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**Tapanee Hongratanaworakit**

### Abstract

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**Physiological effects in aromatherapy**

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The effects of aromas on humans are divided into physiological and psychological effects. The physiological effect acts directly on the physical organism, the psychological effect acts via the sense of smell or olfactory system, which in turn may cause a physiological effect. This paper reviews on the physiological effects which are used for the evaluation of the effects of aromas. Physiological parameters, i.e. heart rate blood pressure, electrodermal activity, electroencephalogram, slow potential brain waves (contingent negative variation), and eye blink rate or pupil functions, are used as indices for the measurement of the aroma effects

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**Key words :** aromatherapy, physiological effects

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## บทคัดย่อ

ฐานันท์ หงส์รัตนาวรกิจ

ผลทางสรีรวิทยาของสุคนธบำบัด

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ผลของสารที่มีกลิ่นหอมต่อมนุษย์แบ่งได้สองด้านคือ ด้านสรีรวิทยาและด้านจิตวิทยา ผลทางด้านสรีรวิทยาออกฤทธิ์โดยตรงต่อร่างกายของสิ่งมีชีวิต ผลทางด้านจิตวิทยาออกฤทธิ์ผ่านทางประสาทสัมผัสของกลิ่นหรือระบบรับกลิ่นซึ่งอาจส่งผลให้เกิดการเปลี่ยนแปลงทางด้านสรีรวิทยาได้ บทความนี้กล่าวถึงงานวิจัยทางสรีรวิทยาที่ใช้ในการประเมินผลของสารที่มีกลิ่นหอม พารามิเตอร์ทางสรีรวิทยาที่ใช้เป็นตัวบ่งชี้ผลของสารที่มีกลิ่นหอม ได้แก่ อัตราการเต้นของหัวใจ ความดันโลหิต การนำไฟฟ้าที่ผิวหนัง คลื่นสมอง คลื่นสมองช่วงความถี่ต่าง ๆ อัตราการกระพริบตา หรือการทำงานของม่านตา

ภาควิชาเภสัชเคมี คณะเภสัชศาสตร์ มหาวิทยาลัยศรีนครินทรวิโรฒ ถนนรังสิต-องครักษ์ อำเภอองครักษ์ จังหวัดนครนายก 26120

Clinical experience in aromatherapy suggests that beneficial effects of aromas or fragrances are not only exerted by inhalation of the vapor but also by absorption of fragrance molecules through the skin. It is long known that inhalation of aromas causes physiological and psychological changes in humans (Tisserand, 1977) and it is assumed that the effects of aromas are evoked by both pharmacological and psychological mechanisms. The former acts directly on the physical organism, the latter acts via the sense of smell and may thereby elicit physiological effects. The physiological and psychological effects are quite distinct although they often occur simultaneously (Jellinek, 1997). In order to study effects of fragrances researchers have taken a great variety of approaches including measuring changes in the patterns of electromagnetic activity in the brain, in physiological parameters, e.g. heart rate, electrodermal activity, blood pressure, muscle tension, skin temperature, and skin conductance (Van Toller *et al.*, 1983; Kanamura *et al.*, 1988; Lorig *et al.*, 1988; Torii *et al.*, 1988; Lorig, 1989; Miyazaki *et al.*, 1991; Buchbauer *et al.*, 1993; Van Toller *et al.*, 1993; Brauchli *et al.*, 1995).

However, to date, reported results of the effects of aromas have been unclear. Many aromas seem to have both stimulating and sedative properties. Therefore, to classify odors as simply 'stimulant' or 'sedative' can be misleading and confus-

ing. Moreover, it is too early to classify essences or aromas according to their action on the physical organisms because there is very little detailed research on the effects of aromas. Thus, this paper reviews selected experimental research on the physiological effects and describes how they may exert therapeutic effects in aromatherapy. The aims of this paper are: (i) to alert aromatherapists on the scientific background underlying potential therapeutic uses of aromas (ii) to encourage the clinical evaluation of aromas.

