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Physiological effects of orange essential oil inhalation in humans

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Abstract: This study was conducted to clarify the physiological and psychological effects of the odor of orange essential oil in humans. Thirteen healthy male university students (mean age 23.0±1.1 years) participated. The study was conducted in an artificial climate chamber with temperature 24°C, relative humidity 50%, and illumination 50 lux. The subjects randomly inhaled orange essential oil for 120 s. Fresh air inhalation was used as the control condition. Heart rate variability (HRV), blood pressure, and pulse rate were continuously measured before (resting time) and during inhalation of the experimental odor. In addition, sensory evaluation and subjective odor intensity were evaluated after inhalation. The high frequency component of HRV was significantly higher, systolic and diastolic blood pressure was significantly lower, and the subjective "feeling of comfort" was significantly greater during inhalation of the orange essential oil than during inhalation of fresh air. These findings indicate that inhalation of orange essential oil effectively induces relaxation in humans.

1. Introduction

Traditional horticultural science has focused on plant production. Nowadays, the interaction between the welfare of human beings and plants is receiving widespread interest (Relf and Lohr, 2003). People-plant interactions are defined as the wide array of human responses (mental, physical, and social) that occur as a result of both active and passive participation with plants (Relf, 1992). One example of a positive response to plants is observed in the postexposure recovery from attention fatigue (Kaplan and Kaplan, 1989; Tennessen and Cimprich, 1995; Lohr *et al*., 1996; Herzog *et al*., 1997; Wells, 2000). In addition, activities that involve direct contact with plants, such as gardening and horticulture, have been used as therapy for different groups of people in various settings to promote health, well-being, and social inclusion (Davies, 1998; Sempik *et al*., 2003).

The natural environment, which includes plants, affects humans via the five senses and provides stimulation via vision (scenery) and olfaction (aroma of the plant) (Tsunetsugu *et al*., 2010). There are two areas of experimental methods to clarify the interactions between people and plants. The first and predominant area of study is field experiments, clarifying the effects of total environments. The second area is through indoor experiments that test each stimulation on the basis of the five senses; the results of indoor experiments can support the outcome of field experiments. Therefore, we focused on indoor experiments based on the physiological effects of plant odor stimulation.

The physiological and psychological effects of essential oils have been acknowledged in folk medicine and aromatherapy for a long time (Tisserand, 1988). Also, essential oils and their components are widely used as constituents of different medical products in the medicine industry, as flavoring additives in the food industry, and as cosmetics and fragrances (Cawan, 1999). Oranges are a favorite fruit worldwide. In a previous ambient odor study, exposure to orange essential oil in a dentist's waiting room decreased anxiety and improved mood in female patients (Lehrner *et al*., 2000).

The present paper reports an indoor experiment conducted in humans to determine the physiological effects of the odor of orange essential oil by measuring HRV, blood pressure, and pulse rate before and during inhalation of orange essential oil and comparing the values with those obtained before and during inhalation of fresh air (control).

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2. Materials and Methods

Subjects

Thirteen healthy male university students were recruited for the study (mean age 23±1.1 years), which was conducted according to the guidelines of the Institutional Review Committee of the Center for Environment, Health and Field Sciences, Chiba University, Chiba, Japan. Before beginning the experiment, the subjects provided written informed consent after a detailed description of the aim and experimental procedures were provided to them.

Experimental stimuli and odor delivery system

Orange essential oil (Ogawa & Co., Ltd., Japan) was used as an experimental stimulus. Fresh air without any odor was used as a control. The odor stimuli were controlled by an odor delivery system that comprised four parts: 1) a polypropylene odor bag, 2) a container, 3) an air pump with a gauge, and 4) a funnel with a plastic tube. The polypropylene odor bag was filled with 24 L of diluted orange essential oil. The odor of orange essential oil flowed from the plastic odor bag through an air pump set at 2.5 L/min and was delivered through a Teflon tube to a funnel located 15 cm from the subject's nostrils.

After inhalation of the odor stimuli, the subjects were asked to evaluate the subjective odor intensity on a 6-point scale, from an "insensible level" (0) to an "unbearable level" (6). The level of subjective intensity was controlled at an "easily sensible level."

Experimental design

The study was conducted in an artificial climate chamber with temperature 24°C, relative humidity 50%, and illumination 50 lux. The time schedule for the experiment is shown in figure 1. After the attachment of sensors for physiological measurement, the subjects were asked to close their eyes and rest. Blood pressure and pulse rates were monitored in real time. After 30 s in a stable state, the subjects were exposed to odor simulation for 120 s. Sensory evaluation was conducted after physiological measurements. The subjects were asked to evaluate their subjective feelings and subjective intensity.

