An Experimental Study on Physiological and Psychological Effects of Pine Scent

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소나무 향기의 생리 심리적 효과에 관한 실험적 연구

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ABSTRACT

The scientific verification of the physiological and psychological effects that result from interaction with green plants would not only provide objective knowledge on the psychological effect of green but would also establish useful grounds for the creation of green spaces that consider human emotions. The present study measured the cerebral activity(cerebral blood flow) and the autonomic nervous system activity(blood pressure, pulse rate, amylase) of fifteen Korean male subjects as they inhaled the natural scent diffused by pine needles. Impression and mood state evaluations of the reactions to the pine scent were carried out using the SD method and POMS. Cerebral activity was observed to be significantly activated in the feeling, judgment, and motor areas of the frontal lobe, as well as the memory area in the temporal lobe. Verbal evaluations by the SD method and POMS indicated a pine scent left natural but stimulated and active impressions, provided vigor, and also reduced confusion. The autonomic nervous system activities, however, showed no significant differences. These findings verified scientifically that a pine scent vitalizes humans both physiologically and psychologically. These results could be useful as fundamental data for the design of green spaces that consider human emotional aspects.

Key Words: Green Plant Scent, Cerebral Activity, Autonomic Nervous System Activity, SD Method, POMS

국문초록

녹지식물과 접함으로써 얻어지는 생리 심리적 효과를 과학적으로 실증하는 것은 녹지의 심리효과에 대한 객관적인 지식의 제공과 더불어 인간의 감성을 고려한 녹지공간을 창출에 있어 유용한 근거가 될 것이다. 본 연구에서는 15명의 한국인 남성을 대상으로 자연 발산하는 소나무 잎의 향기를 맡는 동안 대뇌활동(뇌혈액동태)과 자율신경계활동(혈압, 맥박, 아밀라제)을 측정하고, SD법(Semantic Differential method)과 POMS(Profile Of Mood States)를 이용하여 소나무

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향기에 대한 인상 및 감정상태의 변화를 평가하였다. 그 결과, 소나무 향기는 대뇌활동에 있어 전두야의 감정, 판단, 운동을 담당하는 부위와 측두야의 기억을 담당하는 부위의 활성화를 초래하였다. SD법과 POMS에 의한 언어적 평가에서는 소나무 향기는 자연적이지만, 자극적이고 활발한 인상을 가지며, 활기를 주고 혼란한 정서를 안정시키는 향기로서 평가되었다. 한편, 자율신경계활동에서는 유의한 차이는 보이지 않았다.

실증된 결과를 통해, 소나무 향기가 우리의 생리 심리적인 측면에 활력을 주는 사실이 과학적으로 검증되었으며, 금후 감성을 고려한 녹지환경 디자인을 위한 기초적인 자료로 활용될 것을 기대한다.

주제어: 녹지식물 향기, 대뇌활동, 자율신경계활동, SD법, POMS

Ⅰ. Introduction

Increasing rates of urbanization have directed people's attention to the relief-giving psychological effects that plants can have on their mental stress(Ulrich, 1986; Ulrich *et al.*, 1991). These effects have been understood only as personal experiences until recently. Active efforts now appear to be underway for quantitative and objective verification of these putative effects, based on medical and scientific indicators that employ new advances in measurement techniques(David, 1995; Iwasaki *et al.*, 2007). This type of quantitative analysis may offer objective insight into the psychological effects of plants, and could be a useful indicator for designing green spaces that consider human emotional responses. By doing this in future, green spaces could potentially be utilized as places to improve the health of citizens. At the same time, additional green spaces could be also help solve environmental issues such as global warming and could increase social security finances currently threatened by low fertility and population aging(Marcus and Francis, 1990; Hiroi, 2008).

In previous studies on the physiological and psychological effects of plants, the primary focus was on the visual aspects(Urlich, 1984; Nakamura and Fujii, 1992; Kuroko and Fujii, 2002; Suda *et al.*, 2007). However, the creation of a natural setting often involves all five senses, and attention is now increasingly being paid to hearing, smell, and touch (Japanese Institute of Landscape Architecture, 2000). Among the five senses, olfaction most often goes unnoticed compared to the other senses, Smell is mostly dependent on subtle experiences; therefore studies regarding olfaction tend to lag behind those on other senses. In recent years, however, the field of olfactory research has begun to attract the attention of research due to the upsurge in interest in aromatherapy for use in stress recovery and alleviation of fatigue(Torii, 2002). The olfactory sense in cerebral physiology is known as a primitive sense that is more intimately related to emotions than are the other senses. Stimulations of vision, hearing, and touch are conveyed in the limbic system after reaching the cerebral cortex, whereas the olfactory sensations go directly to the limbic system. Engen(1982), who investigated memory duration in term of visual and olfactory stimuli found that visual memory decreased after four months, whereas olfactory memory had not declined even after 12 months. Because the olfactory sense has direct effects on emotions and readily establishes long-term memories, the possibility exists that the scents of plants could have favorable effects in terms of emotional stress relief.

