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Article

Effects of Tactile Stimulation Using an Assortment of Natural Elements on the Psychophysiological Responses of Adults

Yun-Jin Kim [1], Soo-Wan Choi [1] and Sin-Ae Park [1,2,*]

[1] Department of Bio and Healing Convergence, Graduate School, Konkuk University, Seoul 05029, Republic of Korea; jenny980127@naver.com (Y.-J.K.); sw_0530@naver.com (S.-W.C.)
[2] Department of Systems Biotechnology, Konkuk Institute of Technology, Konkuk University, Seoul 05029, Republic of Korea
* Correspondence: sapark42@konkuk.ac.kr; Tel.: +82-2-450-0537

Abstract: Contact with the natural environment has positive effects on physical and mental health and well-being. This study aimed to investigate the effects of tactile stimulation on the psychophysiological responses of adults, using natural gardening elements. The participants were 30 adults (20–60 years old). The participants received tactile stimulation by touching five natural elements with their hands and feet, and tactile stimulation for each natural element was performed for 90 s. Geranium, tiny ardisia, decomposed granite soil, log hardwood, and culture soil were used as tactile stimulation factors for the hand, and moss, grass, pebble, bark, and culture soil were used as tactile stimulation factors for the foot. Oxyhemoglobin (oxy-Hb) concentrations in the prefrontal cortex during the stimulation as well as blood pressure and pulse rate after each activity were measured. Additionally, the semantic differential method was used to evaluate the psychological effects of contact with the elements on the participants. Compared to before tactile stimulation, the oxy-Hb concentration related to prefrontal lobe cortical activity significantly decreased in some sections using tiny ardisia, log hardwood, and culture soil on the hands, and using grass, moss, pebble, and bark on the feet. Blood pressure also showed a significant decrease after tactile stimulation using geranium, tiny ardisia, and log hardwood. The findings of this study suggest that tactile stimulation using natural gardening elements could be a significant intervention in inducing physiological stability and reducing stress by calming the activity of the prefrontal cortex.

Keywords: natural gardening elements; tactile stimulation; prefrontal cortex activity; near-infrared spectroscopy; physiological relaxation

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1. Introduction

As natural spaces are transformed into artificial spaces, owing to the development of urban and architectural spaces along with the rapid growth of the economy and industry, many city dwellers are living in artificial environments lacking natural objects [1]. The artificial environments of large cities provide life benefits to humans but cause immune diseases, mental diseases, and infectious diseases due to air pollution, noise, electromagnetic waves, and so on [2,3]. However, as the standard of living of residents in cities increases, the demand for improving their quality of living environment also increases. Accordingly, various activities such as agro-healing, horticultural therapy, horticultural activities, and green plant walls focusing on the healing function of nature are gaining attention.

Additionally, various theories based on the nature-friendly aspect have been argued, and interest in the potential of the natural environment to benefit humans is increasing. The natural environment plays an important role in the modern world to help humans overcome diseases. In the stress recovery theory (SRT), Ulrich [4] argues for more contact with nature. Wilson's biophilia theory [5] claims that natural reversion is inherent in human genes, so people are instinctively attracted to nature.

Based on this, studies have been conducted on the identification of human health effects caused by nature or horticultural activities. A gardening program for the elderly significantly improved their brain-derived neurotrophic factor (BDNF) and platelet-derived growth factor (PDGF) levels related to cognitive health factors [6]. Following a horticultural therapy program for people with intellectual disabilities, their interpersonal negotiation strategies, functional adaptive behaviors, and physical abilities for job behaviors, including agility and grasping of the hand, improved significantly [7]. As a result of conducting a healing agriculture program for patients with schizophrenia, their negative symptom responses were significantly reduced and positive effects were found upon rehabilitation [8]. Moreover, a horticultural treatment program was conducted for veterans with mental health problems, and their depression and stress levels significantly reduced [9]. As such, it positively affects the physical, cognitive, and emotional health aspects.

The human health effects of such horticultural activities are generated through the interaction between horticultural and natural healing elements, and humans. To identify this, basic research based on the five human senses using horticulture and natural healing elements is being conducted. In a prior study on visual stimulation in adults, it was observed that increased exposure led to an elevation in the relative theta (RT) power spectrum, an indicator of attentional ability, in the occipital cortex [10]. Additionally, the relative high beta (RHB) power spectrum, an indicator of stress and anxiety, showed a decrease in inducing physiological relaxation [10]. When women's senses of smell were stimulated with various aroma oils, the EEG of their prefrontal cortex significantly increased the ratio of alpha to high beta (RAHB), an index of relaxation and stability, and the relative low beta (RLB), an index of brain activity. Moreover, their blood pressure was significantly reduced and the participants were psychophysiologically stable [11]. In another study, forest-derived visual, auditory, and combined visual–auditory stimuli significantly reduced the concentration of oxy-Hb in the human prefrontal cortex and increased the parasympathetic nervous system (PSNS) activity, resulting in a relaxed state [12]. In particular, the combined stimuli indicated a more pronounced physiological relaxation state than a single stimulus [12].

Among the five human senses, tactile contact has a particularly active and exploratory form of perception in nature, which can help us to realize various characteristics such as the shape, warmth, weight, and texture of an object through the sense of touch [13]. According to a tactile stimulation study conducted using contact with natural materials, a significant decrease in cerebral blood flow (CBF) was observed when the leaves of real plants were touched by hand, but no physiological changes were observed in the leaves of artificial plants [14]. In the case of barefoot contact with wood, the concentration of oxy-Hb in the left and right prefrontal cortex was shown to decrease immediately after contact, and the value of ln(HF) was found to increase significantly, thus affecting the autonomic nervous system (ANS) and causing physiological relaxation [15,16].

However, the number of natural elements used in studying the interaction between the tactile stimulation of natural objects and human psychophysiological aspects is miniscule; moreover, the original form is modified according to the experimenter's intention before the research is conducted. To understand the actual healing mechanism of the natural environment, research on various types and original forms of natural objects is necessary. Therefore, this study aims to investigate the psychophysiological effects on humans when their hands and feet meet various natural gardening elements.

2. Materials and Methods

2.1. Research Participants

Flyers containing information about the research were distributed to apartments and libraries in Gwangjin-gu, Seoul, Republic of Korea. Participants were recruited according to convenience sampling and based on specific criteria to avoid influencing the data. A participant had to be one (a) who did not have any psychopathological disease and did not take related drugs; (b) who was right-hand dominant; (c) who agreed to participate after fully understanding the contents of the research; (d) who had no history of any cardiovascular disease such as high blood pressure, unstable angina, heart attack, and heart surgery; (e) who had no tactile function-related disorders, allergies, respiratory diseases, and insomnia; and (f) who was not pregnant, lactating, or menstruating [11].

A total of 30 adults (7 men and 23 women; average age: 31.2 ± 10.2 years) participated in this study. The researcher explained the contents of the study and precautions to the participants before conducting the experiment and obtained written consent from the participants who agreed to the study. Additional data about their, age, sex, height, weight, and body mass index (ioi 353; Jawon Medical Co., Ltd., Gyeongsan, Republic of Korea) were measured as demographic information. The participants received an incentive (approximately USD 20) after completing the experiment. This study was approved by the Bioethics Committee of Konkuk University (7001355-202106-HR-442).

2.2. Experimental Condition

This study was conducted in a designated experimental space (200 cm × 160 cm) in a laboratory at Konkuk University, Seoul, Republic of Korea. The environmental conditions of the experimental space were as follows: temperature of 24.4 ± 3.1 °C, relative humidity of 15.2 ± 1.8% (O-257; DRETECKOREA Co., Seoul, Republic of Korea), and illuminance of 2679.5 ± 1813.4 Lux. To minimize external visual stimulation, white cardboard was attached to the front of the desk and ivory curtains were attached on both sides.

2.3. Experimental Procedure

This was a crossover experimental study in which each participant performed the experimental protocol presented in Figure 1.

