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Better Nature: Improved Interactions with Nature May Reduce Psychophysiological Stress in Chinese Adults

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Abstract. **Reducing stress associated with technology and the use of electronics is a major issue among Chinese adults. However, no studies have investigated the effect of tactile stimulation of the feet. In this study, we investigated psychophysiological techniques for controlling stress by having participants touch natural materials with the sole of the foot. The study included 90 young Chinese adults with a mean (±SD) age of 21.2 ± 2.7 years. A crossover design was used to examine psychological and physiological differences between touching grass with the sole of the foot and touching wood (control) for 10 minutes. Physiological assessments included blood pressure measurements and electroencephalography, and psychological assessments included the Semantic Differential Method (SDM) and State-Trait Anxiety Inventory (STAI). We observed significant decreases in systolic and diastolic blood pressures in the experimental condition compared with the control condition, along with increases in alpha and beta activities. SDM results indicated that participants were moderately comfortable, very relaxed, and experienced reduced anxiety after stimulation with grass compared with after the control condition. Mean attention and relaxation scores were also significantly higher in the experimental condition than in the control condition. Thus, our results suggest that touching grass with the sole of the foot can lower psychophysiological stress in adults.**

Modern work and living places have shifted from outdoors to indoors, and most individuals spend almost 90% of their time in an indoor environment. Although technological advancements (e.g., mobile phones, computers) have allowed university adults to remained connected, excessive use of electronic devices can substantially increase stress and anxiety (Brod 1984). In addition to increases in the incidence of anxiety, research has indicated that modern Chinese adults are spending less time connecting with nature than ever before, having been described as "urban machines" (Grimm et al. 2008; Seto et al. 2011). Moreover, many indoor environments are constructed using artificial materials and do not provide individuals with the opportunity to interact with green environments (Miller 2005; Turner et al. 2004). Furthermore, recent increases in densification and urban workplace expansion have both decreased the accessibility of natural community settings (Fuller and Gaston 2009; Zhou and Wang 2011). In addition, sedentary pastimes such as browsing the Internet, watching television, and playing video games have decreased the availability of time for positive health measures such as interactions with nature. Indeed, one study reported that most modern children and adults spend their free time engaging in screen-based activities (Hofferth 2009). Moreover, other social factors may impede one's ability to explore nature, such as high academic pressure for researchers and parental concerns regarding safety (Lin and Chen 1995; Valentine and McKendrck 1997). As a result, today's adults are extremely disengaged from nature and face an increased risk of mental health problems (Miller 2005; Soga and Gaston 2016). There is a growing need to connect these individuals with nature to avoid future mental health problems. Daily contact with greenery is viewed as essential for reinforcing and forging favorable emotions toward nature in adults (Kellert 2002; Pyle 1993). Several studies have demonstrated that involvement with nature at an early age increases the preference for and interest in nature (Bixler et al. 2002; Cheng and Monroe 2012). For example, a study performed by Bixler et al. (2002) in the United States indicated that humans who enjoy wild environments frequently had more pleasant cognitive experiences associated with natural environments. A U.K. study by Hinds and Sparks (2008) further revealed that adults who had grown up in village surroundings had a more positive attitude toward nature than those who had grown up in urban areas. These findings suggest that childhood experiences with nature have a lasting effect on one's relationship with nature. Several other researchers and nature advocates have concluded that both direct and indirect contact with natural environments is critical for increasing positive feelings toward nature (Cheng and Monroe 2012; Zhang et al. 2014). Review articles (Hansen et al. 2017; Song et al. 2016) and previous studies (Kaplan 1995; Ulrich et al. 1991) have demonstrated the positive health effects of greenery on the autonomic nervous system, immune activity, and endocrine system. Ikei et al. (2014) and Park et al. (2016) reported that viewing green plants led to psychophysiological relaxation by increasing parasympathetic nervous system activity and decreasing prefrontal cortex activity. They also noted its positive effects on emotional state. Similarly, office workers experienced the same psychological and physiological relaxation during various emotional states after viewing roses (Ikei et al. 2014). A previous study strongly indicated that contact with indoor plants can reduce stress, increase pain tolerance, and provide other psychological benefits (Bringslimark et al. 2009). Moreover, visual stimulation with forest-based photographs has been shown to suppress sympathetic nervous system activity and enhance parasympathetic nervous system activity (Lee et al. 2011; Park et al. 2010). In addition, conditions encouraging calmness lead to reductions in blood pressure and heart rate (Thompson et al. 2012; Tsunetsugu et al. 2013). Ikei et al. (2015) and Igarashi et al. also reported that olfactory stimulation with flower oils (e.g., Hinoki cypress leaf, rose, perilla essential oil, and orange) induces psychological and physiological relaxation effects in the right prefrontal cortex by lowering oxyhemoglobin (oxy-Hb) levels and enhancing parasympathetic nervous system activity. Furthermore, olfactory stimulation with Japanese cedar chips can lead to physiological calmness by lowering blood pressure and total hemoglobin levels in the right prefrontal cortex (Tsunetsugu 2011). Kimura et al. (2011) reported that olfactory and visual stimulation with hiba wood significantly influences systolic and diastolic blood pressures, as well as salivary amylase activity, compared with control conditions without hiba wood. Another study revealed that touching a cypress tree enhanced parasympathetic nervous system activation (Ikei et al. 2017),