In previous findings concerning the effects of plant scents, Torii(2002) examined brain activities using Contingent Negative Variation(CNV) while participants smelled 17 kinds of scents. The scents of sandalwood, bergamot, lemon, marjoram, chamomile and lavender had sedative effects whereas the scents of rose, patchouli, ilang-ilang, clove, basil, peppermint, and jasmine had stimulating effects. Most of the previous studies on plant scents have used the aromas of essential oils, due to the fact that these studies were carried out from the perspective of aromatherapy. In these types of studies, it is easy to control the concentration of scents. this is important since the psychological effects are dependent on scent concentrations. In addition, another important elements in evaluating the psychological effects of scents is the individual differences in scent preferences. Research has repeatedly demonstrated that an individual's experiences and cultural characteristics play a crucial role in deciding his or her preferences for scents and the psychological impacts that those scents can have. Despite extensive reviews that have been conducted on Western herbs using essential oils, it is expected that familiar plant scents that have been used in daily life may have more of a positive psychological impact on Korean people.

The scents experienced in green spaces are often diffused by other plants and the scent concentration is also extremely low compared to that of essential oils. Therefore, the present study set out to review their physiological and psychological effects of using scents diffused by plants growing in living spaces.

In this experiment, the natural scent of a pine tree was used. Pine tree species are widely distributed throughout the Korean peninsula and pine has been used historically in a variety of ways in the Korean lifestyle. For example, pine lumber has been used to building houses and palaces, and pinewood has been used as firewood and in papermaking. In traditional Korean customs, people believe that pine trees bring them good luck(Cho, 2006; Jo, 2008). In addition, the pine tree has been used as a material for traditional artworks, and its image is used as a symbol of the longevity. In poetry and prose written by scholars in the Joseon Dynasty period, the pine tree symbolized integrity, allegiance, good nature and the mountain god(Jin, 2003). The pine tree has long been used as an essential material and has significantly influenced the customs and literary activities of the Korean people.

Therefore, investigating the physiological and psychological effects of pine scent in Korean test subjects may provide objective data to support empirical knowledge. The clarification of this effect can be a useful indicator for the design of green spaces that consider emotional states; furthermore, these have potential also to aid both environmental and welfare problems.

II. Methods

1. Subjects and Experimental Setting

This study included fifteen healthy Korean male subjects(mean±SD: 27.5±2.2 years old). Before the experiment was carried out, the process was precisely explained to the subjects and informed consent was obtained from each individual. The experiment was conducted in the shield room where all the subjects would be exposed to the fewest external factors. The temperature was maintained at 25℃ and 60% humidity and the room was illuminated at 50lux.

2. Olfactory Stimuli

The scent diffused by pine needles was used in this experiment to evaluate the human response in a similar pattern to that which people would smell a plant scent in daily life. Fresh pine tree needles(*Pinus densiflora*) were collected on the day of the experiment. Four gram of needles were collected and put into a sealed bag and the scent was allowed to saturate the bag(refer to Figure 1). The bag was made of polyester material to prevent any scent soaking through(refer to Figure 2). Odorless air was used as the control to the pine scent. In order to present scent of the same concentration to all subjects, the olfactory stimuli presented to the subjects were set to flow out of the bag at a speed of 3L/min using air pump, and the subjects were asked to smell the air or scent at a 10cm distance away from their noses(refer to Figure 1, 3).

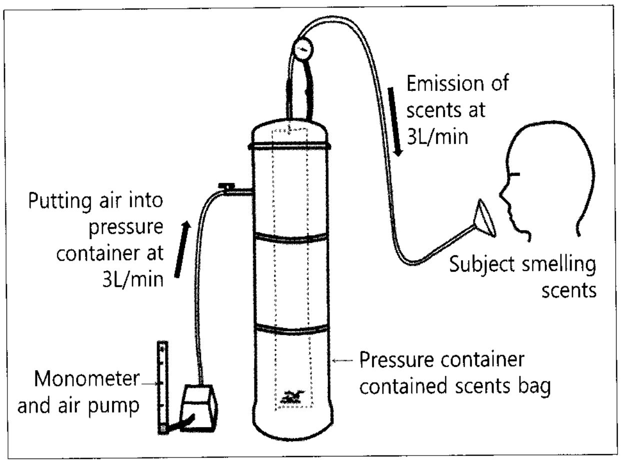

Figure 1. Process of scents presentation
Data: Morikawa *et al*., 2001a: 112.