**Physiological effects**

Physiological effects of aromas can be divided into two types: those which act via the stimulation of the nervous system and those which act directly on an organ or tissue via an effector-receptor-mechanism (Tisserand, 1977). The physiological measures are all under the control of the nervous system. In general, the nervous system of higher organisms can be classified into two major sections, the central nervous system (CNS) and the peripheral nervous system. The CNS includes the brain and spinal cord. Two important functions of the CNS are to receive and process sensory information and to regulate bodily movements. The peripheral nervous system refers to the nervous tissues outside the brain and spinal cord, including the cranial and spinal nerves. The peripheral nerv-

ous system is further divided into the somatic nervous system, concerned with muscular activities, and the autonomic nervous system (ANS) which controls visceral structures (glands and organs of body). In addition, the function of the ANS is to regulate the internal and relatively involuntary responses that are associated with emotions. Finally, the ANS is subdivided into the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). These two branches differ in functions. The SNS is dominant in situations requiring mobilization of energy whereas the PNS is dominant in a rest situation. Some organs are innervated by only one division of the ANS (e.g., the sweat glands, peripheral blood vessels, and adrenal glands are innervated solely by the SNS). Most organs are innervated by both the SNS and the PNS. In those cases, the SNS and the PNS branches usually produce opposite reactions. Among the most significant of the bodily reactions produced by the SNS are pupil dilation, inhibition of salivation (causing a dry mouth), secretion of sweat (causing clammy hands), constriction of blood vessels in the periphery of the body (causing cold hands and feet), dilation of blood vessels in the muscles and brain, increase of heart rate, increase of blood pressure, speeding of breathing rate, and inhibition of digestive processes. Among the bodily reactions produced by the PNS are pupil constriction, increase of salivation, decrease of heart rate, decrease of blood pressure, decrease of breathing rate and increase of digestion and peristaltic processes (Andreassi, 2000).

Evaluation of the effects of aromas on the nervous system may be divided into two different forms of arousal, the cortical arousal such as brain wave activity and the autonomic arousal such as heart rate, skin conductance. Decreases of the cortical arousal and/or the autonomic arousal are interpreted in terms of a sedative/relaxing effect of aromas. In contrast, increases of the cortical arousal and/or the autonomic arousal are interpreted in terms of a stimulating effect of aromas (Stern *et al.*, 2001). The changes of physiological parameters in response to aromas are reviewed throughout this

paper. They are heart rate, blood pressure, electrodermal activity, electroencephalogram (EEG), contingent negative variation (CNV), and eye blink rate or pupil functions.

### Effect of aromas on heart rate

The most common psychophysiological measure of heart activity is heart rate. Faster heart rate is often caused by stress, for example, our heart may race and pound when we are afraid. Other kinds of stress, such as depression, may result in lower heart rate. Generally, the heart is innervated by the ANS. The PNS reduces the activities of the heart and particularly influences heart rate, whereas the SNS increases the activities of the heart and particularly affects the pumping function.

A study conducted at Yale University (Schwartz *et al.*, 1988) used changes of heart rate and blood pressure as indices for the measurement of the sedative effects of aromas. The aroma of spiced apple possesses pronounced vasodepressor and stress reduction effects. Yamaguchi (1990) also used the changes of heart rate for the measurement of effects of lemon and rose aromas. Lemon aroma caused an increase of heart rate whereas rose aroma led to a decrease of heart rate. This finding likely indicates that lemon aroma possesses a stimulating effect (an increase of heart rate), in contrast, rose aroma possesses a sedative effect (a decrease of heart rate). In a similar investigation of Kikuchi and co-worker (1991), lemon aroma enhanced the deceleration of the heart rate, indicating a stimulating effect. On the other hand, rose aroma suppressed it which is likely represented a sedative effect. In the same year, Nagai *et al.* showed that sweet fennel oil suppressed the deceleration of heart rate as well. Brauchli *et al.* (1995) reported that a pleasant and an unpleasant odor presentation affected an autonomic variable, i.e. heart rate. An increase of heart rate was observed during valeric acid presentation. In contrast, a decrease of heart rate was found during phenylethyl alcohol presentation. Phenylethyl alcohol was rated pleasant, while valeric acid was judged unpleasant. Recently, Hongratanaworakit *et al.* (2003b) investigated the

effects of sweet orange aroma on human behavior and detected changes of heart rate in response to olfactory stimulation. They reported that sweet orange aroma caused significant increases of heart rate and subjective alertness after inhalation. These findings seemed to show a stimulating effect of sweet orange oil. Thus the pattern of changes in the heart rate reveal differences between stimulant aromas and sedative aromas.