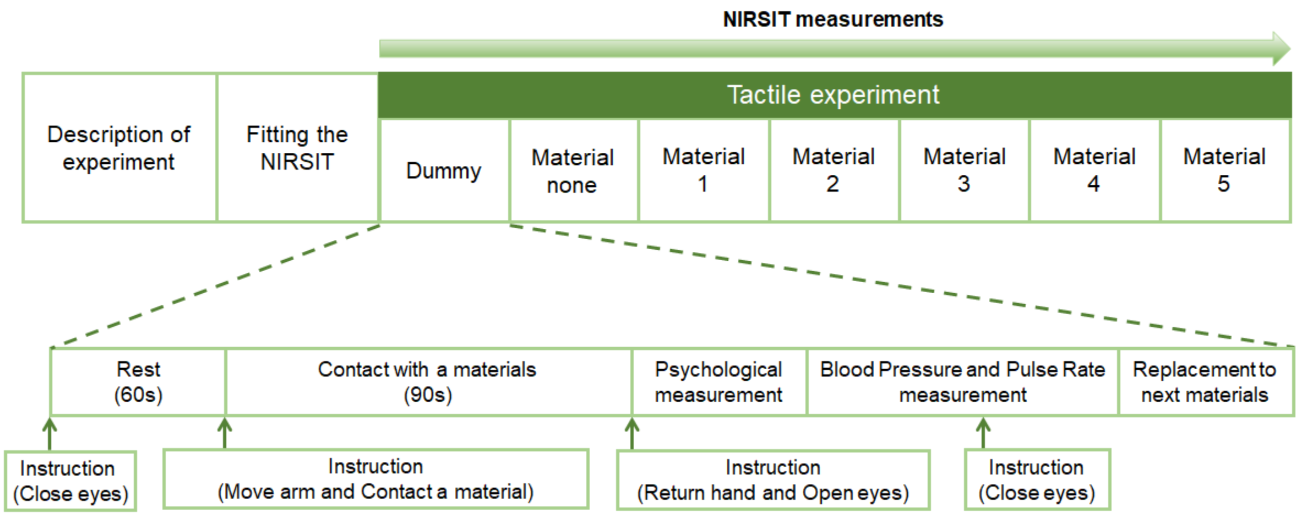


Figure 1. Study procedure. NIRSIT, near-infrared time-resolved spectroscopy.

In this study, a psychophysiological measuring device was worn to measure the concentration of oxy-Hb in the participants' prefrontal lobe cortex during the activity. In addition, a mask, earplugs, and eye patch were worn to minimize external stimulation. After taking a break for 60 s, the participants touched the natural gardening elements for 90 s according to the experimenter's instructions (Figure 2). The order of elements was randomly assigned to each participant. Changes in oxy-Hb concentration were measured during the 90 s of touching a natural element. Immediately after touching the natural gardening elements for 90 s, the blood pressure and pulse rate of the participants were measured, along with their subjective feelings, which were assessed using the semantic difference method (SDM). The participants were instructed not to make large movements or speak during the experiment. The experiment comprised two parts, tactile stimulation of the hands and that of the feet. A break was given between each experiment. The participants visited the laboratory only once to participate in this study, and all experimental procedures were completed within 80 min per participant.

(**A**) (**B**)

Figure 2. Experimental procedure. (**A**) Experimental scene of tactile stimulation (hand); (**B**) experimental scene of tactile stimulation (foot).

2.4. Tactile Stimulation Element

Despite there being many different types of natural elements, the subjects in this study were limited to plant leaves, trees, and soil. As for the tactile stimulation elements for the hand, natural elements that can be encountered during horticulture activities were selected. The plant leaves and soil were divided into two textures (smooth and rough). As for the tactile stimulation elements for the feet, natural elements that can be encountered mainly in gardens or care farms were selected.

2.4.1. Hand

Tactile stimulation of the hand was performed using geranium (*Pelargonium inquinans*), tiny ardisia (*Ardisia pusilla A.DC.*), log hardwood (*Quercus*), decomposed granite soil, and culture soil. The geranium (Ø15 cm pot, 6 ea) (Figure 3A) and tiny ardisia (Ø10 cm pot, 8 ea) (Figure 3B) were prepared so that only the leaves could be touched. The decomposed granite soil (3~9 mm, 8 L) was washed in advance and dried before being used in the experiment (Figure 3C). In the case of the log hardwood (Ø20 cm × 30 cm), oak (*Quercus*) in the form of log hardwood was used in its natural state (Figure 3D). For the culture soil (8 L), a horticultural medium containing coco peat, peat moss, zeolite, perlite, vermiculite, and fertilizer was used (Figure 3E).

2.4.2. Foot

Grass, moss, bark, pebbles, and culture soil were used in the tactile stimulation experiment for the feet. All materials were stored at room temperature in identical boxes (59 × 38 × 15 cm, 27 L). Grass (46 × 36 cm, 1 ea) engrafted to fibrous soil was used (Figure 4A). Dried moss (56 × 36 cm, 1 ea) collected from natural surroundings was soaked in water for a day and used after it was dry (Figure 4B). In the box containing pebbles (1.2~3 cm, 8 L), black gravel and agate stone were mixed in a certain ratio (Figure 4C). The bark (3~6 cm, 8 L) was made of pine and was used without any chemical treatment (Figure 4D). For the culture soil (8 L), a horticultural medium containing coco peat, peat moss, zeolite, perlite, vermiculite, and fertilizer was used (Figure 4E).

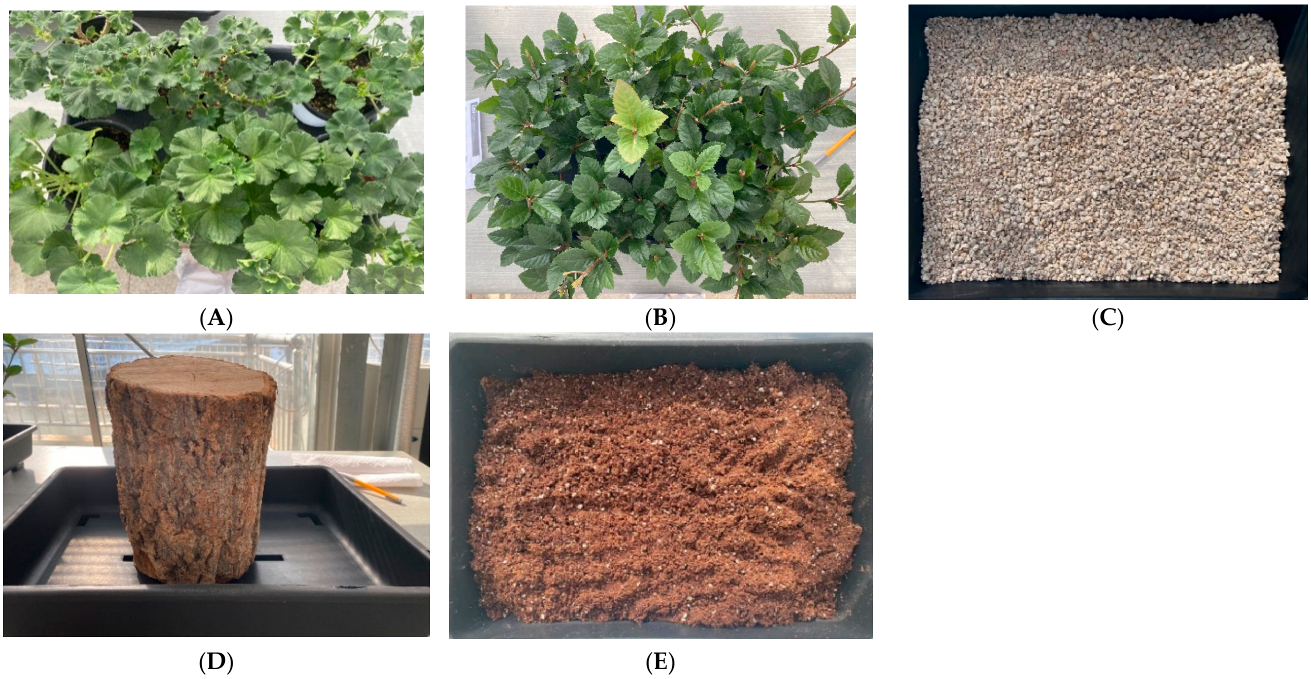


Figure 3. Materials used for the hand tactile experiment. (**A**) Geranium (*Pelargonium inquinans*); (**B**) tiny ardisia (*Ardisia pusilla A.DC.*); (**C**) decomposed granite soil; (**D**) log hardwood (*Quercus*); and (**E**) culture soil.

