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Physiological and Psychological Effects of Scent of Soil on Human Beings

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Abstract

This study examines heart rate and heart rate fluctuation when subjects are presented with the scent of soil and their psychological changes as expressed by scores of the Profile of Mood States (POMS) and Visual Analog Scale (VAS) as indexes. In the experiment, we directed the subjects to rest in a sitting position for 5 min. (Pre.), to smell the scent for 1 min. (No Stim., Stim.), and to rest in a sitting position for 15 min. (Post 5, Post 10, Post 15). Psychological evaluation was performed before and after the experiment (Pre., Post). The scent stimulation was made by opening/closing a bottle with screw-on cap that contained the soil. In the control group, the bottle is always closed. In the stimulus group, the bottle was opened only at the time of Stim. For the physiological evaluation, although we could observe no change in the control group, in the stimulation group, the subjects' heart rates decreased at Stim. and Post 15. For the psychological evaluation, VAS scores of "Feel relaxed" and "Feel soothed" increased and POMS scores of "Strain-Uneasiness", "Anger-Hostility", and "Confusion" decreased. In open-ended questions, some of the subjects recalled memories of insect-collecting, horticulture, forests and parks. There was a negative correlation between heart rate decrease (Stim.) and increase in the VAS scores of "Feel relaxed" ($r = -0.896$, $p < 0.001$) and "Feel soothed" ($r = -0.684$, $p = 0.014$). The healing effects from the scent of soil included subjects' memories that were considered to have influenced the heart rate.

Keywords

Soil, Heart Rate Variability, POMS, VAS, Autobiographical Memory

1. Introduction

Forests constitute 30% of the total land area on earth. Forests occupy 68% or 2/3 of the total land area in Japan, making it the country with the second highest percentage of forests in the world, after Finland. The healing effect of forests has attracted wide attention in recent years and can be considered one of the benefits of forest resources. There have been studies that reported a reduction in stress [1] [2] and a decline in the mortality rate from cardiac disease by "forest bathing" [3]. In the forest, fallen leaves and withered branches cover the forest floor. The layer of such deposited fallen leaves is called the humus layer. In soil science, it is called the O layer (in forestry Ao layer). Organic matter in the O layer decomposes within several years. Some of this matter is emitted into the atmosphere as carbon dioxide or becomes dissolved organic matter and remains in the soil as microbial metabolites. Thus, in the forest, fallen leaves go into the soil, which results in material circulation [4]. Soil is not only the largest feature of the forest, but also is a source of its scent. However, there has been very little attention paid to the effects of the scent that is emitted from the soil. Interest is increasing in clarifying the effect of the scent of a forest on humans in the field of aromatherapy. In it, the report of an antitumor action [5] [6] [7] etc. is made about the effect to the humans of monoterpenes, such as an herb and a needle-leaf tree. Nakamura, *et al.* examined and identified the components of the forest atmosphere such as terpenes, and reported that human beings can easily absorb such components [8]. However, there are no reports on the scent that occurs from soil, which is one of the biggest features of the forest environment. Hanyu *et al.* [9] examined soil and reported that the scent and texture of soil in a forest have a relaxing effect; however, there are very few reports on the effect of the scent of soil on human beings. Accordingly, this report aims to examine the effect of the scent of forest soil on human beings.

2. Methods

2.1. Subjects

Twelve male students (age: 24.6 ± 1.8 years old) with no olfactory disturbance received an explanation of the purpose of this study and gave their written consent to participate in accordance with the principles of the Helsinki Accords. The subjects selected one of 12 cards. Of the 12 cards, six cards were labeled "1st control group/2nd stimulation group" and the other six cards were labeled "1st stimulation group/2nd control group. The experiment was conducted from 23 November to 5 December in 2015.

2.2. Test Samples

The soil samples that were used for scent stimulation were collected from the green belt area at the University of Tsukuba administrative building north parking lot (36˚6'47.40"N 140˚6'14.10"E). The vegetation in the artificial forest from which the soil was collected included mainly evergreen oak trees, dotted Japanese oak, Japanese cedar, maple, and chestnut trees. The soil samples (taken from the organic sedimentary layer containing fallen leaves of evergreen oak trees to a depth of about 15 cm including topsoil) were put into a bottle measuring 15 cm in height and 10 cm in diameter with a screw-on cap.