Measurement

HRV, blood pressure, and pulse rates were measured as physiological indices. These indices are frequently employed to estimate changes in autonomic nervous activity (Tsunetsugu *et al*., 2010). The time interval between two consecutive R waves (R-R interval) on an electrocardiogram was measured using a portable electrocardiograph (Activtracer AC-301A, GMS, Japan) with three disk electrodes that were attached to the patient's chest; this data was then analyzed using the maximum entropy method (Memcalc/win; GMS, Japan). Two major spectral components of HRV were calculated: low frequency (LF: 0.04-0.15Hz) and high frequency (HF: 0.15-0.4 Hz) components (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). HF is considered to reflect parasympathetic nervous activity (Cacioppo *et al*., 1994), which increases under relaxation conditions, while LF/(LF+HF) is considered to reflect sympathetic nervous activity (Weise and Heydenreich, 1989), which increases under stressful conditions.

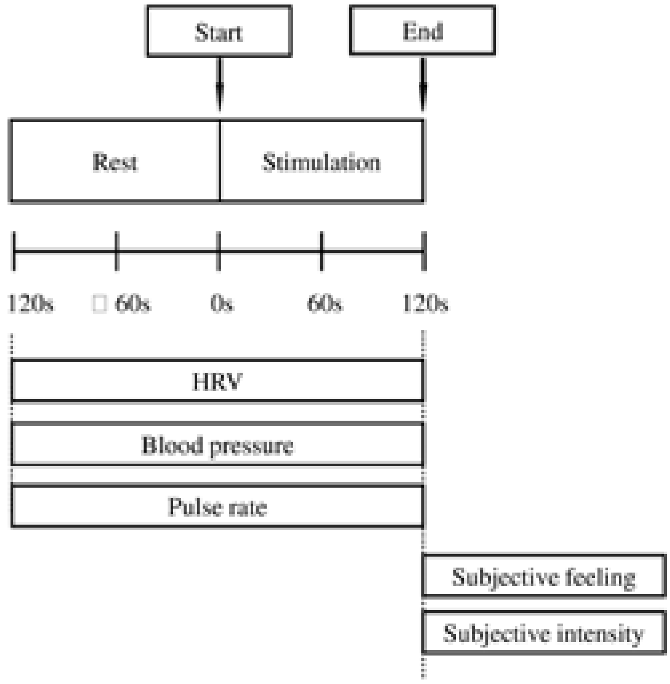

Fig. 1 - Time schedule for the experiment conducted to investigate the physiological indices of the olfactory effects of orange essential oil odor.

Blood pressure and pulse rates were measured on the left middle finger (Finometer pro, FMS Ltd. Co., Netherland). This method is noninvasive, and data is available per second.

Sensory evaluation was conducted after odor inhalation. The subjects were asked to evaluate and rate their "feeling of comfort," "feeling of being soothed," and "feeling of naturalness" on a 13-point scale.

Statistical analysis

A paired t-test was used for comparison of HRV, blood pressure, and pulse rate measurements during inhalation of orange essential oil with those during inhalation of fresh air. The Wilcoxon signed-rank test was used to analyze the subjective feelings scores. Statistical analysis of physiological data was processed with EXCEL 2003 (Microsoft Inc., Japan). Each measured value is represented as mean ± SD. A *P*-value of <0.05 was considered statistically significant.

3. Results

The subjective odor intensity ratings revealed the orange essential oil to be at the "easily sensible level",