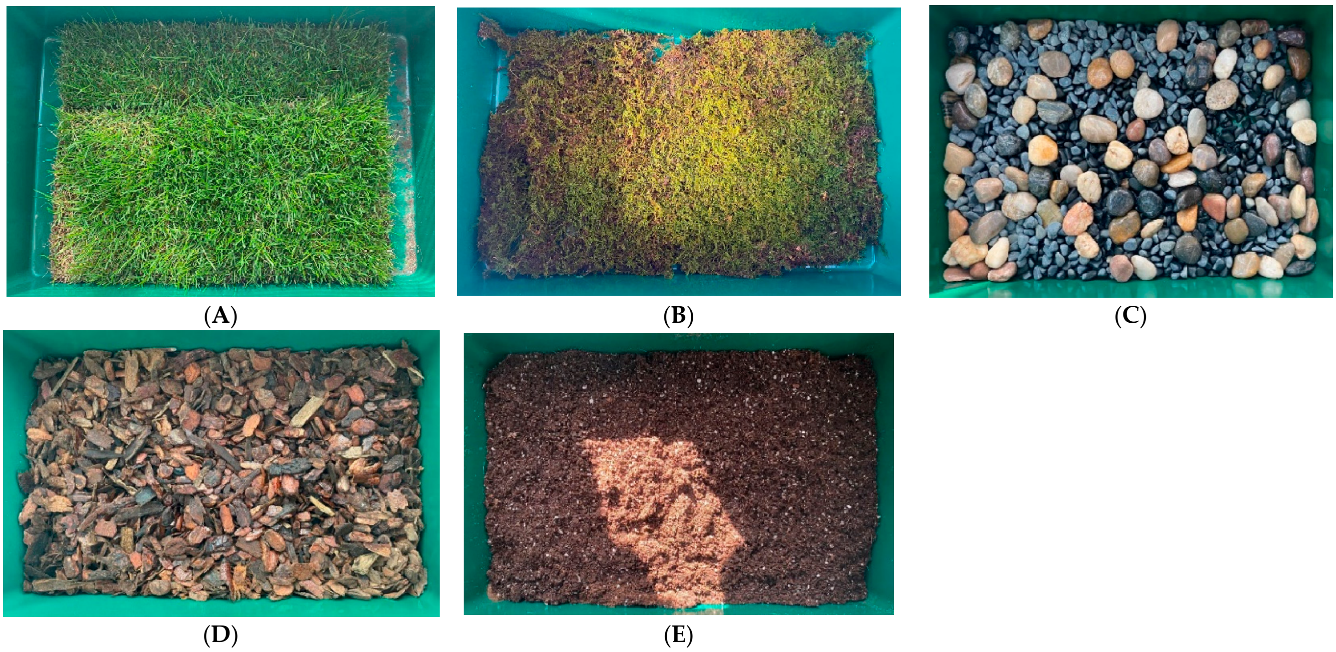
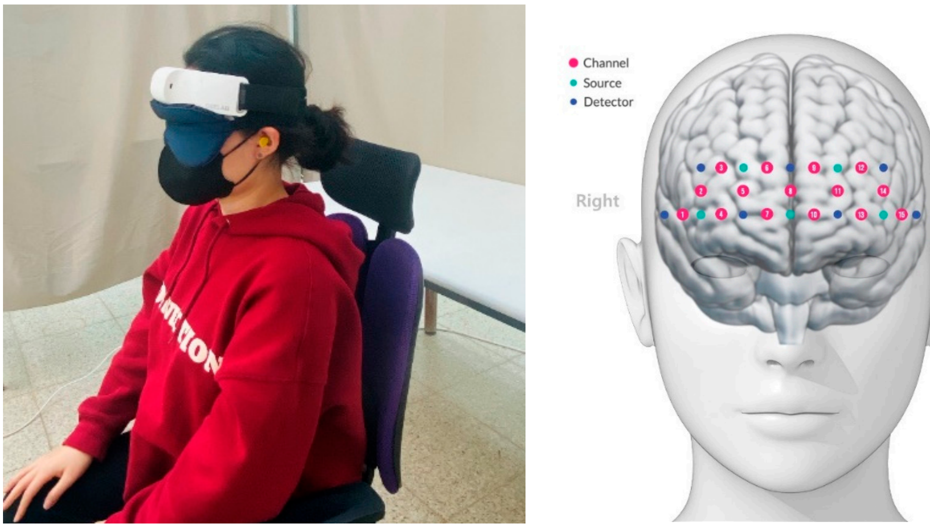


Figure 4. Materials used for the foot tactile experiment. (**A**) Grass; (**B**) moss; (**C**) pebbles; (**D**) bark; and (**E**) culture soil.

2.5. Measurement Items

2.5.1. Near-Infrared Time-Resolved Spectroscopy

NIRS was used for physiological measurements. In this study, functional near-infrared spectroscopy (fNIRS) was used to measure brain activity when the participants came into contact with the elements of natural origin (Figure 5A). fNIRS is non-invasive and measures concentration changes in oxyhemoglobin (HbO) and deoxyhemoglobin (HbR) based on nerve activation, and is easy to use and safe on the test subjects. It also contributes to measuring functional brain activity and cognitive function [17].



(**A**) (**B**)

Figure 5. Wearing instrument: (**A**) brain imaging equipment (NIRSIT Lite, OBELAB Inc., Seoul, Republic of Korea); (**B**) location of channel, source, and detector (NIRSIT Lite Channel Information, OBELAB Inc., Seoul, Republic of Korea).

fNIRS data were recorded through a NIRSIT Lite (OBELAB Inc., Seoul, Republic of Korea) comprising 5 light sources, 7 collectors, and 15 channels (Figure 5B). Light intensity data of the PFC region were collected at a sampling rate of 8.138 Hz using 780 and 850 nm wavelengths. The channels are located in the aPFC (CH 2 to 14), DPFC (CH 1), and the orbital part of the IFG (CH 15) in Brodmann's area. CH 1~7 can be divided into the right prefrontal lobe and CH 9~15 into the left prefrontal lobe.

2.5.2. Blood Pressure and Pulse Rate

Blood pressure and pulse rates are used as measures of the autonomic nervous system (ANS). After tactile stimulation using the natural elements, the participants' blood pressure was measured using a blood pressure monitor (T4 with Intellisense; Omron Co., Kyoto, Japan) on their left arm while they were resting after the stimulation. The measurement items included their pulse rate (HRV), systolic blood pressure (mmHg), and diastolic blood pressure (mmHg).

2.5.3. Psychological Measurement

The modified SDM [18] was used to evaluate the psychological effect on the participants based on tactile contact and to identify the characteristics of each element. The modified SDM used in this study consisted of seven items, and the Likert score was 13 out of 13: "Comfortable–Uncomfortable", "Relaxed–Alert", "Natural–Artificial", "Warm–Cold", "Smooth–Uneven", "Moist–Dry", and "Soft–Hard".

2.6. Data Processing and Analysis

fNIRS data were processed through the NIRSIT Lite Analysis Tool v3.2.4 (OBELAB Inc., Seoul, Republic of Korea). The light intensity data measured using the instrument were converted into a time series of changes in HbO and HbR concentrations by applying the modified Beer–Lambert law (MBLL). In this experiment, only HbO data were used; a high-pass filter (cutoff frequency 0.005 Hz) and a low-pass filter (cutoff frequency 0.01 Hz) were applied to the converted data to remove noise, such as the heart rate, respiration, and excessive movement. The signal-to-noise ratio criterion for removing channels with a low signal quality was less than 30 dB, and excessive peaks (more than 10 mM and less than −10 mM) on the △HbO time series graph were considered as noise and removed. All data values were calculated based on 2 s before material contact. Referring to previous studies [19,20], the collected PFC data were divided into R-PFC (CH1-7) and L-PFC (CH9-15), and the average value for 90 s was calculated. Then, for more detailed analysis, they were further divided into data of 30 s and analyzed. Channels corresponding to each region were averaged and used for data statistical processing.

A paired *t*-test was performed on the processed fNIRS data, blood pressure, pulse rate data, and SDM, using SPSS (version 25 for Windows; IBM Corp., Armonk, NY, USA). Differences before and after touching the natural objects were analyzed. All significance levels were set at $p < 0.05$. For demographic information, descriptive statistics such as the mean and standard deviation were performed using Microsoft Excel (Office 2016; Microsoft Corp., Redmond, WA, USA).