2.3. Sample Analysis

Qualitative analysis of the soil for scent stimulation was conducted using GC/MS (GCMS-QP2010 Plus, Shimadzu Corp.) by the headspace method. The collected soil was put into a vial with 10 cc septum and 2 ml was poured from the headspace by a split trace after leaving it standing at 23˚C for 1 hour. The column (Stabilwax®-DA, Shimadzu Corp.) used was 0.25 mm i.d. × 30 m with film thickness of 0.25 μm. Ion source temperature and interface temperature were set at 200˚C; in the oven program, the temperature was first set at 40˚C for 5 min. and then increased to 200˚C at increments of 5˚C/min. and when it reached 200˚C, was then set for 10 min. at this temperature. Each component that was identified by a similar search (GCMS solution, Shimadzu Corp.) was expressed by the area percentage method (**Table 1**).

2.4. Method of Evaluation

Physiological evaluation was performed by measuring heart rate and heart rate fluctuation for which 2-lead electrocardiogram recorders were used. The R-R interval was computed with a memory heart rate meter (LRR-03, GMS), and heart rate (HR), low frequency component (LF; 0.04 - 0.15 Hz), High frequency component (HF; 0.15 - 0.4 Hz), and ratio (LF/HF) of LF component and HF component were analyzed by the heart rate fluctuation real-time analysis program (MemCalc/Tarawa, GMS) [10]. Psychological evaluation was made using the Visual Analogue Scale (VAS), Profile of Mood States (POMS), and open-ended questions. Measurement of VAS was conducted using a measure where the left end (0 mm) of the scale (100 mm) indicated a state of "no feeling" and the right end (100 mm) indicated a state where the subject had "maximum feeling". The subjects were directed to indicate their current state by checking the scale and evaluating the VAS results by the distance (mm) from the left end of the scale to the checked point (mm). Using the VAS scale, there were 12 questions for the control group and 13 for the stimulation group with the addition of a question for evaluating the scent of soil (**Table 2**). The short form of the Profile of Mood States (POMS-SF) was used to evaluate 30 items on mood states with a

Table 1. Terpenes from the soil for scent stimulation.

Component	Composition ratio (%)
α-Pinene	14.96
3-Carene	39.81
β-Myrcene	21.27
D-Limonene	23.97

five-grade evaluation and to determine T-Scores for the six mood scales of "Tension-Anxiety", "Depression", "Anger-Hostility", "Vigor", "Fatigue" and "Confusion".

2.5. Measurement Procedures

The experiment was conducted in a room with a room temperature of 24˚C ± 0.5˚C, and relative humidity of 31% ± 1%. The subjects sat quietly for about 10 min. after entering the room. Physiological evaluation was measured as follows: 5 min. rest (Pre.), 1 min. no stimulation or stimulation (No Stim. or Stim.), and 15 min. rest. The subjects sat with their eyes closed during measurement (Pre. to Post 15). Psychological evaluation (VAS and POMS) was conducted before and after (Pre., Post) physiological evaluation. At Post, the evaluation included the time when the scent was detected.

2.6. Method of Stimulation

Before starting the experiment, the bottle with a screw-on cap for scent stimulation into which soil was put, was positioned so that the opening of the bottle was 10 cm from the nose of the subject. The scent stimulation was made by opening/closing the cap. After 5 min. rest with the cap closed (Pre.) the control group sat with the cap closed (No Stim.) and the stimulation group (Stim.) sat with the cap open so they were able to smell the scent. After that, both groups rested for 15 min. (Post 5, Post 10, Post 15) with the cap closed.

2.7. Method of Evaluation

For physiological evaluation, the mean for each value of Pre., No Stim., Stim., Post 5, Post 10, and Post 15 was determined. For heart rate (HR) and heart rate fluctuation (LF, HF, LF/HF) the Fisher (LSD) multiple comparison was conducted on each group in the generalized linear model for five points (Pre., Stim., Post 5, Post 10, Post 15). Temporal changes between both groups were examined by two-way analysis of variance (interaction) in the generalized linear model. Wilcoxon signed-rank test was used for VAS and POMS. The data for the physiological/psychological evaluation was indicated by mean ± standard deviation.

3. Result

3.1. Physiological Evaluation

Table 3 indicates changes in heart rate (HR) and heart rate fluctuation (LF, HF,

Table 2. Questions for VAS.