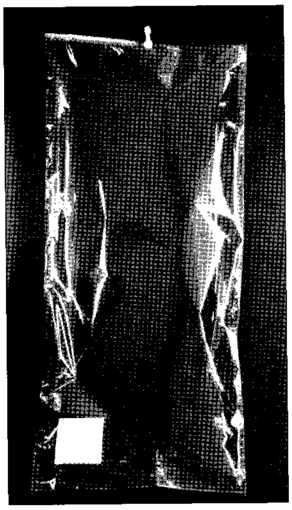

Figure 2. Scent bag contained pine needles 4g and odorless air 18L

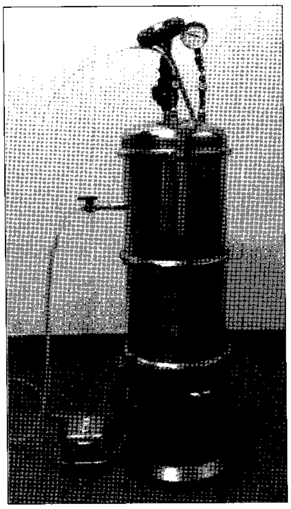

Figure 3. Air pump and pressure container

3. Data Collection

1) Measurement of Physiological Aspects

Most previous studies on the comfort provided by nature had mainly been conducted by verbal evaluations such as questionnaires. However, in recent years, with the advancements in measurement devices, some researchers have started to measure human responses to stimulation by nature. Investigation of physiological aspects can use an objective index rather than verbal evaluation because response can be quantitatively evaluated as they occur and the responses to stimulation can be measured during the stimulation. In contrast, in the case of a questionnaire, subjects have to recall their mood state after the stimulation is finished, and it is only possible to evaluate it with words provided by the experimenter. Therefore, in this study, physiological aspects were reviewed using indexes such as the cerebral activities and autonomic nervous system activities. For the measurement of the cerebral activity, FMRI, MEG, EEG and CNV are typically used. However in the present study, the changes in Cerebral Blood Flow (CBF), which reflects cerebral activities, were monitored using Near-InfraRed Spectroscopy(NIRS, OMM-2001, Shimadzu Co. Ltd., Japan), which has been a focus of recent studies regarding to the physiological effects of nature(refer to Figure 4). NIRS is a spectroscopic method that measures hemoglobin concentration changes. In particular, it can measure the specific area of the brain that is activated, as the localized blood volume in that area changes quickly. It has the advantages of being non-invasive and of providing direct assessment of brain function. Subjects also have little discomfort since the device is simple. It can be very useful method for measuring the subject's cerebral activities in their natural situations while sitting or performing some motion, unlike the case for fMRI and MEG where subjects must remain supine. Most previous research using NIRS has only conducted by limited measurement of two channels in the prefrontal cortex. However, for comprehensive measurement of cerebral activity, all functional localizations of the cerebral cortex should be considered. Accordingly, in this study, a total of 47 channels(ch) were picked across the frontal, parietal, temporal, and occipital cortex of the right hemisphere(refer to Figure 5, 6). The measurement interval was set at 0.49 seconds so that any changes to the brain activity could be measured in detail. For the autonomic nervous system activities, blood pressure and pulse rate were used as the indexes. An digital blood pressure monitor

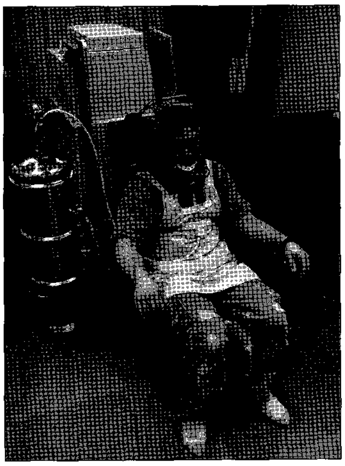

Figure 4. The measurement pictures of cerebral activities by near-infrared spectroscopy

Data: Shimadzu Co. Ltd., 2003: 1-59.

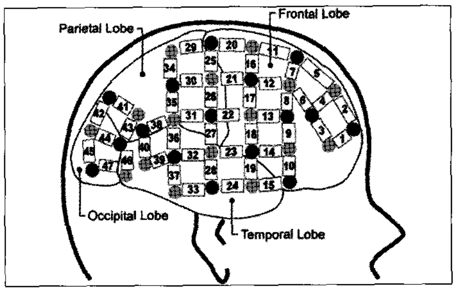

Figure 5. Measurement region in cerebral activity

Legend: 1~47 Channel number, Measurement position
Emitor of near-infrared light
Detector of near-infrared light

Data: Suda *et al.*, 2007: 215.

