is the spectral analysis of heart rate variability (HRV), which is a signal analysis based on the amplitudes of the cardiac interval signal at various frequencies. The HRV power spectrum can be classified into three major frequency bands, which are each associated with different functional influences on the R–R interval time, including: (1) the very low frequency band (VLF, 0.01-0.04 Hz), associated with the regulation of peripheral vasodilatation and body temperature, (2) the low frequency band (LF, 0.01-0.04 Hz), associated with the reaction of pressure receptor and regulation of arterial pressures, (3) the high-frequency band (HF, 0.15-0.4 Hz), reflecting the effects of respiratory activity on the cardiac interval signal (Mulder, 1979; Saul, 1990). Many studies showed that an increase in mental effort was typically related to a reduction in the power associated with the low frequency band in the HRV power spectrum, implying a temporary suppression of normal arterial pressure regulation (Aasman et al, 1987; Mulder, 1979; Tattersall and Hockey, 1995; Vicente et al., 1987). For example, in one such study, the validity of the spectral analysis of HRV as a measure of mental workload was investigated using a psychomotor task. The results demonstrated the existence of a strong relationship between the subjective ratings of effort and the mid-frequency band of the HRV power spectrum (Vicente et al., 1987). Many studies (Rimoldi et al., 1990; Pagani et al., 1991; Montano et al., 1994) have shown that whenever the signal produced by HRV was adequate and the sympathyovagal balance was shifted toward a sympathetic predominance with mental stress (Pagani et al., 1991) the LF or LF/HF component was augmented (Montano et al., 1994). This suggests that various conditions do affect the modulation of the heart by the autonomic nervous system and have validated the use of HRV as a measurement of autonomic activity. Shusterman et al. (2005) suggested that intensity of sympathetic nerve activity could be an indicator of mental stress. In driving task, indicator of HRV was used to evaluate driving fatigue by Li et al. (2003) and Yang et al. (2005). Their finding was four (electrocardiogram) HRV power spectra on time domain significantly related to fatigue level. The indicators of HRV on time domain including standard deviations of R-R interval ascending, low frequency power increased, high frequency power decreased, and sympathetic/parasympathetic balance index raised could be used to qualify the level of fatigue.

METHODS AND MATERIALS

Subject

Twenty university students including 15 males and 5 female with age from 20 to 25, average 21.5±1.3, participated as volunteer subjects. They had normal hearing and normal or corrected-to-normal vision. Each participant met all the inclusion criteria: no medical, psychiatric, or head injury, and not using any medications or drugs. An informed written consent form was obtained from all the participants after the procedure of the study was explained and the laboratory facilities were introduced to them. They were paid for their participation in the study.

Experiment protocol

The experiment task was clearly explained first, and participants were required to record their EEGs and HRVs before starting the experimental session. The subjects were divided into two experimental groups: those who inhaled essential oil (bitter orange essential oil was employed in this study) and those who inhaled pure air (placebo test) as the control group. The EEGs and HRVs were measured at rest condition for five min under the experimenter's instruction. After the measurement of the EEG and HRV were finished, the subjects undertook their school courses about four hours. Similar EEG and HRV recordings were conducted immediately after their school courses. After inhaling essential oil for 15 min, the participants repeated the EEG and HRV measurement mentioned above, and then finished the whole test. At the end of each EEG and HRV measurements, self-report assessments of task loading were obtained by using the NASA-Task Load Index (TLX) rating scale (Hart and Staveland, 1988) after four-hour school courses. The participants were instructed to avoid alcohol and caffeine in the 24 hours before the test. On the test day, the experimental task started at 8 AM. Participants performed the task alone in a dimly lit, sound-attenuated, electrically shielded test room.