Feel tired	Feel discomfort	Feel disgust	Feel depressed
Feel nervous	Feel excited	Feel thrilled	Feel refreshed
Feel comfortable	Feel relaxed	Feel soothed	Feel sleepy
Like scent of soil			

LF/HF). Heart rate significantly decreased after soil scent stimulation as indicated by the following results: Pre. level was 74.3 ± 6.5 bpm; during Stim. ($p = 0.01$), it was 72.0 ± 6.8 bpm and the level at Post 15 ($p = 0.022$) was 71.6 ± 7.8 bpm. There was also no interaction. Both control and stimulation groups showed no change in LF, HF, and LF/HF ratio and expressed no interaction.

3.2. Psychological Evaluation

3.2.1. POMS

Table 4 indicates T-Scores of POMS before and after the experiment. In the control group, "Tension-Anxiety" significantly decreased from a Pre. level of 41.5 ± 8.6 to a Post level ($p = 0.017$) of 38.9 ± 7.2 "Vigor" also showed a significant decrease from a Pre. level of 37.7 ± 7.2 to a Post level ($p = 0.026$) of 34.8 ± 5.2. In the stimulation group, significant decrease was seen for "Tension-Anxiety" which decreased from a Pre. level of 45.4 ± 14.7 to a Post level ($p = 0.017$) of 38.1 ± 7.0 and "Anger-Hostility" decreased from a Pre. level of 41.5 ± 4.2 to a Post level ($p = 0.011$) of 38.2 ± 1.8 and "Confusion" decreased from a Pre. level of 54.3 ± 13.9 to a Post level ($p = 0.018$) of 47.6 ± 8.6.

3.2.2. VAS

Table 5 shows VAS scores before and after the experiment. In the control group "Feel excited" significantly decreased from the Pre. level of 26.0 ± 20.8 mm to a Post level ($p = 0.009$) of 19.7 ± 21.4 mm and "Feel thrilled" decreased from a Pre. level of 26.2 ± 20.6 mm to a Post level ($p = 0.033$) of 19.5 ± 20.7 mm. In the stimulation group, "Feel nervous" decreased significantly from a Pre. level of

Table 3. Changes in heart rate and heart rate fluctuation.

	Pre	(No) Stim.	Post 5	Post 10	Post 15
Control Group					
HR (bpm)	72.0 ± 10.2	72.7 ± 6.2	73.9 ± 8.3	73.8 ± 8.3	72.8 ± 7.6
LF ($msec^2$)	836.5 ± 126.6	737.3 ± 136.7	1054.1 ± 273.5	920.7 ± 194.3	974.0 ± 150.3
HF ($msec^2$)	410.1 ± 91.5	386.8 ± 74.3	351.2 ± 72.1	325.1 ± 75.7	398.4 ± 88.7
LF/HF ratio	3.8 ± 1.0	5.3 ± 3.0	10.6 ± 6.7	8.2 ± 3.9	5.5 ± 2.3
Stimulation Group					
HR (bpm)	74.3 ± 6.5	72.0 ± 6.8*	74.2 ± 7.1	73.0 ± 6.3	71.6 ± 7.8*
LF ($msec^2$)	908.6 ± 157.8	1296.7 ± 325.4	855.8 ± 118.2	975.4 ± 130.6	1081.9 ± 236.2
HF ($msec^2$)	374.9 ± 134.5	616.2 ± 263.3	368.2 ± 123.0	399.5 ± 90.5	457.5 ± 113.9
LF/HF ratio	8.4 ± 3.7	9.8 ± 6.3	9.1 ± 3.7	7.4 ± 4.0	6.1 ± 3.1

*$p < 0.05$; The values are mean ± SD; The control group first rested for 5 min. (Pre.), next, they smelled no scent for 1 min. (No stim.), and then they rested again for 0 to 5 min. (Post 5), for 5 to 10 min. (Post 10), and for 10 to 15 min. (Post 15). The stimulation group first rested for 5 min. (Pre.), next, they were presented with the scent of soil for 1 min. (Stim.), and then rested for 0 to 5 min. (Post 5), for 5 to 10 min. (Post 10), and for 10 to 15 min. (Post 15).

Table 4. Changes in POMS scores before and after the experiment (T-scores).