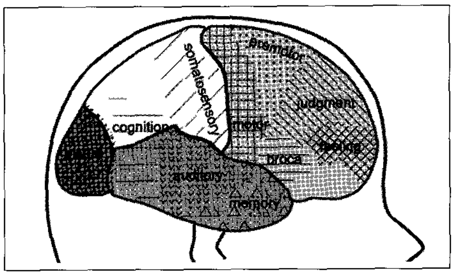

Figure 6. Localization of function in the brain

Legend: Frontal lobe, Parietal lobe, Temporal lobe, Occipital lobe
Feeling area: ch 1, 3
Judgment area: ch 2, 4, 5, 6, 8, 9
Premotor area: ch 7, 11, 12, 16
Broca's area: ch 10, 14
Motor area: ch 13, 17, 18, 20, 21
Somatosensory area: ch 22, 25, 26, 27, 29, 30, 31, 34, 35
Auditory area: ch 28, 32, 37
Memory area: ch 15, 19, 24, 33
Cognition area: ch 38, 39, 40, 41, 43
Visual area: ch 42, 44, 45, 47

Data: Yamauchi and Ayukawa, 2001: 10-11.

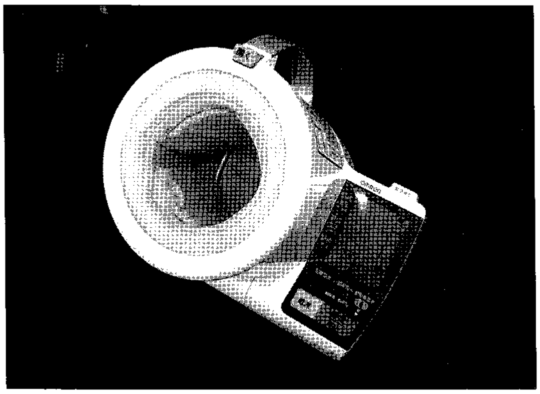

Figure 7. Measurement device of blood pressure and pulse rate activity

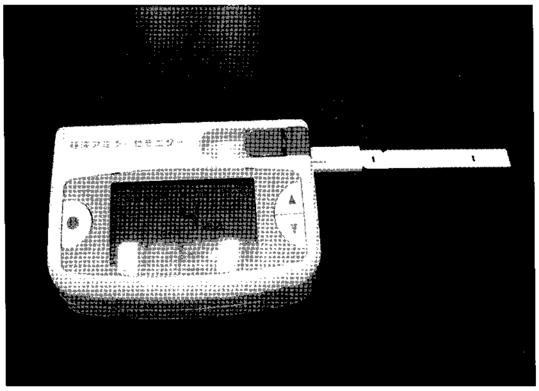

Figure 8. Measurement device of salivary amylase concentration

was used for easier measurement(HEM-1010, OMRON Co. Ltd., 2006), systolic and diastolic blood pressures were both analyzed(refer to Figure 7). In addition, salivary amylase concentration was measured as an index of the stress hormone. The measurement of salivary amylase has the advantage that measurement(NIPRO, INNOMEDICS Co. Ltd., 2007) is easy and provides a rapid results, unlike cortisol measurements used in other studies(refer to Figure 8).

2) Verbal Evaluation

In this study, the psychological aspects of pine scents were identified by verbal evaluations based on a psychological questionnaire in addition to measurement of physiological aspects. For the index, the Semantic Differential(SD) method, which evaluates the impression of pine scent, and the Profile Of Mood State(POMS) were used. The SD rating scale is designed to measure the connotative meaning concept, as designed by Osgood, and is wildly used in psychological testing(Osgood *et al.*, 1957; Iwashita, 1983).

In the present study, 15 adjective pairs, expressing scent images were selected based on previous studies on scents and were evaluated at seven levels(Jo *et al.*, 2007). POMS is one of psychological tests that examines subjects' feelings and mood states. A shortened version of 30 items which included key words such as 'unhappy', 'tense', 'careless', and 'cheerful' was used.

4. Procedure

Figure 9 shows the experimental protocol. Following explanations about the overview and details of the experiment, the subjects were asked to wear the required NIRS measuring devices and the measurement conditions were checked. Before the full-scale experiment, a measurement practice was conducted in order to relieve any anxiety felt by subjects due to the measurement protocol. The subjects were then stabilized for a while, their blood pressure, pulse rate and salivary amylase were measured, and questionnaires for SD method and POMS were filled out. The subjects were asked to become stabilized again(2 minutes), and after their CBF became sedative, the pine scent was presented. The CBF was continuously monitored during both stimulation and rest states. After the CBF measurement was finished, measurement of the autonomic nervous system and verbal indices was repeated. All physiological measurements were made while the subjects were sitting on a chair with their eyes closed. The