HRV data collection

During the 5-min test, Mind Media B.V.Netherlands used the oscillatory method to obtain heart rate, systolic pressure, and diastolic pressure. It then conducts a standard 5-min HRV test. For HRV recording, a finger photoplethysmograph (PPG) was used. A PPG is a non-invasive transducer to measure the relative changes of blood volume in a subject's finger to measure the heart rate of the subject. Peak-to-peak intervals are determined followed by time and frequency domain analyses. The HRV analysis follows closely the 1996 international standard (Task Force of the European Society of Cardiology and North American, 1996). It is noted above that irregular heartbeats (those with peak intervals greater than 4 standard deviations in the 5-min test data) are excluded from the raw data prior to HRV analysis (as recommended by the 1996 Standard).

EEG data collection

During task performance, EEG was recorded by using an electrode cap (Quick-Cap, Compumedics NeuroScan, El Paso, Texas) with Ag/AgCl electrodes placed at F3, Fz, F4, Cz, Pz, O1, Oz, and O2 in the International 10–20 montage with an electronically linked mastoid reference (Andreassi, 2000). Two Ag/AgCl electrodes were placed 2 cm above and 2 cm below the left eye to record vertical electrooculogram (EOG). Two electrodes were positioned at 1 cm external to the outer canthus of each eye for horizontal EOG recording. A ground electrode was placed on the forehead. Electrode impedances were kept below 10 kΩ. The EEG and EOG were amplified by SYNAMPS amplifiers (Compumedics Neuroscan, Inc.) and sampled at 500 Hz. The EEG epochs were then corrected by eye movement by using the Ocular Artifact Reduction command of SCAN 4.3 (Compumedics Neuroscan, Inc.) and then underwent movement-artifact detection by using the Artifact Rejection command (Semlitsch et al., 1986). The recorded EEG during 5-min rest condition was subsequently transformed from time into frequency domains by fast Fourier transform (FFT) using a 5-s Hanning windowing function. The EEG power values were summed at 0–4 Hz, 4–8 Hz, 8–13 Hz, and 13–20 Hz, representing the frequency bands of delta (δ), theta ( ), alpha ( ), and beta ( ) activities, respectively (Fisch, 1991). We analyzed the relationship between EEG power of , , , / , / and (+)/ indices (Brookhuis and Waard, 1993; Eoh et al., 2005; Ryu and Myung, 2005; Cheng et al., 2007). The basic index means the relative power of the EEG , and bands. The band was not included in our analysis, since it happens in a deep sleep state and usually overlaps with artifacts. The relative power equation of , , and bands are represented respectively as:

Relative power of = (power of) / (power of + power of + power of) (1)

Relative power of = (power of) / (power of + power of + power of) (2)

Relative power of = (power of) / (power of + power of + power of) (3)

EEG power measured at recording sites F3, Fz, F4, Cz, Pz, O1, Oz, and O2, were analyzed by means of separate repeated-measures analyses of variance (ANOVA) with the within-subjects factors "session" including before (BT), immediately after (AT), and 15 min after (15-min AT) tasks, and "electrode" including recording sites F3, Fz, F4, Cz, Pz, O1, Oz, and O2). Where appropriate, differences from, sessions, electrodes, or electrode-by-session interactions were further evaluated with Fisher LSD post hoc tests (nominal level of alpha: $P < 0.05$).

NASA-TLX rating scale

The NASA-Task Load Index (NASA-TLX) consists of six component scales: mental demand, physical demand, temporal demand, performance, effort, and frustration level. An average of these six scales, weighted to reflect the contribution of each factor to the workload of a specific activity from the perspective of the rater (subject), is proposed as an integrated measure of overall workload. Each dimension (subscale) has a twenty point Likert scale with the end points labeled ‘‘Low’’ and ‘‘High’’, respectively. The performance scale is logically reversed and has endpoints labeled ‘‘Good’’ and ‘‘Poor’’. While an overall TLX score can provide details about the overall workload of a task, the subscales specify the area of particular concern for a task. This type of information is hard to discern from more objective measures. While the TLX has some advantages, subjective measures are also known to be problematic. One major area of concern is the reliance on individuals completing the scale to know that they are experiencing and how to interpret those feelings.