### Effect of aromas on blood pressure

Blood pressure is one of the most frequently measured physiological variables. It is used as a general index of cardiovascular function and health. The maximal, or systolic blood pressure occurs when the ventricle of the heart contracts. Following the period of cardiac contraction, there is relaxation of the ventricle, during which blood pressure is at a minimum; a measurement at this time yields diastolic blood pressure. Blood pressure is regulated by various factors such as blood volume, peripheral resistance. In general, diastolic blood pressure varies mostly with peripheral resistance, whereas systolic blood pressure is related to both peripheral resistance and stroke volume. Blood volume is much less familiar than blood pressure. It refers to the amount of blood that is present in a certain portion of body tissue at a given time. If blood volume is low, then blood pressure is reduced. The more blood is pumped by the heart and the more blood vessels constrict, the higher the blood pressure. All of the blood vessels of the body, except the capillaries, are innervated by nerve fibers from the SNS alone (Andreassi, 2000). This is controlled via the vasomotor center, which is located in the reticular substance of the brain (lower pons and upper medulla). The hypothalamus of the brain can exert powerful inhibitory or excitatory effects on the vasomotor center. Thus, blood pressure was recorded as an indicator of the arousal level.

Warren *et al.* (1987) patented the use of a nutmeg-based aroma to reduce stress in humans as measured by the reduction in blood pressure and self-ratings. Subjects were stressed by mental arithmetic and sentence completion tasks under an aroma with and without nutmeg oil. This study re-

vealed that nutmeg oil reduced systolic blood pressure by 9 mmHg. In addition, subjects rate themselves as having increased calmness and happiness as well as decreased anxiety, anger and embarrassment. These effects may be due to myristicin and elemicin, two ingredients of nutmeg oil which convert to the mood-alerting hallucinogens trimethoxy-amphetamine (TMA) and methoxy-methylenedioxy-amphetamine (MMDA). As in the European Patent (1991), the odorants, i.e. nutmeg oil, neroli oil, valerian oil, mace extract, myristicin, elemicin and isoelemicin, were investigated. When these odorants were used in a perfume compound at appropriate levels, a significant decrease of systolic blood pressure has been found. A study conducted at the Royal Sussex County Hospital (Woolfson *et al.*, 1992) showed that foot massage with essential oil of lavender lowered blood pressure as well as heart and respiratory rates of the patients in an intensive care unit. Transdermal absorption of sandalwood oil and one of its main components,  $\alpha$ -santalol led to a trend towards a larger decrease of systolic blood pressure as compared to the placebo group (Hongratanaworakit *et al.*, 2003a). Furthermore, effects of chiral fragrances on human blood pressure and self-evaluation were explored by Heuberger *et al.* (2001). In their studies, chiral fragrances (enantiomers of limonene and carvone) caused increases of blood pressure, subjective restlessness and alertness. These findings are likely to represent a stimulating effect of these fragrances. Recently, Hongratanaworakit *et al.* (2002) have demonstrated that ylang-ylang oil exhibited a harmonizing effect. Inhalation of the ylang-ylang oil led to a decrease of blood pressure and an increase of subjective attention. In addition, transdermal absorption of the mixed oil of bergamot oil and lavender oil caused a significant decrease of blood pressure. This finding points towards a decrease of autonomic arousal (Hongratanaworakit *et al.*, 2003c).

### Effect of aromas on electrodermal activity

The electric conductance of the skin is one of the most widely used indices of the level of arousal. It was observed that most people are

familiar with having cold, clammy hands under stressful circumstances, such as meeting new people or having to perform in front of an audience. The coldness comes from constriction of the smooth muscles surrounding the blood vessels, while the dampness is caused by the sweat gland activity. The sweat glands secrete a salty solution in response to emotional and stress stimuli, and this salty solution conducts electricity. Therefore it would seem plausible that this electric conductance property is closely associated with psychological processes such as attention and emotion (Edelberg, 1972; Fowles, 1973; Lykken *et al.*, 1971; Prokasy *et al.*, 1973). It is now accepted that changes in the skin conductance represent changes in the sweat gland activity. These are mediated by cholinergic sympathetic fibers (Lader *et al.*, 1980). Sweat glands are innervated solely by the SNS division and therefore electrodermal measures are useful indicators of the SNS activity during emotional states. The SNS activity is associated with increased sweat gland activity and this activity in turn is associated with high skin conductance.