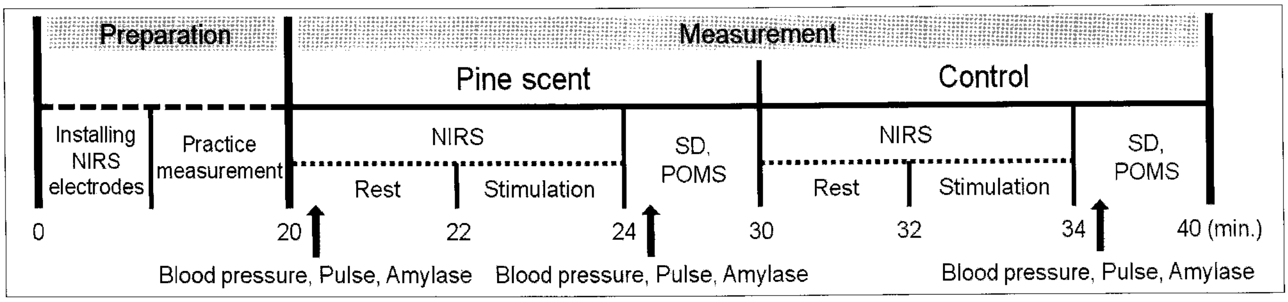

Figure 9. The experimental protocol

order of stimulus presentation to each subject, including the control of odorless air, was decided at random.

5. Data Analysis

Changes in CBF were compared with the *T*-test between the rest state and stimulation state. Cerebral oxygenated hemoglobin(OxyHb) was used in the analysis, which best reflects the brain activities among the indicators measurable with NIRS. The rest state was 20 seconds before the subjects had started to smell, since that time was regarded to be when the subject was in the most relaxed state and the stimulation state time was 90 seconds in 2 minutes by consideration of olfactory adaptation. In order to confirm the feature that changed CBF while the subjects smelled the scent, the mean for 20 seconds of rest state was also compared with the mean of the each and 30 seconds in the stimulation state. The mean changes in blood pressure, pulse rate, and amylase were compared before and after smelling, using the one-sample *t*-test. The results of the SD method were analyzed and evaluated to control the pine scent. Each score of the POMS was then evaluated and the score given to each item was converted to a T score. A change in feeling was reviewed using the Wilcoxon rank-sum test. Significance was established at $p<0.05$.

III. Results and Discussions

1. Cerebral Activity

CBF changes in the right brain after smelling the pine scent are shown in Figure 10. Significant increases in CBF concentration were observed in ch1, ch2, ch3, ch4, ch6, ch10, ch14, ch17 and ch33($p<0.05$). Therefore, pine scent was verified to activate primarily the frontal lobe and a partial region of the temporal lobe of the cerebral cortex.

Table 1 shows the comparison of CBF concentrations between the resting state and the stimulation state, each 30 seconds. At 0-30 seconds, a significant increase($p<0.05$) was only observed in ch33. From 30.49 seconds to 60 seconds, the CBF concentrations of ch3 and ch14 increased($p<0.05$), while ch1, ch2, ch3, ch6, ch10, ch17($p<0.05$)and ch3 and ch4($p<0.01$) increased at 60.49-90 seconds. The olfactory stimulations are generally understood to move from the limbic system to the cerebral cortex in the cerebrum, i.e., from the temporal lobe to the frontal lobe. The olfactory substance enters through the olfactory bulb and passes into the olfactory tract, stimulating the amygdaloid body, hypothalamus, and parahippocampal gyrus, in turn. Lastly, the substance reaches the orbitofrontal cortex and dorsolateral cortex in the prefrontal lobe. Ch33, in which the response was first observed, is located in the temporal lobe. The region combines each stimulation such as vision, hearing and olfaction according to the functional localizations in the cerebral cortex. Accordingly, stimulation of smelling is believed to be interpreted in this area.

After 30 seconds of smelling, many channels in the frontal lobe became considerably activated and there was the start of

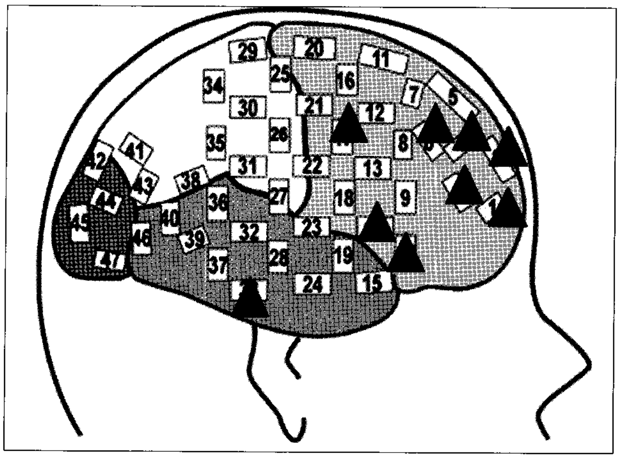

Figure 10. Cerebral blood flow changes in the right brain by pine scents

Legend: ▦ Frontal lobe □ Parietal lobe
■ Temporal lobe ■ Occipital lobe
▲: Channel with significant increases in cerebral blood flow