RESULTS

The EEG indices, classified into two kinds—the basic index and the ratio index, were derived from the reorganized data. Since the basic indices have a tendency to contradict each other, the ratio indices were calculated to amplify the differences. The known ratio indices / , / , and (+)/ were analyzed in previous studies (Brookhuis and Waard, 1993; Pyun and Kim, 2000; Ryu and Myung, 2005). ANOVA results of the six basic and ratio indices for experiment and control groups are presented in Table 1 and Table 2 respectively.

Table 1 ANOVA summary for EEG measurement in experiment group.

Index	Location	Session	Interaction
θ	<0.01**	0.718	0.819
α	<0.01**	<0.05*	0.880
β	<0.01**	<0.01**	0.997
θ/α	<0.01**	0.224	0.574
β/α	<0.01**	<0.05*	0.070
$(\alpha+\theta)/\beta$	<0.01**	<0.01**	0.171

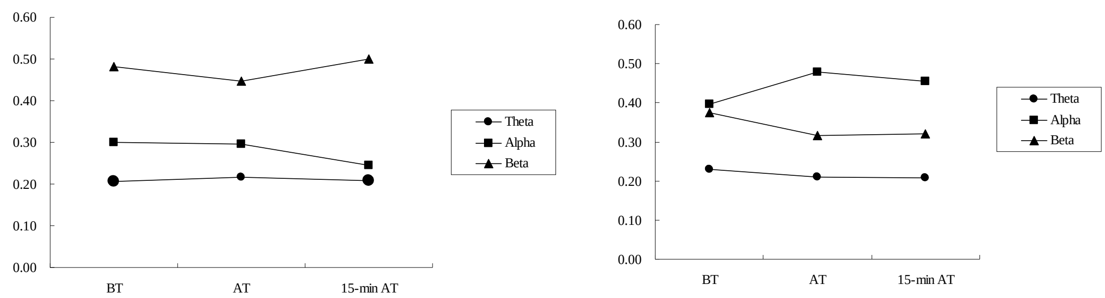
*Significant at $\alpha = 0.05$, **Significant at $\alpha = 0.01$.

Table 2 ANOVA summary for EEG measurement in control group.

Index	Location	Session	Interaction
θ	<0.01**	0.796	0.819
α	<0.01**	0.0575	0.880
β	<0.01**	0.0534	0.997
θ/α	<0.01**	0.224	0.574
β/α	<0.01**	<0.05*	0.063
(α+θ)/β	<0.01**	0.0614	0.193

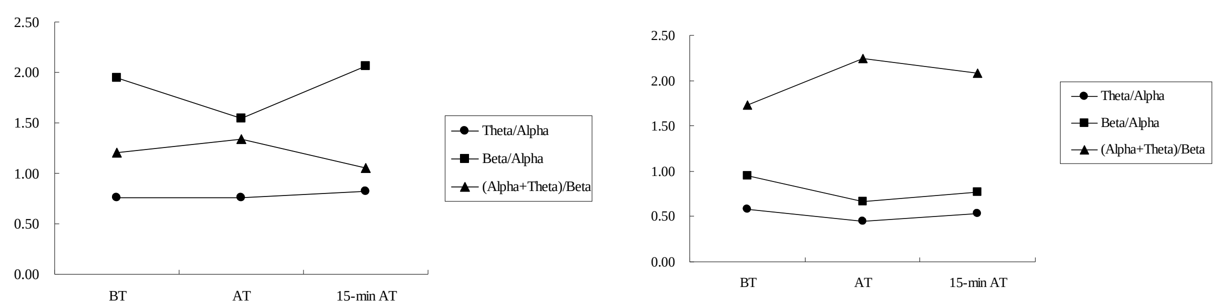
*Significant at α = 0.05, **Significant at α = 0.01.