	Control group		Stimulation group	
	Pre.	Post	Pre.	Post
Tension-Anxiety	41.5 ± 8.6	38.9 ± 7.2*	45.4 ± 14.7	38.1 ± 7.0*
Depression	43.1 ± 5.0	42.5 ± 4.2	47.7 ± 12.2	42.3 ± 3.3
Anger-Hostility	38.7 ± 2.5	38.2 ± 2.4	41.5 ± 4.2	38.2 ± 1.8*
Vigor	37.7 ± 7.2	34.8 ± 5.2*	37.2 ± 6.5	37.6 ± 6.1
Fatigue	44.1 ± 9.5	45.1 ± 9.8	48.2 ± 10.6	43.5 ± 11.2
Confusion	49.6 ± 9.9	48.2 ± 5.9	54.3 ± 13.9	47.6 ± 8.6*

POMS: Profile of Mood States; *$p < 0.05$; The values are mean ± SD.

Table 5. Changes in VAS scores before and after the experiment and evaluation of the scent of soil.

	Control group		Stimulation group	
	Pre.	Post	Pre.	Post
Feel tired	23.6 ± 16.9	31.6 ± 19.8	43.0 ± 25.5	33.1 ± 16.2
Feel discomfort	18.1 ± 15.2	17.5 ± 14.4	28.1 ± 25.3	28.9 ± 27.7
Feel disgust	8.7 ± 9.4	18.0 ± 16.2	18.3 ± 14.7	20.2 ± 19.7
Feel depressed	9.9 ± 10.8	8.2 ± 7.7	19.5 ± 21.7	15.6 ± 17.5
Feel nervous	19.7 ± 18.7	12.1 ± 10.1	38.3 ± 25.9	13.0 ± 14.1*
Feel excited	26.0 ± 20.8	19.7 ± 21.4*	25.8 ± 20.6	22.4 ± 22.7
Feel thrilled	26.2 ± 20.6	19.5 ± 20.7*	31.3 ± 18.1	31.7 ± 22.8
Feel refreshed	31.8 ± 0.2	20.3 ± 19.5	33.4 ± 21.7	32.8 ± 19.4
Feel comfortable	29.8 ± 19.1	26.8 ± 8.5	33.5 ± 21.8	44.8 ± 21.8*
Feel relaxed	33.1 ± 17.6	28.1 ± 22.1	36.9 ± 23.3	52.7 ± 16.1*
Feel soothed	22.8 ± 20.3	22.0 ± 19.7	25.8 ± 23.3	46.2 ± 20.5*
Feel sleepy	24.5 ± 18.3	31.8 ± 15.9	32.5 ± 15.2	42.5 ± 22.5
Like scent of soil				54.6 ± 6.0

VAS: Visual Analogue Scale; *$p < 0.05$; The values are mean ± SD.

38.3 ± 25.9 mm to a Post level ($p = 0.012$) of 13.0 ± 14.1 mm, and "Feel comfortable" significantly increased from a Pre. level of 33.5 ± 21.8 mm to a Post level ($p = 0.050$) of 44.8 ± 21.8 mm. "Feel relaxed" increased from a Pre. level of 36.9 ± 23.3 mm) to a Post-level ($p = 0.041$) of 52.7 ± 16.1 mm, "Feel soothed" increased from a Pre. level of 25.8 ± 23.3 mm to a Post level ($p = 0.038$) of 46.2 ± 20.5 mm.

3.3. Image of Soil Scent

We asked the stimulation group open-ended questions about their image of soil scent after they had smelled the soil. All the subjects gave a reply except for one.

Eight subjects imagined landscapes and experiences related to soil scent, and one subject had no image. Two participants replied as to whether they liked the soil scent or not (**Table 6**).