3. Results

3.1. Demographic Characteristics

Adults aged 31.2 ± 10.2 years participated in this study (seven men, 26.7 ± 2.6 years; 23 women, 32.6 ± 11.3 years) (Table 1). The average height was 164.4 ± 6.6 cm, while the average body weight was 63.2 ± 13.1 kg. The overall average body mass index (BMI) was 23.3 ± 4.1 kg m^{-2}, which is within the normal range as per the criteria specified by the World Health Organization.

Table 1. Demographic information of the participants in this study.

Variable	Male (*n* = 7)	Female (*n* = 23)	Total (*N* = 30)
		Mean ± SD	
Age (years)	26.71 ± 2.56	32.57 ± 11.28	31.20 ± 10.21
Height [1] (cm)	173.50 ± 2.19	161.50 ± 4.46	164.40 ± 6.58
Body weight [2] (kg)	75.90 ± 8.78	59.10 ± 11.66	63.20 ± 13.12
Body mass index [3] ($kg \cdot m^{-2}$)	25.20 ± 2.80	22.60 ± 4.34	23.30 ± 4.13

[1] Height was measured using an anthropometer (Ok7979; Samhwa, Seoul, Republic of Korea) without shoes; [2] body weight was measured using a body fat analyzer (ioi 353; Jawon Medical, Republic of Korea); [3] body mass index was calculated using the formula: [weight (kg)]/[height $(m)^2$].

3.2. Tactile Stimulation (Hand)

3.2.1. Near-Infrared Time-Resolved Spectroscopy

Figure 6 shows the comparison of the total and section-wise average oxy-Hb concentrations in the prefrontal cortex before and after touching the five natural elements. All data were calculated as the difference to the 2 s baseline period immediately before the participant touched the element. Compared to before tactile stimulation, the concentration of oxy-Hb in the participants' left prefrontal lobe after touching the tiny ardisia, log hardwood, and culture soil significantly decreased in the 0–30 s interval of the stimulation ($p < 0.05$; Figure 6A). There was no significant difference in the concentration of oxy-Hb in the right prefrontal lobe ($p > 0.05$; Figure 6B). However, comparing the changes in the oxy-Hb concentration per second in the left and right prefrontal cortex showed that the oxy-Hb concentration tended to be maintained at a lower level when touching the element than before touching it.

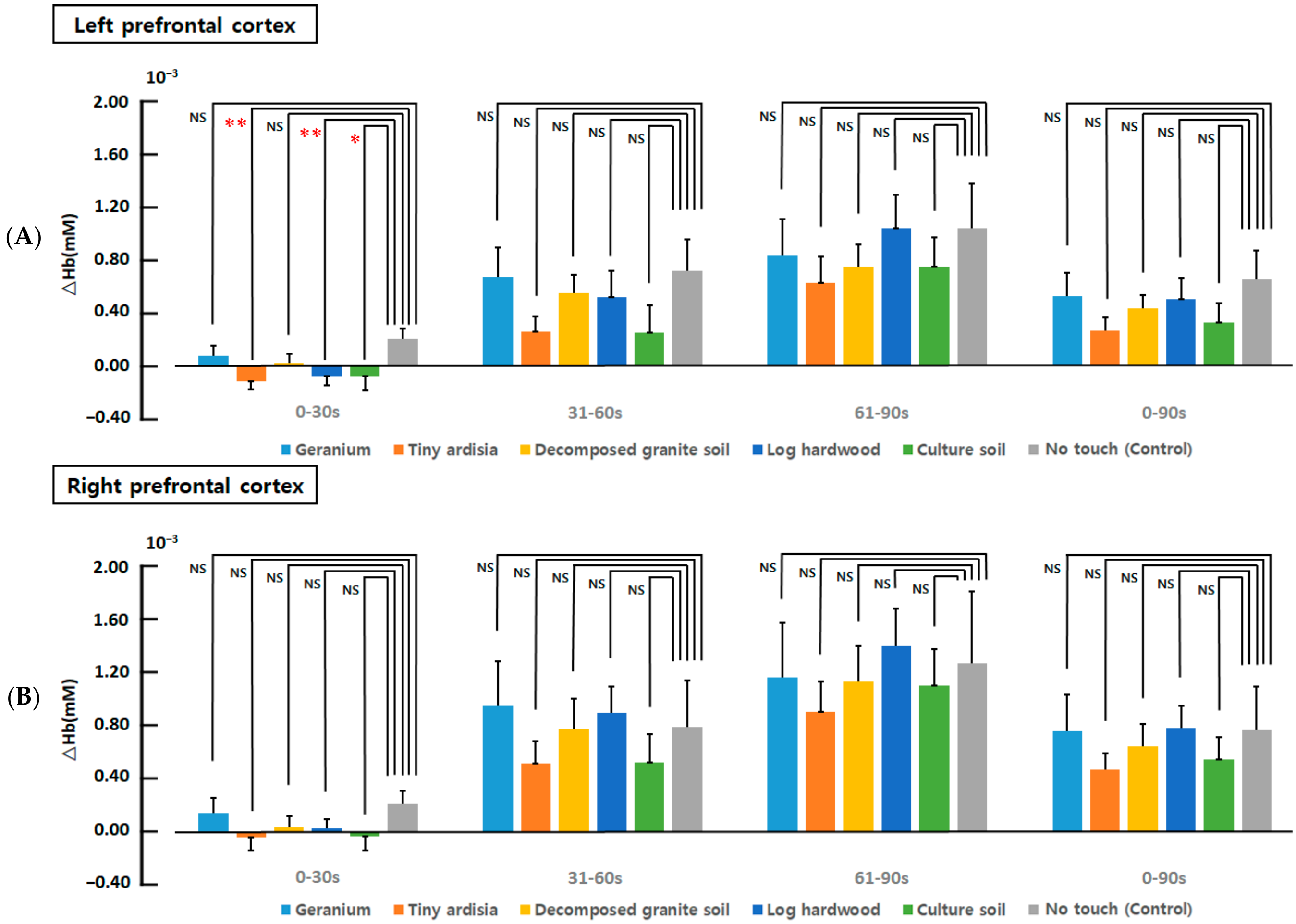


Figure 6. Comparison by section according to materials (hand). (**A**) Left; (**B**) right. Statistical significance as determined using the paired *t*-test. *, ** significant at $p < 0.05$ or 0.01, respectively; NS, not significant.

3.2.2. Pulse Rate and Blood Pressure

Comparing the pulse rate and blood pressure before and after tactile stimulation for each element showed that there was no significant difference in the pulse rate ($p > 0.05$; Table 2), while the systolic blood pressure showed a significant decrease after stimulation with tiny ardisia ($p < 0.05$; Table 2), and the diastolic blood pressure showed a significant decrease after stimulation with geranium, tiny ardisia and log hardwood ($p < 0.05$; Table 2).

Table 2. Change in pulse rate and blood pressure due to tactile stimulation using five natural elements (hand).

Variable	No Touch (Control)	Geranium	Tiny Ardisia	Decomposed Granite Soil	Log Hardwood	Culture Soil
	Mean ± SD [1]					
Pulse rate Significance [2]	77.73 ± 9.87	76.63 ± 9.49 0.317	77.73 ± 9.16 1.000	78.10 ± 9.50 0.724	77.07 ± 9.40 0.487	77.93 ± 8.80 0.857
Systolic pressure Significance [2]	117.07 ± 16.60	114.37 ± 12.95 0.066	113.97 ± 13.95 0.012 *	116.33 ± 16.43 0.532	115.40 ± 15.46 0.206	118.37 ± 15.38 0.255
Diastolic pressure Significance [2]	75.30 ± 11.82	73.33 ± 10.04 0.045 *	73.07 ± 9.41 0.034 *	74.93 ± 9.70 0.712	72.87 ± 10.81 0.020 *	74.80 ± 10.93 0.644

[1] SD: standard deviation. [2] * $p < 0.05$ using the paired *t*-test.