Table 1. Comparison of cerebral blood flow concentration between the rest state and the stimulation state, each 30 seconds

Channel	Changes in cerebral blood flow during stimulation period		
	0~30(sec.)	30.49~60(sec.)	60.49~90(sec.)
ch1	-	-	▲ $p<0.05$
ch2	-	-	▲ $p<0.05$
ch3	-	▲ $p<0.05$	▲ $p<0.01$
ch4	-	-	▲ $p<0.01$
ch6	-	-	▲ $p<0.05$
ch10	-	-	▲ $p<0.05$
ch14	-	▲ $p<0.05$	-
ch17	-	-	▲ $p<0.05$
ch33	▲ $p<0.05$	-	-

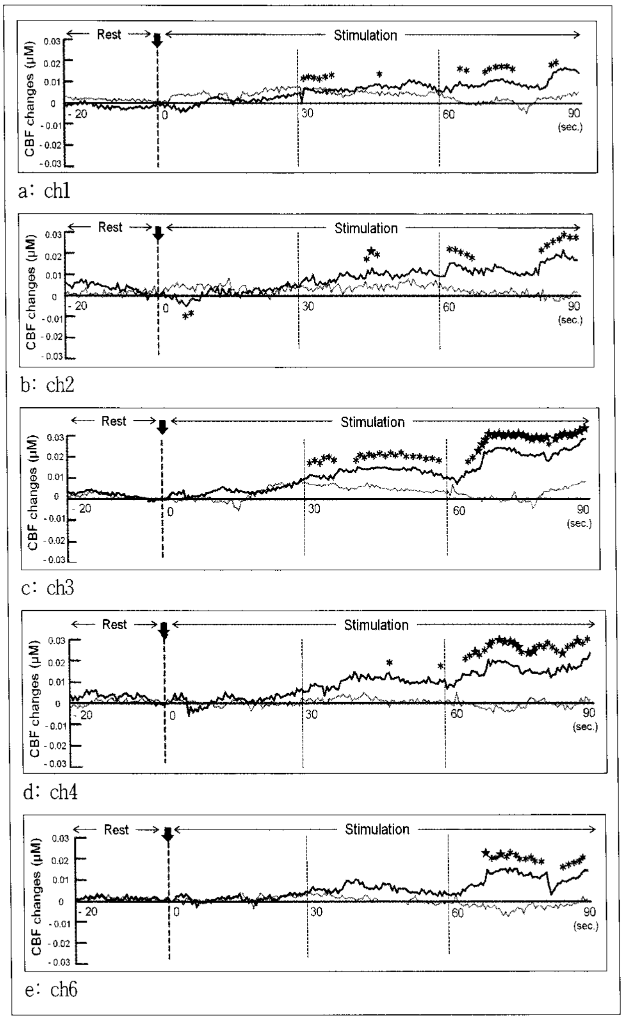

Figure 11. The cerebral blood flow in the prefrontal lobe while the subject was smelling

Legend: ── Pine scent, ── Control

*: p<0.05, ★: p<0.01 🠗: Scent presentation

a: N=15, b: N=15, c: N=15, d: N=15, e: N=14.

a response in ch14 and ch3. The frontal lobe, including the orbitofrontal cortex, is considered to take charge of functions such as emotions, judgment, and perception. Therefore it is can be assumed that the last of the stimulation judgment activities and emotions regarding the pine scent occurred in the frontal part of the brain. The ch17, located on the premotor cortex, also plays a role in the control of skeletal muscle activation. Therefore, it was assumed that the pine scent would promote the subjects' motion. Figure 11 shows the CBF in the prefrontal lobe while the subject was smelling (ch1, ch2, ch3, ch4, ch6). There were no special changes in CBF for odorless air whereas the concentration of CBF started to increase steadily with inhalation of the pine scent. Comparing the concentrations in the resting state and stimulated state(mean of each second), most of the channels except for the ch6 had started to increase significantly, and more considerable increases were observed 60 seconds later.

Through these findings, it is assumed that 1) pine scent has an active effect particularly in the frontal and temporal lobes of the cerebral cortex, with activated regions covering a wide range of the prefrontal lobe; 2) about 1 minute is needed for the activation to be observed; and 3) the scent promotes brain functions such as emotions, judgment, and perception, based on the functional localizations of the cerebral cortex.