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Before the experiments, each subject's written informed consent was obtained. The study was performed with the approval of a local Ethics Committee College of College of Architecture and Urban Planning, Tongji University, China. Each subject's written informed consent was obtained for publication and also consent was obtained for publication images. The authors declare that they have no competing interests. Ahmad Hassan carried out design of the study, performed the statistical analysis, and drafted the manuscript. Prof. Zhang Deshun supervised during the experiment. All authors read and approved the final manuscript. The data are confidential.
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relative to touching marble. Despite these findings, evidence-based studies regarding the effects of tactile stimulation remain lacking. Previous research has indicated that active involvement with greenery (i.e., planting) exerts greater effects on cognition than control conditions that do not involve greenery (Lee et al. 2013). Additional studies have indicated that engaging in planting activities reduces psychophysiological stress relative to that experienced during a mental task (Lee et al. 2015). Although such studies have clearly indicated the positive health effects of involvement with nature, there is a dearth of scientific evidence regarding the physiological and psychological effects of nature-based tactile stimulation. Previous studies have relied on physiological and psychological indices such as heart rate, heart rate variability, and Profile of Mood States–based methods (Hassan et al. 2018c). However, no studies have used the SDM, STAI, or electroencephalography (EEG). EEG is accurate, relatively noninvasive, nonfatiguing, and reasonably inexpensive. In addition to revealing variations in brainwave activity, EEG can be used to investigate the effects of various sensory inputs such as hearing, taste, vision, and smell (Hassan et al. 2018a). Furthermore, EEG devices are now being used in experiments involving brain-computer interfaces (Hassan et al. 2018a), and in the management of stress, anxiety, and other psychiatric diagnoses (Nishimura and Mitsukura 2013). EEG is normally divided into delta waves (equal to 4 Hz), beta waves (above 13 Hz), theta waves (4 to 8 Hz), alpha waves (8 to 13 Hz), and gamma waves. Higher mental stress or workload is associated with the disappearance of alpha waves and the emergence of beta waves (Nishimura and Mitsukura 2013). Some studies have also reported that alpha waves decrease and theta waves increase as work pressure or stress increases (Ajiro et al. 2009). In 1996, Brookings et al. used EEG to examine differences in levels of workload or stress that cannot be identified using other devices, observing that EEG activity differs based on exposure to different environments, making this approach more accurate for estimating neurophysiological behaviors in humans (Ajiro et al. 2009). In the present study, we aimed to investigate both physiological and psychological responses to touching grass with the sole of the foot by measuring blood pressure, EEG, and emotional responses.

Methods

Participants. A total of 90 Chinese adults (mean age ± SD: 21.2 ± 2.7 years) were recruited for this study. No participants reported a history of physical or mental health disorders. Participants with any psychophysiological health problems were excluded during the selection process. We also controlled for tobacco and alcohol intake. Before the experiment, the participants were fully informed regarding the research methodology, following which they provided written informed consent. This study was approved by the local ethics committee of College of Architecture and Urban Planning, Tongji University (China).

Protocol. A within-subject design was used to evaluate physiological differences between the two tasks. All participants were divided into two groups of 45 students: Group A and Group B. On the first day, participants in Group A touched grass with the toes of both feet for 10 min, while participants in Group B touched wood with the toes of both feet for 10 min. On the next day, each group performed the opposite task. Both tasks were performed in a sitting position and at the same time of day (Fig. 1).

Materials. A very common ornamental grass grown in China was used as a base material for tactile stimulation. The experimental method was taught to each participant before the start of the experiment. A wooden plank of almost the same size and length was used as a control material. Both materials were prepared and adjusted based on the size of the human foot. The experiment was performed in a laboratory room situated at Building #5 of the College of Landscape Architecture. The experiment was performed under silent conditions, and all recording instruments were placed behind the participants to avoid any disturbance during the experiment. The experiment was performed during the winter, and the room was maintained at a temperature of 26 °C. Calm lighting conditions were selected, and hanging curtains were used to cover the windows near the experimental location to shield the environment from direct sunlight.