3.2.3. Semantic Differential Method (SDM)

Figure 7 shows the results of the SDM for the natural elements that were touched by the hand. There was no significant difference in terms of feeling "comfortable–uncomfortable" ($p > 0.05$; Figure 7A) on touching. Participants were "slightly to moderately relaxed" when touching the geranium ($p < 0.01$; Figure 7B), and were "moderately natural" when touching the log hardwood ($p < 0.001$; Figure 7C). This was shown to induce additional relaxation than when tactile stimulation was not performed. In terms of feeling warm–cold, when touching the tiny ardisia, decomposed granite soil, log hardwood, and culture soil, their feelings ranged from "indifferent to slightly cold" ($p < 0.05$; Figure 7D). When touching the tiny ardisia, decomposed granite soil, and log hardwood, their feelings ranged from "indifferent to finding it moderately uneven" ($p < 0.001$; Figure 7E). When touching the culture soil, participants felt it to be "slightly to moderately moist," and when touching the tiny ardisia and decomposed granite soil, they felt it to be "slightly to moderately dry" ($p < 0.001$; Figure 7F). When touching the tiny ardisia and culture soil, they felt "moderately to very soft", and when touching the decomposed granite soil and log hardwood, they felt "slightly to moderately hard" ($p < 0.001$; Figure 7G).

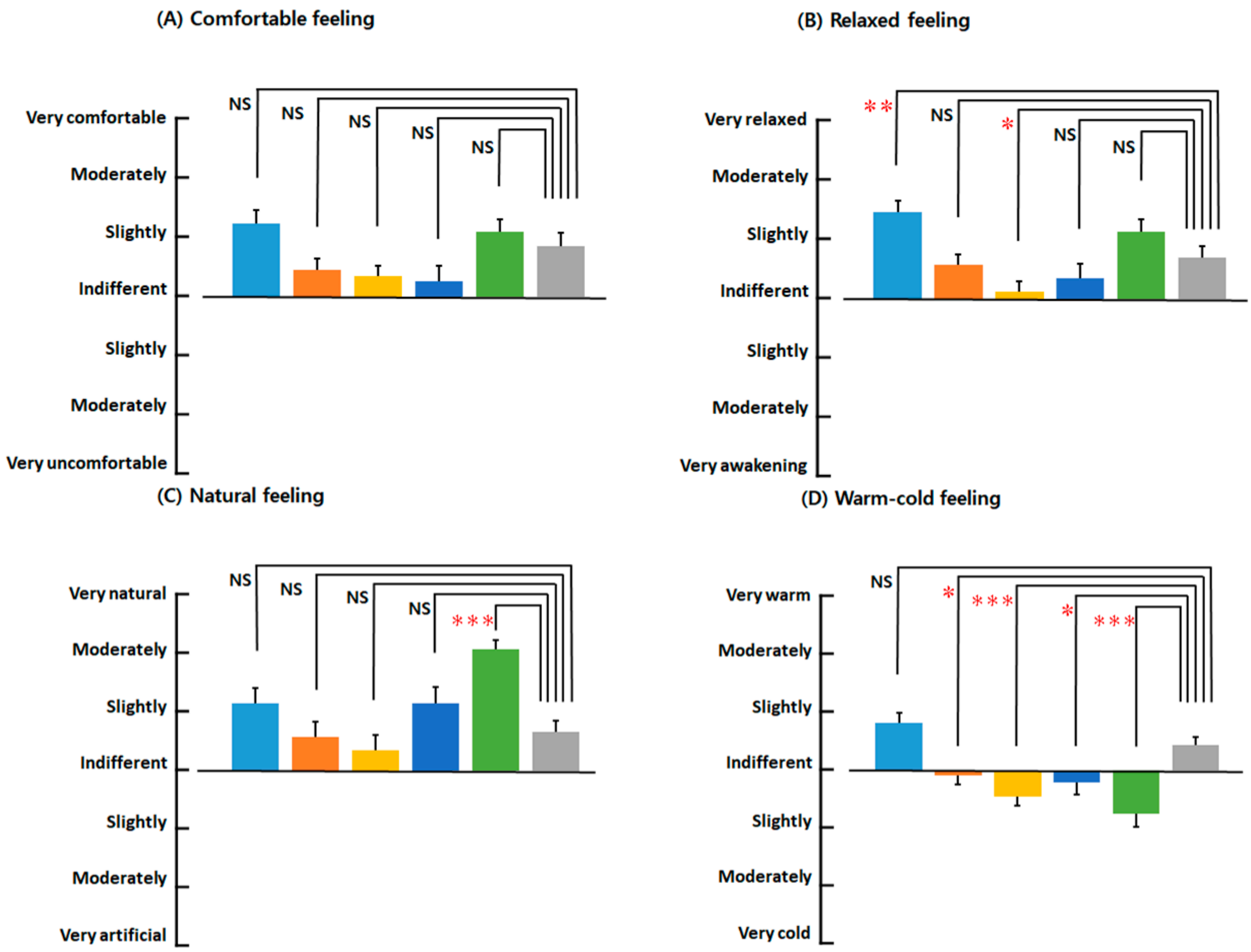


Figure 7. *Cont.*

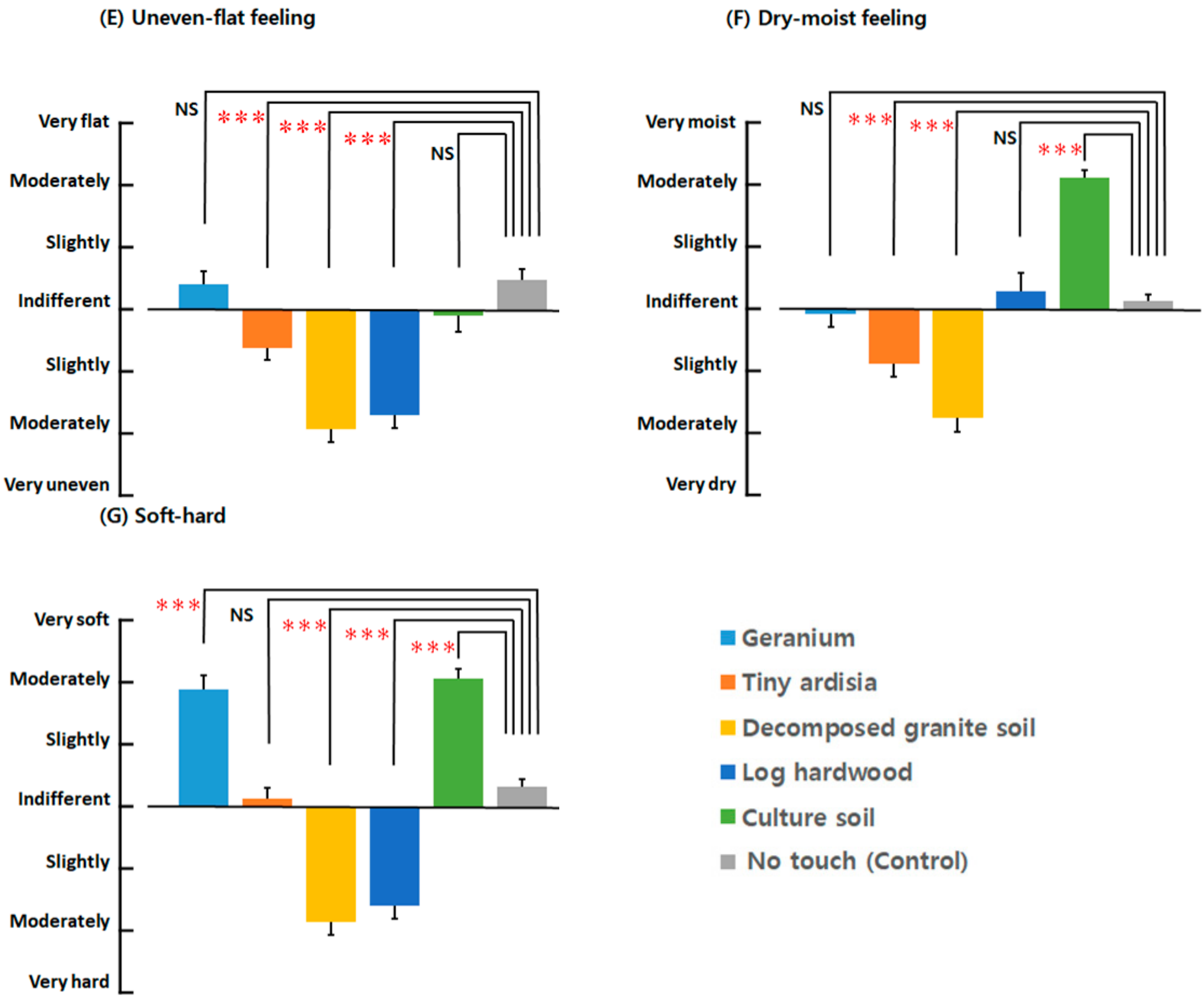


Figure 7. Comparison of responses using an SDM for stimulation using natural elements (hand). (**A**) feeling comfortable; (**B**) feeling relaxed; (**C**) feeling natural; (**D**) feeling warm; (**E**) feeling uneven; (**F**) feeling moist; and (**G**) feeling soft. Statistical significance was determined using the paired *t*-test. *, **, *** significant at $p < 0.05$, 0.01 or 0.001, respectively; NS, not significant.