2. Autonomic Nervous System Activities

Figure 12 shows changes in the systolic and diastolic blood pressures induced by smelling pine scent. Stimulations by the control and pine scent were lower than the rest period for both systolic and diastolic blood pressure, but the differences were not statistically significant. No significant difference was observed in pulse rate after stimulation(refer to Figure 13). In general, the autonomic nervous system activities change only in response to exercise or stress; therefore it was assumed that the inhalation of the pine scent for a two-minute period would not stimulate autonomic nervous system responses. This results was the same as previously seen in studies that used coffee scent and Japanese cedar scent; that is, no significant difference was noted in the blood pressure(Morigawa, 2001a; 2001b). However, some previous researches regarding nature experiences has reported an effect on blood pressure; for example, Tsunetsugu *et al.*(2007) showed that systolic and diastolic blood pressure were significantly lower after 15 minutes of walking in a forest area than in a city area. Accordingly, it is assumed that nervous system activities can be changed more by complex sensory inputs including vision, olfaction, touching, etc., than by a single stimulation of the olfactory sense.

Figure 14 shows the result of amylase following inhalation of pine scents. There was no significant difference although there was a tendency towards decreased amylase, when compared with the control.

3. Verbal Evaluation

Figure 15 shows the results of the impression evaluation by the SD method. A significant difference was observed in 7 out of 15 adjective pairs between the control and pine scents. Pine scents scored significantly higher for items such as

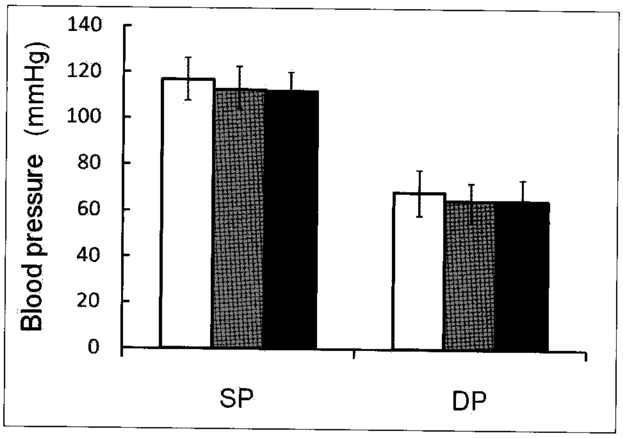

Figure 12. Changes in systolic and diastolic blood pressures induced by pine scents
Legend: □ Rest, ▦ Control, ■ Pine scent

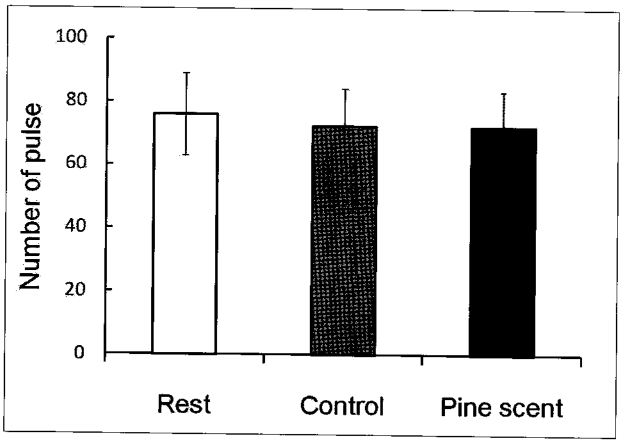

Figure 13. Changes in pulse rate induced by pine scents

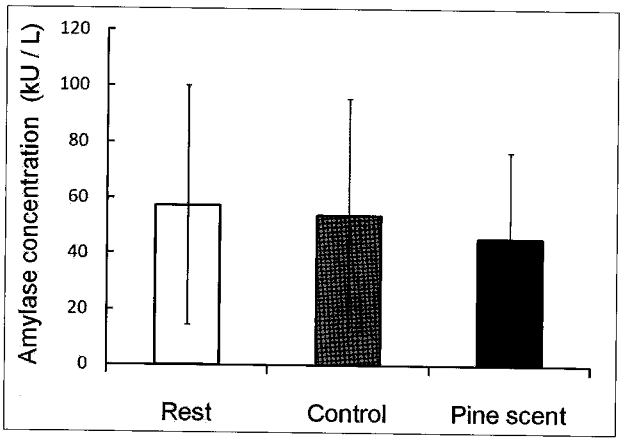

Figure 14. Changes to salivary amylase concentration by pine scents

'natural', 'woody', 'rural($p<0.01$)', 'stimulative', 'refreshing', 'distinctive' and 'active($p<0.05$)' than the control. Through these results, it was clear that pine scents not only had natural associations such as 'woody' and 'rural' but also left stimulative impressions such as 'distinctive' and 'active'.