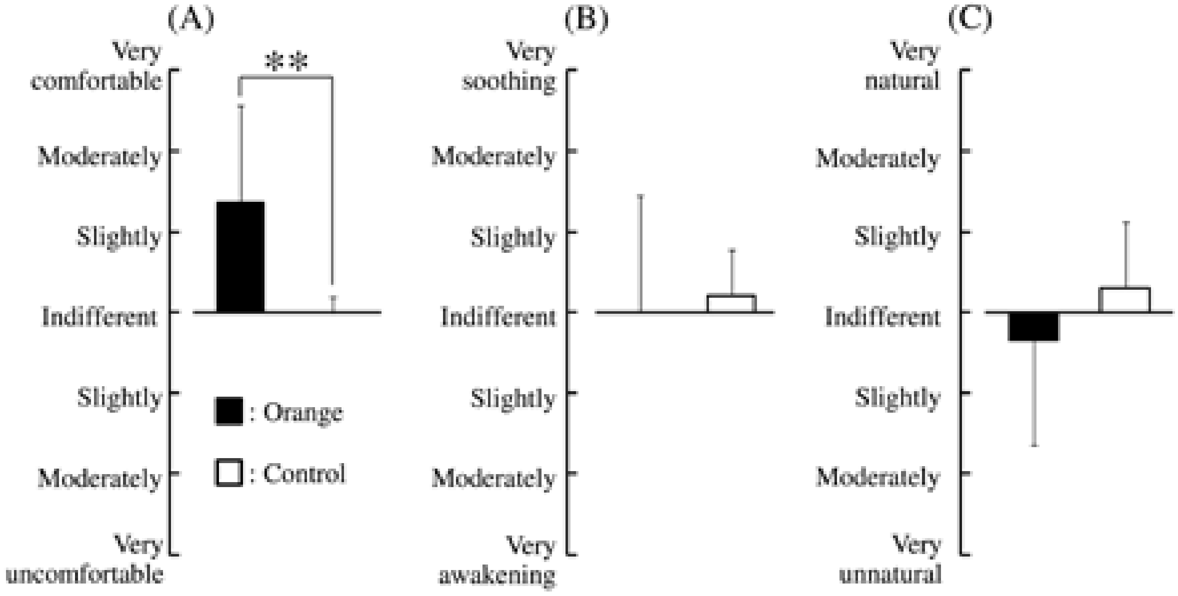

Fig. 2 - Changes in subjective feelings after inhalation of an orange essential oil or fresh air as a control. (A) feeling of comfort; (B) feeling of being soothed; (C) feeling of naturalness.
n= 13, mean ± standard deviation.
**P < 0.01 as determined by the Wilcoxon signed-rank test.

which was significantly different from control (fresh air) inhalation. Figure 2 reports results of sensory evaluation of subjective feelings during orange essential oil inhalation. With regard to the "feeling of comfort," the subjects rated orange essential oil as "moderately comfortable," which was significantly different from control inhalation (Fig. 2 A). With regard to the "feeling of being soothed" (Fig. 2 B) and "feeling of naturalness" (Fig. 2 C), no significant differences were observed between the ratings for orange essential oil and those for fresh air.

Figure 3 shows the HF component of HRV recorded every 30 s during the 120 s of essential oil inhalation; this was significantly enhanced compared with that during control inhalation (Fig. 4).

The relative systolic blood pressure, measured every 30 s during exposure, tended to be lower with orange essen-

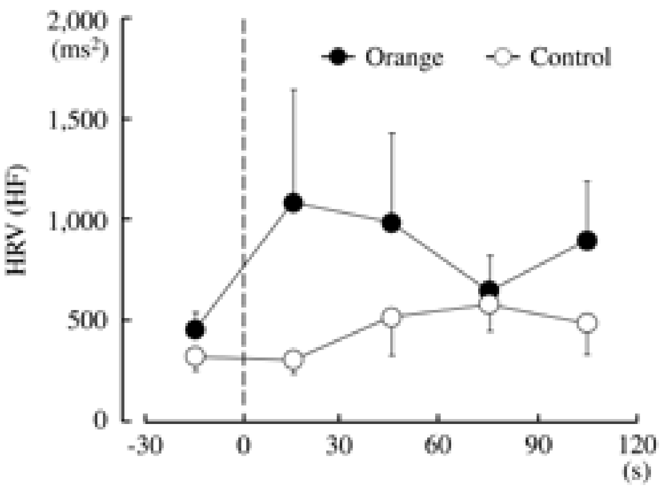

Fig. 3 - Changes in the high frequency component of heart rate variability during 120 s of inhaling an orange essential oil or fresh air as a control.
n= 13, mean ± standard deviation, determined by the paired t-test.