3.3. Tactile Stimulation (Foot)

3.3.1. Near-Infrared Time-Resolved Spectroscopy

Figure 8 shows the comparison of the total and section average oxy-Hb concentrations in the participants' prefrontal cortex before and after touching the five natural elements. All data were calculated as the difference from the 2 s baseline period immediately before the participant touched the natural element. Compared to before tactile stimulation, the concentration of oxy-Hb in their left prefrontal cortex was significantly lower with grass, moss, pebbles, and bark in the 0–30 s period of stimulation ($p < 0.05$; Figure 8A). In the 31–60 s period, the oxy-Hb concentrations after touching moss and bark were significantly lower ($p < 0.01$; Figure 8A). Compared to before tactile stimulation, the concentration of oxy-Hb in the right prefrontal cortex was significantly lower when touching moss and bark in the 0–30-s interval ($p < 0.01$; Figure 8B). In the 31–60 s period, the concentration of oxy-Hb with the bark was significantly lower ($p < 0.05$; Figure 8B).

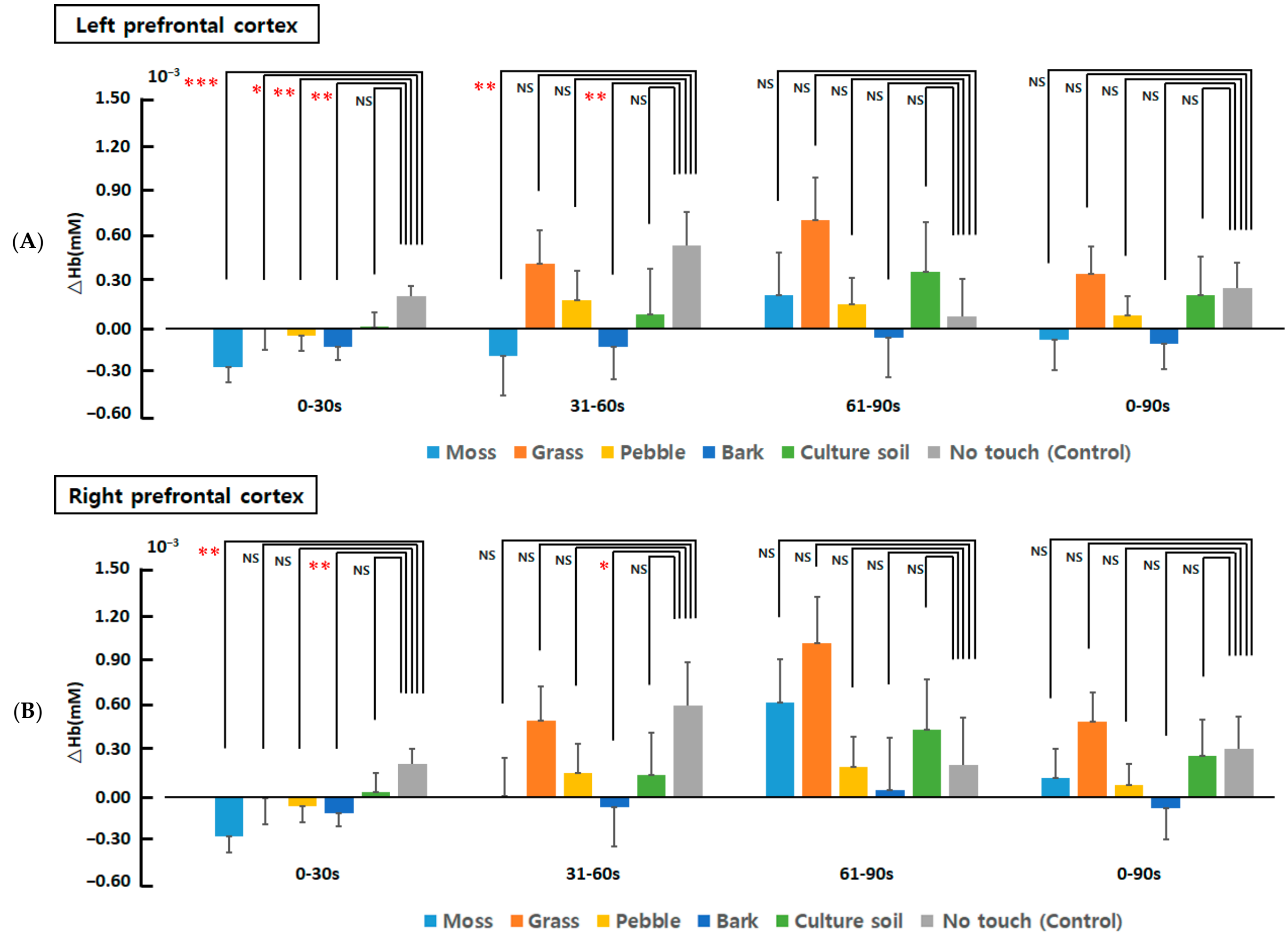


Figure 8. Comparison by section according to materials (foot). (**A**) Left; (**B**) right. Statistical significance was determined using the paired *t*-test. *, **, *** significant at $p < 0.05$, 0.01 or 0.001, respectively; NS, not significant.

3.3.2. Pulse Rate and Blood Pressure

Comparing the pulse rate and blood pressure before and after tactile stimulation using the five elements, no significant difference was seen in the pulse rate ($p > 0.05$; Table 3). On the other hand, the difference in systolic blood pressure increased significantly after touching the grass, moss, and culture soil ($p < 0.05$; Table 3), but there was no significant difference in the diastolic blood pressure ($p > 0.05$; Table 3).

Table 3. Change in pulse rate and blood pressure due to tactile stimulation using the five natural elements (foot).

Variable	No Touch (Control)	Grass	Moss	Pebbles	Bark	Culture Soil
	Mean ± SD [1]					
Pulse rate Significance [2]	75.73 ± 9.67	75.47 ± 10.36 0.813	76.50 ± 10.64 0.473	75.70 ± 11.35 0.978	75.93 ± 9.62 0.861	77.30 ± 11.00 0.266
Systolic pressure Significance [2]	114.03 ± 14.28	116.83 ± 15.24 0.036 *	116.07 ± 15.14 0.047 *	114.53 ± 14.08 0.725	114.90 ± 13.66 0.416	118.27 ± 16.83 0.001 **
Diastolic pressure Significance [2]	73.97 ± 10.72	74.90 ± 10.10 0.358	75.43 ± 11.49 0.165	75.50 ± 11.49 0.201	74.37 ± 8.97 0.660	75.13 ± 10.42 0.325

[1] SD: standard deviation. [2] * $p < 0.05$, ** $p < 0.01$ using the paired *t*-test.

3.3.3. SDM

Figure 9 shows the SDM results of the participants' feelings when their feet came into contact with the natural elements. They felt "slightly to moderately comfortable and relaxed" when touching grass ($p > 0.05$; Figure 9A,B), which was found to induce significantly more relaxation than when no tactile stimulation was performed. When touching grass, moss, and culture soil, they felt the elements to be "slightly to very natural" ($p < 0.001$; Figure 9C), more so than the other elements. They felt "indifferent to moderately cold" when touching all the elements ($p < 0.05$; Figure 9D). When touching a pebble and bark, they felt "slightly to moderately uneven" ($p < 0.001$; Figure 9E). When touching the moss, grass, and culture soil, they felt "slightly to very moist" ($p < 0.001$; Figure 9F). When touching the moss, grass, and culture soil, they felt "slightly soft to very soft" ($p < 0.001$; Figure 9G), and when touching the pebbles and bark, they felt "indifferent to moderately hard" ($p < 0.01$; Figure 9G).