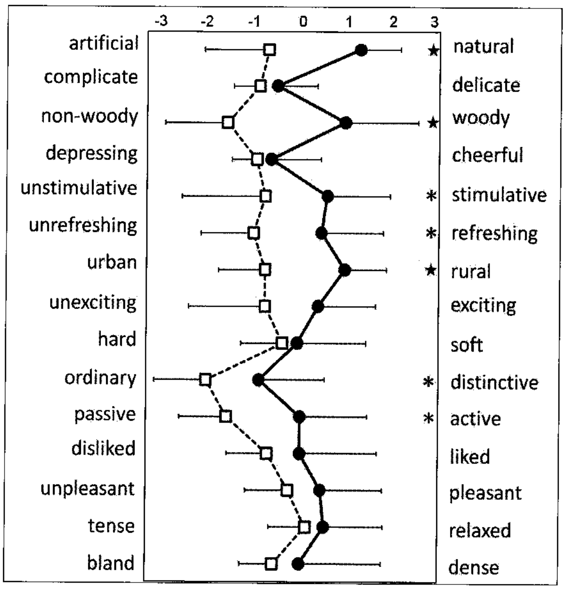

Figure 15. Impression evaluation by pine scent
Legend: --□-- Control, —●— Pine scent
*: $p<0.05$, ★: $p<0.01$

The results of changes in mood state revealed by the POMS questionnaire are shown in Figure 16. Pine scents had a higher score in the vigor item($p<0.05$) and had lower score in the confusion item($p<0.01$) than did the control air. Accordingly pine scents was evaluated as a scent that reduced confusion and invigorated mood states. Correlations were found between the result of the SD method and POMS; the natural impression of pine scent influenced the relief of confusion, and the stimulative and active impressions gave vigor. Pine scents clearly had natural and stimulative impressions that provded a reduction in confusion and a promotion of vigor in the psychological aspects.

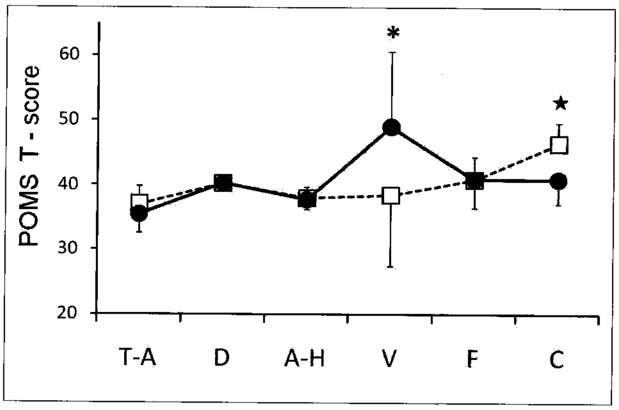

Figure 16. Changes in mood states by pine scent
Legend: T-A: Tension-Anxiety, D: Depression-Dejection, V: Vigor, A-H: Anger-Hostility, F: Fatigue, C: Confusion
--□-- Control, —●— Pine scent
*: $p<0.05$, ★: $p<0.01$

4. The Correlations between Cerebral Responses and Verbal Indicators

The pine scents gave a natural and active impressions and these impressions affected the study's participants by not only by boosting their mood state but also by physiologically activating their cerebral activity. Therefore, pine scents clearly produced vitality in both physiological and psychological terms. The psychological aspects of pine trees can be applied to planting plans in green space. For example, because the cerebral area in charge of emotions and judgments was activated by pine scent, planting pine trees near schools could be assumed to be beneficial for the cerebral activation of students on of students; whereas motor area activation could be encouraged by planting pine trees in sports parks.

Ⅳ. Conclusions

The purpose of this study was to evaluate the value of green plants, focusing on physiological and psychological aspects. The physiological and psychological effect of plants scents were clarified experimentally. The material studied was the scent of a pine tree, which is a representative plant material in green space and is used frequently in Korean daily life. While Korean male subjects were smelled the scents diffused from pine needles, their cerebral activities and autonomic nervous system activities were measured; in addition, verbal evaluations by SD method and POMS were carried out.

Upon smelling the pine scent, cerebral activities were activated, in particular the areas in charge of judgment, feeling, motor activity of the frontal lobe as well as the memory area of temporal lobe. Through these findings, specific cerebral functions were assumed to be promoted by pine scent. No significant activation was seen for the autonomic nervous system. Previous studies have found reductions in blood pressure due to contact with nature; therefore, these findings should be re-evaluated using different experimental settings. The evaluation of impression by the SD method showed that pine scent was appraised as a natural scents, and as a stimulative and active scents. In POMS, vigor and an ease of confused feelings were responses to smelling pine scent.

In conclusion, based on these findings, pine scents was scientifically verified to provide vitality to human physiological and psychological aspects. These effects are assumed to be closely related to the fact that pine trees greatly influence the feelings and spirit aspects of Koreans, and to the fact that pine plant material is in regular use in their daily lives. Thus, these physiological and psychological values of pine trees should be considered design of green spaces.

In this study, physiological and psychological effects of pine scent were measured experimentally with a limited subjects group(with respect to age and gender) and in an indoor setting for a clearer analysis of the physiological responses. The accumulation of data based on different experimental settings is needed to confirm the validity of application of these findings to real green spaces.

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