Parasuraman *et al.* (1992) reported that periodic half-minute bursts of peppermint aroma during a vigilance task increased skin conductance. In addition, Steiner (1994) studied the effects of rose and jasmine aromas by using skin conductance as an indicator of arousal. The interesting findings showed that electrodermal activity of the synthetic rose and jasmine aromas indicated much lower arousal effect than those of the corresponding natural products. This is important because, in many of the reported studies on the effects of these aromas, it is not clearly indicated whether the sample employed was synthetic or natural. Since the natural aromas are more expensive than the synthetic ones, the synthetic ones are more likely to be used in some cases. Bergamot oil, lavender oil and a 2:1 mixture of the two were also tested in this study. When the electrodermal activity and the subjective measures of the activation were explored, the mixture ranked lower arousal effects than either of the single ones. This point seemed to raise the danger in assuming a combination of the physi-

ological effects in the case of mixtures. The effects of odors on autonomic activity (skin conductance level) were studied by Brauchli *et al.* (1995). 2-Phenylethanol, a widely used as a fragrance similar to the odor of roses, showed a decrease of skin conductance level and was rated as a pleasant odor. On the other hand, pentanoic acid, an odor related to sweat or cheese, showed an increase of skin conductance level and was judged as an unpleasant odor.

### Effect of aromas on electroencephalogram (EEG)

The effects of aromas are evaluated by electroencephalogram (EEG). EEG measurements show brain wave responses expressed in brain wave amplitude and frequency. Aromas produce cortical brain wave activity responses involving alpha, beta, delta, and theta waves. Brain waves are known to vary with extreme sensitivity according to the level of consciousness of the subject. Brain waves are distinguished by their frequency. The waves with 8-13 Hz are called alpha wave, those with higher frequency beta wave, and those with lower frequency theta and delta waves. When engaged in reading or concentrated thought, or in highly emotional, or other tense mental states, beta wave is dominant and alpha wave is inhibited. On the other hand, alpha wave is dominant in mentally relaxed state. Thus, brain waves are faithfully reflect human levels of consciousness, psychological state and degree of arousal.

Lorig and Schwartz (1988) recorded the brain waves of subjects exposed to the four types of aromas, i.e., eucalyptus, lavender, spiced apple and odorless solvent as control. The results showed that all aromas were associated with different alpha wave and theta wave distributions. Spiced apple odor was the most effective in stimulating alpha activity which seemed to elicit a relaxing effect of the odor. A study conducted at University of Occupational and Environmental Health, Kitakyushu, Japan (Sugano, 1988; 1989) used changes of the EEG as indices for the measurement of the effects of aromas. The aromas of lavender, cineol,

jasmin, sandalwood and alpha-pinene were explored. A relaxing effect (increase of alpha wave activity) was found upon presentation of lavender, cineol, sandalwood and alpha-pinene. In contrast, a stimulating effect (increase of beta wave activity) was found upon presentation of jasmin odor. Nakagawa *et al* (1992) reported that methyl jasmonate and cineol aromas inhibited the enhancement of alpha and theta waves which seemed to show a stimulating effect of the odors. On the other hand, jasmin lactone odor enhanced the amount of alpha and theta waves which likely indicated a relaxing effect of the odor.

### Effect of aromas on contingent negative variation (CNV)

The contingent negative variation (CNV) is a slow negative brain potential occurring between a warning stimulus (S1) and an imperative stimulus (S2). Generally, the CNV is highly sensitive to psychological variables. Donchin (1973), for instance, found that the instruction set affected CNV amplitude in identical evocation paradigms. The CNV is also affected by subject variables such as anxiety and stress. Knott and Irwin (1967) found a decrease of the CNV amplitude in anxious subjects. Studies relating to the use of chlordiazepoxide and caffeine (known central nervous system depressor and stimulator, respectively) showed that a decrease of the CNV was detected after the administration of chlordiazepoxide and an increase of the CNV was found after the administration of caffeine (Janssen *et al.*, 1978). The stimulant increased the magnitude of the CNV, in contrast, the depressor decreased the magnitude of the CNV. Investigation of Ashton and colleagues (1974) also supported these findings. The CNV was used as an indicator of the arousal effects of aromas (Torii *et al.*, 1988; Kanamura *et al.*, 1988). Torii and his group found that the presentation of jasmin aroma caused a significant increase of the CNV, whereas lavender aroma caused a significant decrease of the CNV. When subjects took a cup of coffee, the CNV was changed in the same direction as smelling jasmin, i.e. an increase of the CNV. It seemed to show a