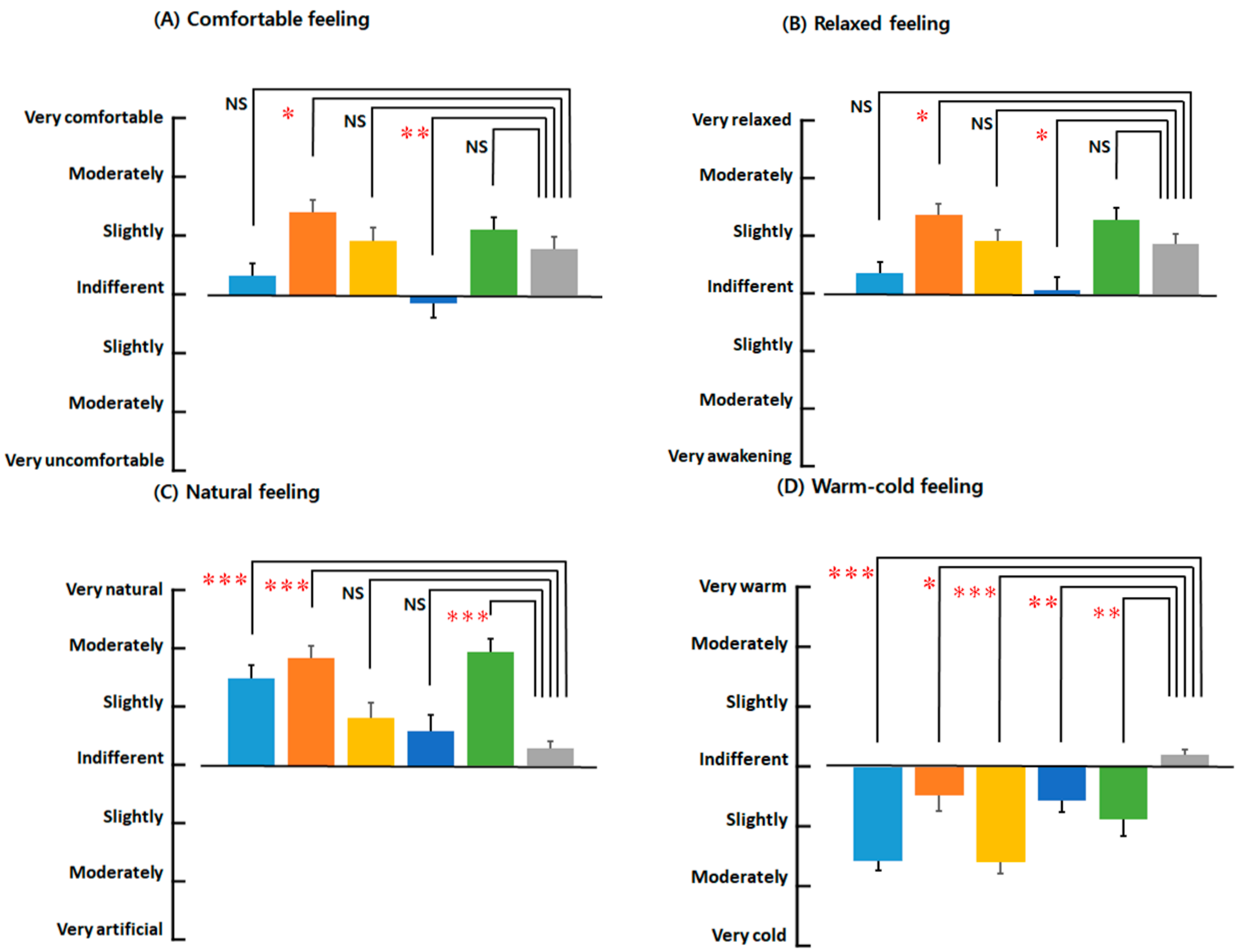


Figure 9. *Cont.*

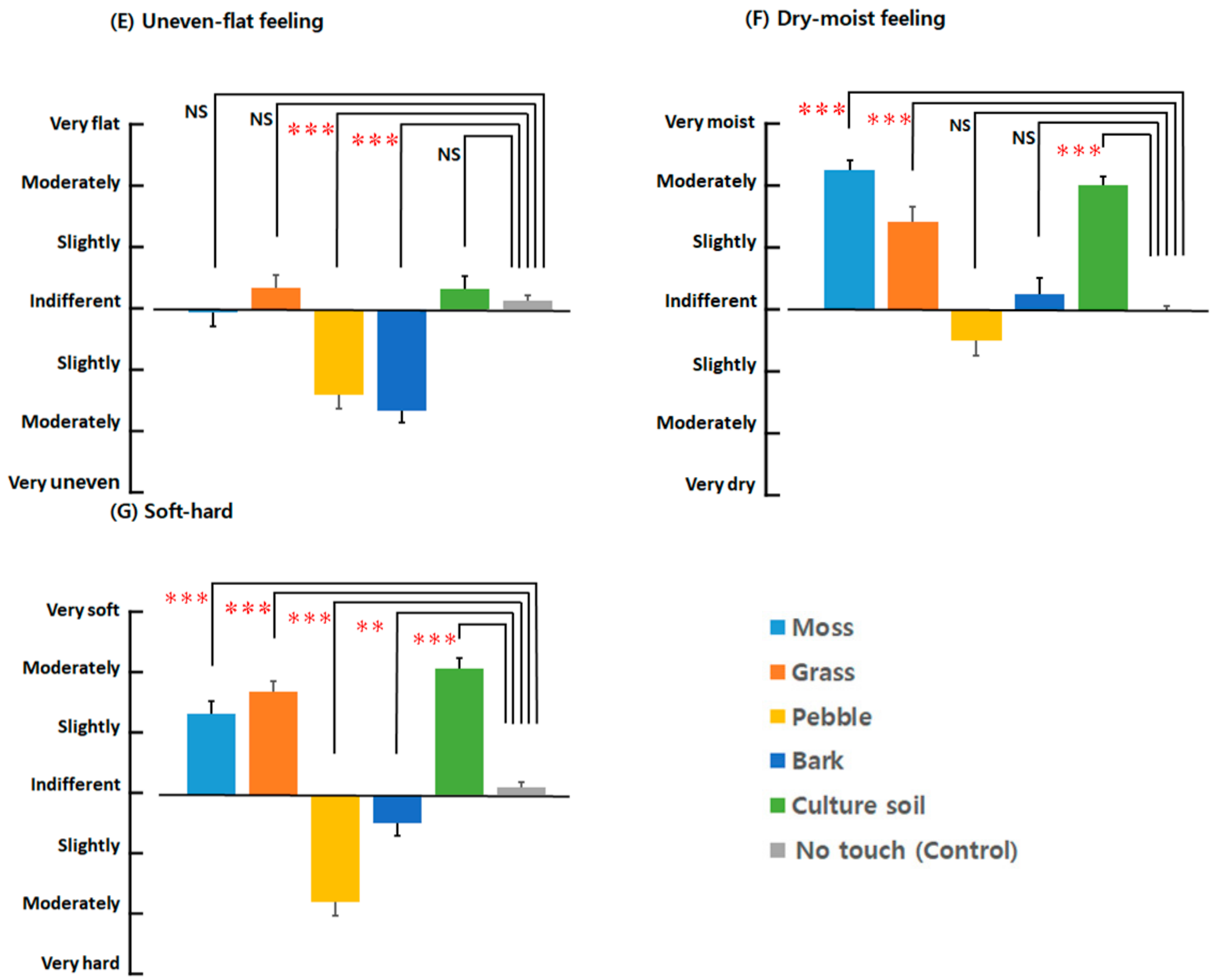


Figure 9. Comparison of an SDM according to agricultural resources elements (foot). (**A**) Feeling comfortable; (**B**) feeling relaxed; (**C**) feeling natural; (**D**) feeling warm; (**E**) feeling uneven; (**F**) feeling moist; and (**G**) feeling soft. Statistical significance was determined using the paired *t*-test. *, **, *** significant at $p < 0.05$, 0.01 or 0.001, respectively; NS, not significant.