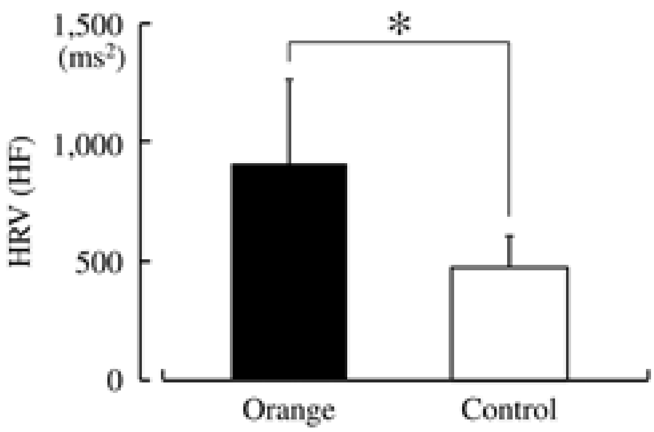

Fig. 4 - Changes in the average high frequency component of heart rate variability during 120 s of inhalation of an orange essential oil or fresh air as a control.
n= 13, mean ± standard deviation
*P < 0.05 as determined by the paired t-test.

tial oil inhalation than during control inhalation (Fig. 5). The average relative systolic blood pressure (Fig. 6), relative diastolic blood pressure (Fig. 7), and average relative diastolic blood pressure showed similar results (Fig. 8).

4. Discussion and Conclusions

In this study, subjects exposed to the odor of orange essential oil for 120 s showed a significantly greater "feeling of comfort" compared with those who were exposed to fresh air without any odor. The results regarding psychological states indicated that inhalation of orange essential oil has beneficial effects. Inhalation of essential oil is believed to produce reliable and predictable effects on psychological state (Sanderson and Ruddle, 1992), and previous studies have investigated this possibility. The effects of orange essential oil have been demonstrated through relief from anxiety and tension and improvements in mood (Lehrner *et al*., 2000, 2005). Subjective relaxation effects have also been found for lavender essential oil (Diego *et al*., 1998; Motomura *et al*., 2001; Moss *et al*., 2003; Bur-

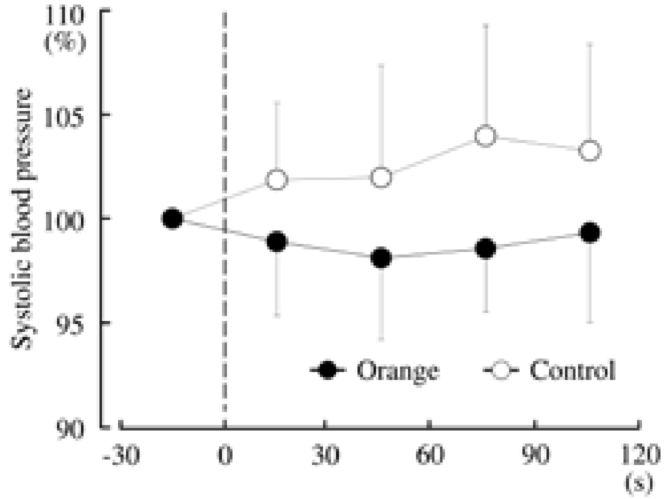

Fig. 5 - Changes in the relative systolic blood pressure during 120 s of inhalation of an orange essential oil or fresh air as a control. n= 11, mean ± standard deviation, determined by the paired *t*-test.

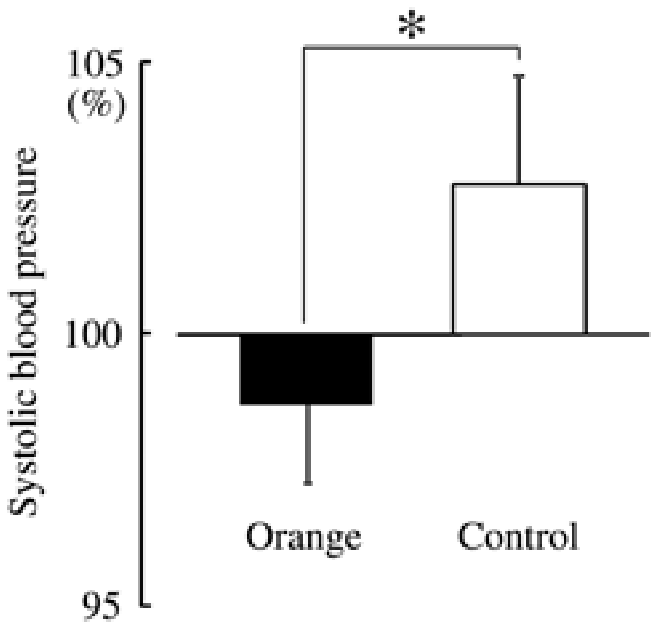

Fig. 6 - Changes in the relative average systolic blood pressure during 120 s of inhalation of an orange essential oil or fresh air as a control.
n= 11, mean ± standard deviation.
*$P < 0.05$ as determined by the paired *t*-test.