stimulate effect of jasmin aroma. In contrast, when subjects took a nap, the CNV was changed in the same direction as smelling lavender, i.e. a decrease of the CNV. It likely showed a relaxing/sedative effect of lavender aroma. Furthermore, Kanamura *et al.*, (1989) also reported that citrus aromas and some floral bouquets (described as happy and excited agents) led to an increase of the CNV. Some sweet and heavy floral and oriental perfumes led to a decrease of the CNV. They imply that these aromas have a direct physiological effect on the central nervous system arousal thereby altering the CNV. In a similar work of the Kubota group (1992), chiral fragrance molecules affected the changes of the CNV. They reported that l-carvon showed a sedative effect whereas d-carvone elicited a stimulant effect. Further work by Manley at Takasago International Corporation (Manley, 1993) was conducted to evaluate various essential oils and aromatic chemicals that are used to create fragrances. The CNV responses to those substances were recorded. The results revealed that basil, clove, geranium, lemon grass, nerol, patchouli, peppermint, rose and ylang ylang caused an increase of the CNV magnitude (stimulating effect). On the other hand, bergamot, chamomile, lemon, marjoram and sandalwood caused a decrease of the CNV magnitude (relaxing effect). A few aromas showed mixed or inconclusive effects on the CNV such as valerian and sage.

### Effect of aromas on eye blink rate or pupil functions

Generally, eye blink rate or pupil dilation/constriction are indicators of cognitive processing and the level of arousal (Cramon, 1977). Electro-oculography is a method of recording eye movement and position by means of potential differences from electrodes placed around the eyes. Movement of the eyes is controlled by muscles which are innervated by the CNS.

Steiner *et al.* (1977) explored the effects of odors, i.e., rosemary, bromstyrol, tuborose and banana, on pupil functions. They found all odors elicited pupil enlargement which likely represents an

increase of arousal. In a similar study of Miyazaki and co-worker (1991), the effects of inhalation of aromas on the light reflex of the pupil as well as on performance in a cognitive task were investigated. They found that orange oil increased the rate of constriction of the pupil, i.e. increase of the PNS activity, and decreased the dilatation time of the pupil, i.e. decrease of the SNS activity. In addition, sweet fennel oil reduced the mental stress and fatigue caused by a computerized arithmetic assignment. The effect was significant in the measurement of the contraction ratio of the pupil (Nagai *et al.*, 1991). Recently, Hongratanaworakit *et al.*, (2003a) have studied the effects of sandalwood oil and  $\alpha$ -santalol on humans after percutaneous absorption. They found that both aromas showed a significantly larger decrease of eye blink rate as compared to the placebo group. This finding points towards a decrease of arousal in terms of the ANS.

### Concluding remarks

Scientific evaluation of aromatherapy stimulated the issues of the new concepts concerning the effects of aromas. The changes of physiological parameters after receiving the aromas are widely used for the scientific verification of relaxing/sedative and stimulating effects of aromas. Many commercial aroma products have been developed on the basis of the new concept of aromatherapy. These products claimed various effects such as calming/relaxing, stimulating/uplifting, refreshing, sleep well, healing and so on. Some products claimed only one effect, while some claimed more than one effect. Although the marketability of aroma products has grown considerably, the effects of aromas have been inconsistent. This trend of research and development in this field is expected to continue and to be faithful in assessing the psychological effects of aromas. Further advanced research on the endocrine, immunological, pharmacological effects of aromas has already commenced and should show significant results in the near future.

Finally, the purpose of this selective review is to alert aromatherapists to these possible and current therapeutic applications of aromas. What

is now required is their evaluation through formal clinical trials. It should be clear from the above discussion that evaluation will be complex, and will involve varied skills. It is hoped that this paper encourages the necessary collaborations between aromatherapists, scientists and psychologists in researching this intriguing area.

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