In two groups, all indices showed significant difference in location, and all indices except and / showed significant difference in session. Student-Newman-Keuls (SNK) post hoc analysis for the factor of location showed that the frontal (F3, Fz, F4), centro-parietal (Cz, Pz) and occipital (O1, Oz, O2) were separated into statistically different groups (= 0.05). In the post hoc analysis for the factor of the session, AT and 15min-AT revealed significantly different. No indices showed a significant difference of interaction effect. For experiment group, 15 min of inhaling essential oil after the experimental task was completed, the basic indices and had decreased and increased respectively, and recovered to the level in the BT session. For control group, the basic indices and tend to decrease and increase respectively, but not reveal statistically significant difference. EEG plots of two indices whose main factor was statistically significant as depicted in Fig. 1(a) and 3(b). For experiment group, the ratio indices / revealed significantly decreased immediately for 15 min of inhaling essential oil after the experimental task than those before. Additionally, ratio indices (+)/ showed significant decrease after 15 min of inhaling essential oil, and recovered to the value even lower than the BT session, as shown in Fig. 2(a). For control group, except / showed significant increase after 15 min of placebo test, other ratio indices reveal no statistically appreciable difference, as shown in Fig. 2(b).



(a) (b)

Fig. 1 Comparison of EEG basic indices among three sessions. BT: before task, AT: immediately after task. (a) and (b) are experiment group and control group.



(a) (b)

Fig. 2 Comparison of EEG ratio indices among three sessions. BT: before task, AT: immediately after task. (a) and (b) are experiment group and control group respectively.

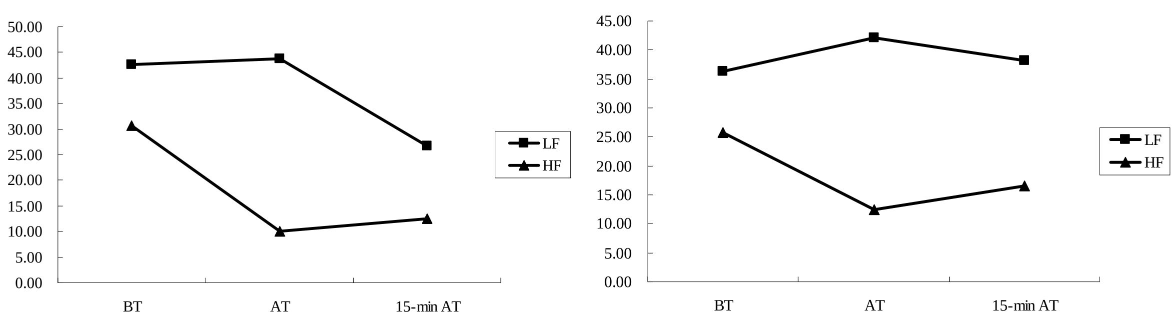
Table 3 shows the average values of HRV including LF, HF and LF/HF. HRV plots of three indices values were shown as Fig. 3 and Fig. 4. For experiment group, 15 min of inhaling essential oil after the experimental task was completed, the sympathetic nervous activity index LF had decreased and recovered to the level in the BT session, and the parasympathetic nervous activity index HF had increased but revealed no statistically significant difference with AT session. For control group, both LF and HF revealed no statistically significant difference with AT session. After 15 min of inhaling essential oil, the average values of sympathovagal balance index LF/HF had decreased for both experiment and control groups, but experiment group (P=0.00037) had decreased more than control group (P=0.000754) did. The mean rating scale of mental fatigue tended to increase immediately after the completion of the task for both experiment and control groups. For experiment group, at 15 min rest after the completion of the experimental task the rating scale had decreased and was nearly equal to the value in the BT session. The rating scale revealed a statistically pronounced difference between AT and 15-min AT. For control group, the mean rating scale of mental fatigue didn't recover to the level in the BT session after 15 min of placebo test. The mean rating scale of mental fatigue tended to increase immediately after the completion of the task for both experiment and control groups. For experiment group, at 15 min rest after the completion of the experimental task the rating scale had decreased and was nearly equal to the value in the BT session. The rating scale revealed a statistically pronounced difference between AT and 15-min AT. For control group, the mean rating scale of mental fatigue didn't recover to the level in the BT session after 15 min of placebo test.