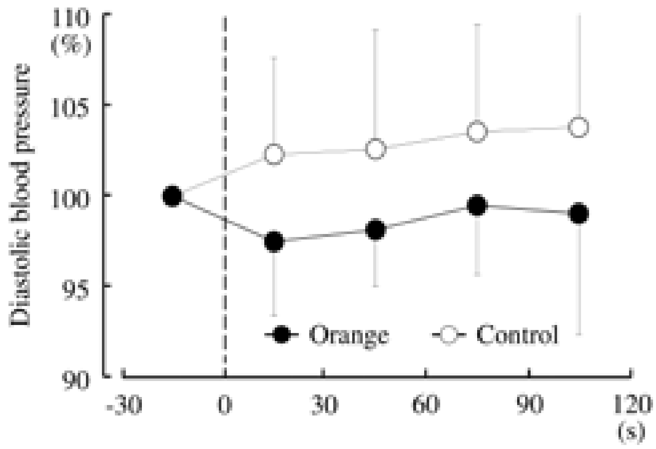

Fig. 7 - Changes in the relative diastolic blood pressure during 120 s of inhalation of an orange essential oil or fresh air as a control. n= 11, mean ± standard deviation, determined by the paired *t*-test.

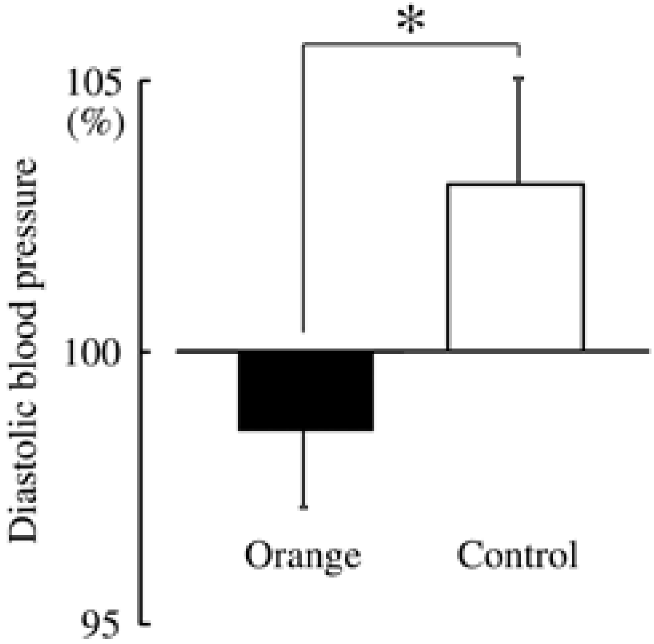

Fig. 8 - Changes in the relative average diastolic blood pressure during 120 s of inhalation of an orange essential oil or fresh air as a control.
n= 11, mean ± standard deviation.
*$P < 0.05$ as determined by the paired *t*-test,

nett *et al*., 2004) and peppermint essential oil (Ilmberger *et al*., 2001; Raudenbush *et al*., 2001, 2002).

The data obtained in this study suggest that the inhalation of orange essential oil has positive effects on autonomic nervous system activity. The test subjects showed a significant enhancement of parasympathetic nervous activity, which has a relationship with relaxation. The results from the present study are consistent with those of a previous study that investigated the HF component of HRV in healthy, young, adult university students (Park *et al*., 2007; Tsunetsugu *et al*., 2007; Park *et al*., 2008; Lee *et al*., 2009; Park *et al*., 2009, 2010; Lee *et al*., 2011).

During inhalation of orange essential oil for 120 s, both systolic and diastolic blood pressure were significantly lower than those during control inhalation, indicating that the inhalation of orange essential oil has a significant relaxing effect on the human body compared with the inhalation of fresh air.

The results of this study demonstrate that when subjects were exposed to an odor simulating the natural environment, they experienced the environment via the five senses, including olfaction. These findings strongly support the belief that plant odor, such as that of oranges, is a factor for inducing relaxation in humans during exposure to the natural environment.

In conclusion, we measured physiological and psychological indices for the olfactory effects of orange essential oil and found that the HF component of HRV was significantly higher, systolic and diastolic blood pressure were significantly lower, and the subjective “feeling of comfort” was significantly greater during inhalation of orange essential oil than during inhalation of fresh air.

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