4. Discussion and Conclusion

In this study, we compared subjects which were presented with the scent of soil (stimulation group) and those which were not (control group). Consequently, although the control group showed no physiological changes, the stimulation group showed a significant decrease in heart rate (Stim., Post 15). The heart rate is determined by the firing frequency of the sinus node (pacemaker cells). This frequency is influenced by the dominant sympathetic nerve and vagus nerve, thus leading to either excitability or inhibitory. For this reason, periodic activity of the brain stem and higher order cerebral cortex that synchronize with signals from arteries and veins and changes in blood pressure influence behavior, emotions, circadian rhythm, which increase through hyperactivity of sympathetic nerve functions, and decrease through hyperactivity of parasympathetic nerve functions [11]. In this study, the heart rate of the stimulation group decreased, but there was no significant difference between HF that is a parasympathetic nerve index of heart rate fluctuation and LF/HF that is a sympathetic nerve index. Thus, we conclude that neither the parasympathetic nerves nor the sympathetic nerves function independently. In the open-ended questions about what kind of image subjects associated with the soil scent, some of the answers included "insect collecting" in the mountains, a forest, and horticultural therapy. A study on POMS reported that "forest bathing" improved mental health [12] and horticultural therapy reduced negative emotions [13]. For psychological evaluation, POMS scores of "Tension-Anxiety" and "Vigor" decreased in the control group. Moreover, VAS scores of "Feel excited" and "Feel thrilled" decreased. In the stimulation group, POMS scores of "Tension-Anxiety", "Anger-Hostility"

Table 6. Image of the scent of soil.

Answers to open-ended questions:
· I was reminded that when I was a child I caught a beetle in a mountain.
· I did not feel disgust, and if anything, I felt soothed.
· I had a nostalgic feeling that reminded me of my early childhood when I played in the sandbox at a park.
· I felt nostalgic and remembered my childhood and playing with beetles.
· When I was a high school student, I studied horticultural therapy.
· I imagined rice fields and the area around my parents' home.
· I imagined a forest.
· I was reminded of the soil in fields of rice and vegetables. (Since there are rice fields and vegetable fields around my parent's home, I had experienced smelling soil in the past).
· I had thought that the soil might have an unpleasant smell; however, it was not as unpleasant as I had expected.
· Imagined a park.
· I could not imagine anything.
· Non-response.

and "Confusion" decreased. In addition, VAS scores of "Feel nervous" decreased and "Feel comfortable", "Feel relaxed" and "Feel soothed" increased. From the above results, we conclude that subjects expressed improvement in their mood and were more relaxed when they were presented with the scent of soil. Some of the answers indicated that the scent of soil recalled childhood memories with subjects using such phrases as "in my early childhood", "in my childhood" or "when I was a child". In many cases, the scent made subjects recall memories of early childhood that were older than those created by visual or verbal cues [14] and raised a more emotional response [15]. The sense of smell enters the limbic system which is responsible for processing memory and creating emotion and reaches the hypothalamus that is also an autonomic nerve center. Accordingly, the emotional response from an individual who is stimulated by a scent can cause physiological changes in brain waves and various autonomic nerve functions. The heart rate is adjusted by the autonomic nervous system or endocrine system, and can change according to the subject's posture, and physical and mental activities [16]. Therefore, for the heart rate that showed significant difference, we performed a Pearson's correlation analysis among the degrees of changes at the points of Stim and Post 15 against Pre, and the degree of changes at the point of Post against Pre in VAS and POMS, and examined the psychological factors related to heart rate (**Table 7**). As a result, the degree to which the heart rate decreased after smelling soil scent had a significant negative correlation

Table 7. Correlation between the changes in heart rate in the stimulation group and the degree of VAS and POMS.

	HR (Stim.-Pre.)	HR (Post 15-Pre.)
VAS (Post-Pre.)		
Feel tired	0.013	−0.091
Feel discomfort	−0.035	−0.326
Feel disgust	0.164	−0.212
Feel depressed	−0.120	−0.558
Feel nervous	0.049	−0.489
Feel excited	−0.127	−0.571
Feel thrilled	0.588*	0.069
Feel refreshed	−0.347	0.145
Feel comfortable	−0.511	0.077
Feel relaxed	−0.896***	0.034
Feel soothed	−0.684*	0.166
Feel sleepy	0.169	0.320
POMS (Post-Pre.)		
Tension-Anxiety	−0.138	−0.277
Anger-Hostility	0.513	0.126
Confusion	0.355	0.052

*$p < 0.05$, ***$p < 0.001$; The values are correlation coefficient.

with the factors "feel relaxed" ($r = -0.896$, $p < 0.001$) and "feel soothed" ($r = -0.684$, $p = 0.014$) as indicated by the increase in the VAS scores. Therefore, in this study, we found that the healing effects and autobiographical memories induced from smelling the soil may lead to hyperactivity of parasympathetic nerve functions or suppression of sympathetic nerve functions which may influence the heart rate.

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