Table 3 ANOVA results for HRV measurement in experiment and control groups.

Test condition	HRV	BT	AT	15-min AT
experiment group	LF(%)	42.55	43.72	26.79**
	HF(%)	30.64	10.06	12.52
	LF/HF	1.70	4.63	2.68***
control group	LF(%)	36.38	42.05	38.24
	HF(%)	25.81	12.37	16.46
	LF/HF	1.76	3.62	2.52***

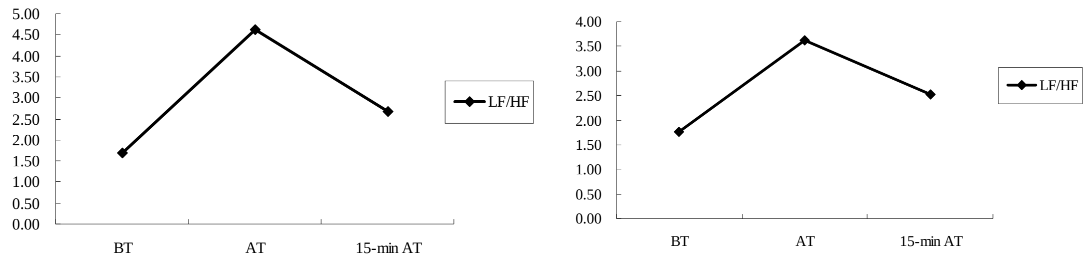
*Significant at $\alpha = 0.05$, **Significant at $\alpha = 0.01$, ***Significant at $\alpha = 0.001$.

(comparison between AT and 15-min AT)



(a) (b)

Fig. 3 Comparison of sympathetic nervous activity index LF and parasympathetic nervous activity index HF among three sessions. BT: before task, AT: immediately after task. (a) and (b) are experiment group and control group.



(a) (b)

Fig. 4 Comparison of sympathovagal balance index LF/HF among three sessions. BT: before task, AT: immediately after task. (a) and (b) are experiment group and control group.

CONCLUSIONS

The study employed a scientific measurement to evaluate the effect on decreasing mental fatigue for inhaling essential oil. The EEG and HRV measures, incorporated NASA-TLX rating scale were used to be the objective and subjective assessments on fatigue respectively. After four-hour school courses induced a tendency toward mental fatigue for the subjects. Research has shown that waves are associated with increased alertness and arousal, waves occur during relaxed conditions, at decreased attention levels and in a drowsy but wakeful state, and waves mainly occur at sleep state one (Grandjean and Olroyd, 1988; Okogbaa, Shell, and. Filipusic, 1994; Rains and Penzien, 2003). A state of subject's activation was calculated as the ratio index (+)/ . The ratio indices / and / are related to subject's alertness level (Brookhuis and Waard, 1993). For 15 min of inhaling essential oil after the experimental task, we found EEG basic indices of α and θ bands were decreased while β band was increased for experiment group, and the degree was superior to the control group, for 15 min of placebo test after the experimental task. In addition to basic indices, EEG ratio indices of $(\alpha+\theta)/\beta$ and θ/α were decreased at the same condition, while β/α was increased for experiment group, and the degree was also superior to the control group. It appeared that 15-min of inhaling essential oil had more effect on decreasing mental fatigue than placebo test. Additionally, for HRV measurement in experiment group, 15 min of inhaling essential oil after the experimental task was completed, the sympathetic nervous activity index LF had decreased and recovered to the level in the BT session, and the parasympathetic nervous activity index HF had increased but revealed no statistically significant difference with AT session. For control group, both LF and HF revealed no statistically significant difference with AT session. The value of low frequency band/high frequency band (LF/HF) ratio of HRV power for experiment group decreased significantly more than that for control group. For subjective measure, the NASA-TLX rating scale of the experiment group had more mental relaxation than that of control group. It revealed that the subjects had remarkable effect to decreasing mental fatigue after inhaling essential oil. To summarize as mentioned above, our study found that essential oil had obvious effect on decreasing mental fatigue and facilitating relaxation.

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