4. Discussion

This study investigated the psychophysiological response in 30 adults to tactile stimulation using natural gardening elements. To compare the activation of the prefrontal lobe cortex and autonomic nervous system of the participants, their oxy-Hb concentration, blood pressure, and pulse rate were measured. Additionally, by measuring the SDM of the participants, we tried to measure the psychological effects of contact with natural elements. As a result, in some sections with geranium, log hardwood, and culture soil, the change in oxy-Hb concentration with the tactile stimulus to the hand was maintained at a lower level than before touching the natural element (Figure 6). In addition, the blood pressure decreased significantly with the geranium, tiny ardisia, and log hardwood when touching the natural elements ($p < 0.05$; Table 2). In some sections with grass, moss, bark, and pebbles, the change in oxy-Hb concentration with the tactile stimulus to the feet was significantly reduced after touching the natural elements compared to before touching them (Figure 8). These results suggest that exposure to the natural environment has positive effects on physiological relaxation and stress recovery.

The frontal lobe is located in the anterior part of the cerebral hemisphere and plays an important role in various cognitive processes and emotional processing [21]. In particular, the prefrontal cortex not only accepts and processes information from all other cortical areas, but also accepts information from the sensory receptor system and enables immediate responses [22]. NIRS used in this study is a non-invasive method for monitoring oxy-Hb concentrations, since is not affected by head motions due to the temporal resolution of the device [23,24]. Near-infrared light spectroscopy is a method that can continuously measure the hemodynamic parameters of the prefrontal cortex [23,25]. When brain activity increases, cerebral blood flow increases, and the level of cerebral blood flow affects the concentration of oxy-Hb [26,27]. According to a previous study, olfactory stimulation using perilla essential oil reduced the concentration of oxy-Hb in the prefrontal cortex and induced physiological relaxation [28]. In addition, touching wood with the palm of the hand, more than other materials, decreased the concentration of oxy-Hb, calming the activity of the prefrontal cortex and inducing physiological relaxation [29]. A decrease in oxy-Hb concentration shows physiological and psychological relaxing effects.

With tactile stimulation from tiny ardisia, log hardwood, and culture soil on the hand, the concentration of oxy-Hb in the left prefrontal cortex significantly decreased in the 0–30 s interval (Figure 6), but there was no significant difference in the right prefrontal cortex (Figure 6). A previous study showed a transient decrease in oxy-Hb concentrations in the left prefrontal cortex immediately after contact with all substances [16]. In addition, most previous NIRS studies reported that only one frontal lobe region was significantly activated [28,29], and hemispheric differences were seen in brain activation [30]. However, the mechanism underlying hemispheric regions making an asymmetrical contribution to the results is unknown and requires further research [19,31]. With tactile stimulation from grass, moss, bark, and pebbles on the foot, the concentration of oxy-Hb in the left/right prefrontal lobes in the 0–60 s period decreased significantly after touching the natural elements compared to before touching them (Figure 8). These results are consistent with previous studies showing that the concentration of oxy-Hb is lowered when tactile stimulation is through contact with wood, a natural element [16,18]. The results of this study indicate that physiological stability is induced when tactile stimulation is performed using natural elements.

Blood pressure is regulated physiologically by the autonomic nervous system [32], and it has been shown to induce changes in blood pressure under the influence of stress or relaxation [11,33]. Blood pressure increases under stressful conditions and decreases under relaxed emotional conditions [34–36]. In a previous study, adults were randomly divided into four groups (control group, horticultural activity group with green plants, horticultural activity group without green plants, and green exercise group), and the findings showed that in the group whose horticultural activity involved green plants, the participants' blood pressure was significantly lowered post-activity compared to beforehand and the other green exercise groups [37]. In a gardening program conducted for elderly women, their blood pressure was significantly reduced, which had positive effects on lowering stress [38]. In this study, blood pressure was found to decrease after performing tactile stimulation through the hand using natural gardening factors. Thus, tactile stimulation performed through the hand using natural gardening elements can induce physiological relaxation and is effective in reducing stress.

However, unlike the results of tactile stimulation of the hand, when the participants' feet touched grass, moss, or culture soil, their systolic blood pressure increased. Therefore, it is necessary to consider the characteristics of these three natural resource factors. The three natural gardening factors were evaluated as moist, natural, and cold by the experiment participants compared with other factors in common. According to a study by Filingeri [39], the lower the temperature, the higher the sensitivity of the skin to humidity. A study by Ikei [15] mentioned the possibility that human physiological changes according to the sense of touch can be affected by the temperature of the material. Depending on the nature of these factors, they can affect blood pressure. The results in this experiment appear to have been influenced by the differences in the temperature of the materials. Therefore, future studies need to consider these temperature differences.

Before the urbanization of regions caused by industrialization, humans lived in close contact with nature [19]. In urban areas, people are constantly exposed to stimuli that require their attention, causing mental fatigue [40]. Miyazaki [41,42] argued for the "back to nature" theory, claiming that human physiological functions are best adapted to the natural environment. In addition, Ulrich [43] said that contact with nature can induce human psychological stability, reduce fatigue, and relieve stress. It can also prevent illness and promote recovery to a positive state of well-being [44,45]. A previous study on high-school students showed that viewing green plants in an indoor environment was associated with the stabilization of the autonomic nervous system and parasympathetic nervous activity [46]. The visual stimulation of four types of houseplants (real plants, artificial plants, plant photos, and no plants) to adults showed that RT increased in both occipital lobes when observing real plants, whereas RHB showed a decrease, thereby reducing stress, anxiety, and tension [10]. On observing pots with and without houseplants, in male college students in their 20s, the concentration of oxy-Hb in the prefrontal lobe cortex was significantly lowered when they saw the houseplants, indicating a biological state of armament [47]. Further, comparing the emotional state of elementary-school students during horticultural and non-horticultural activities showed that they felt more natural and comfortable during horticultural activities [48]. Therefore, a state of physiological relaxation is induced when humans are exposed to natural environments or stimuli derived from nature. Moreover, exposure to a restorative environment, such as a natural environment, can contribute to psychological and physiological recovery [49,50]. In this way, healing through nature has been used as an efficient way to improve human physical and mental health and well-being. These experiences with nature provide people with various benefits to their health and well-being. To identify the mechanism through which these benefits are delivered, an integrated interpretation is needed through additional research in the future [51].

This study investigated the effects of tactile stimulation according to natural gardening elements on the psychophysiological responses of adults. This study expanded to more diverse natural elements than previous studies and used two places, the hand and foot, as the contact points of the body. In addition, an unprocessed, natural state was used. In future studies, the following are considered necessary: First, the oxy-Hb concentration was maintained at a lower level during tactile stimulation than before tactile stimulation, but no significant difference was observed when tactile stimulation was prolonged. Compared to other senses, Meissner's corpuscle, which accepts tactile sensations, always has the characteristic of reacting sensitively. As the measurement was made for a relatively short time, it is necessary to measure the change when the tactile element is touched for a long time in future research. Second, there were no psychophysiologically significant differences in some of the natural factors used in this study. Among the tactile stimulation elements, no significant difference in decomposed granite soil (hand) and cultured soil (foot) was found. Research on the tactile stimulation of natural elements is very insufficient, so generalizing the results only from this study is difficult. Therefore, verifying the results of tactile stimulation with natural elements through further research is necessary. Additional research on tactile stimulation with various natural elements is considered necessary. Third, the material surface temperature was not measured. The natural gardening elements used in this experiment were maintained at room temperature (25 °C), but Ikei [19] also mentioned the possibility that human psychophysiological changes could be affected by the temperature of the material. Therefore, considering these differences in the future is necessary. Fourth, the results for the hands and feet were different in this study. In most gardening activities, your hands are likely to be exposed to natural elements. However, the feet are relatively less exposed to natural elements, and this difference may have influenced the results. Therefore, in future research, it is necessary to discuss whether it has a practical impact when applied to horticultural activities. Finally, as the activity of only the prefrontal lobe was measured in this study, it is necessary to expand the range to measure psychophysiological changes in the parietal lobe, which is responsible for motor and somatosensory functions [52].

5. Conclusions

This study was conducted to investigate the effects of tactile stimulation using natural plant products on the psychophysiological responses of adults. Compared to before tactile stimulation, the oxy-Hb concentration related to prefrontal lobe cortical activity significantly decreased in some sections. The participants' blood pressure also showed a significant decrease after tactile stimulation. These results suggest that tactile stimulation using natural elements such as plants and soil, among others, can be a significant intervention in reducing stress by inducing physiological relaxation and calming the activity of the prefrontal cortex. In other words, exposure to a natural environment has positive effects on mental recovery and well-being. The results of this study can be useful fundamental data for constructing a horticultural therapy program, considering the purpose of the program and the characteristics of the natural elements used for stimulation.

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