Measurements. After a brief explanation of the experimental details in a large lecture hall, each participant was sent to the experimental room. The physiological recording device contained blood pressure and EEG headset devices. Both were attached to the participant's arm and head. After a 5-min rest period in a seated position, participants performed the given task for 10 min. Systolic blood pressure, diastolic blood pressure, and pulse rate were recorded using an Omron sphygmomanometer (HEM-7011; Omron, Shanghai, China) both before and after each activity. EEG data were acquired using a MindWave-EEG headset (NeuroSky Beijing Oriental Creation Technology Co., Ltd., Beijing, China). This EEG headset can record brainwaves from the human forehead at the FP1 position (frontal lobe) located above the eye (Robbins and Stonehill 2014). It is primarily divided into four different parts: a Bluetooth device, an ear clip, a sensor arm containing the EEG electrode, and a headband. Basically, to detect and filter EEG signals, the device is fitted with two dry sensors. Electrical signals captured from the forehead can be identified by the sensor tip. This sensor also detects the ambient noise produced by the movement of human muscles and bulbs, electrical sockets, and other electrical devices. The ear clip behaves as a reference and ground that allows the chip (ThinkGear) to filter out the electrical noise (Vourvopoulos and Liarokapis 2014). The device records the raw signal in power spectrum form (e.g., high alpha or beta), along with signals associated with attention or meditation. The raw EEG data are collected at a rate of 512 Hz (Sałabun 2014), while the measured values are obtained each second. The device also contains a small microchip that transfers and processes the electrical signals directly to the computer via Bluetooth. Raw EEG data indicated high alpha and beta activity were obtained at 1-min intervals at each site, and overall averages over the 10-min task were compared between the two conditions. The headset contains an EEG e-Sense Metric that can also group brainwave frequencies into attention and meditation categories. According to the EEG e-Sense Metric, meditation and attention data range from 1 to 100 (0 to 20: very low; 20 to 40: slightly low; 40 to 60: natural state; 60 to 80: slightly high; 80 to 100: very high) (Sałabun 2014). Psychological status was assessed using the STAI (Hidano et al. 2000) and SDM (Osgood et al. 1957) questionnaires. SDM scores are calculated along a 13-point self-rating scale based on different factors: "comfortable/uncomfortable," "relaxed/alert," and "natural/artificial." Previous studies have indicated that the SDM is valid and reliable for the assessment of mood. The 20-item STAI is a self-rated questionnaire designed to assess participants' feelings (e.g., "I feel nervous," "I feel anxious," etc.) across four scales. STAI scores were calculated by summing ratings for each of the 20 items, with lower scores considered indicative of lower anxiety. The participants

Fig. 1. Tactile stimulation of the feet with grass or wood (control).

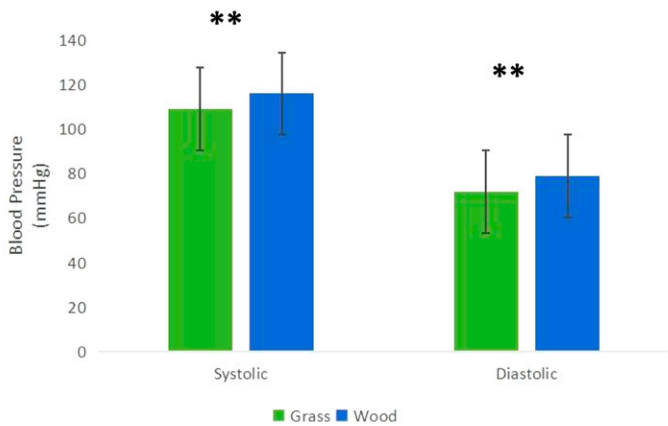

Fig. 2. Comparison of systolic and diastolic blood pressures (mm Hg) (touching grass vs. control group). N = 90, mean ± SE, paired *t* test.

completed both the SDM and STAI before and after each task.

Statistical analysis. SPSS 16.0 (SPSS Inc., Chicago, IL, USA) was used to perform statistical analyses. Repeated-measures analyses of variance (ANOVA) and paired *t* tests were used to evaluate the physiological differences between two conditions. For physiological data, the level of statistical significance was set at $P < 0.05$. Wilcoxon signed-rank tests were used to analyze psychological data, which were evaluated using a significance level of $P < 0.01$.

Results

As indicated in Fig. 2, systolic ($P = 0.003$) and diastolic ($P < 0.001$) blood pressure significantly decreased after 10 min of tactile stimulation with grass, relative to 10 min of tactile stimulation with wood. However, no significant differences in pulse rate ($P = 0.75$) were observed between the two conditions. Significant differences in EEG activity were also observed between the two conditions. In the 1-min analysis, increases in high alpha activity were observed as participants began to touch the grass, relative to activity levels observed in the control condition. However, in the 10-min analysis, paired *t* tests revealed no significant differences in overall mean values between the two conditions. Furthermore, ANOVA revealed significant differences in high alpha activity between the two conditions ($F_{1,88} = 4.11$, $P = 0.04$), indicative of relaxation during the experimental condition. Moreover, no significant ($F_{9,88} = 1.52$, $P = 0.13$) effect of time was observed for the two conditions. Our findings also indicated that mean high alpha activity changed in both the experimental (26,767.52 ± 3127.9) and control groups (24,845.28 ± 1834.6). In contrast, Fig. 3B shows that different results were obtained for high beta activity. Our 1-min analysis indicated that high beta activity began to decrease as participants began to touch the grass, relative to levels observed in the control condition. Moreover, mean beta activity was higher between the two conditions after 10 min. However, paired *t* tests revealed no significant differences in overall mean values between the two conditions. Furthermore, repeated-measures ANOVA revealed no significant group differences in high beta activity (i.e., attention) ($F_{1,88} = 0.16$, $P = 0.68$). A significant ($F_{9,88} = 4.829$, $P = 0.000$) effect of time was observed between the two conditions after 1 min ($P = 0.05$). In addition, high beta values changed in both the grass (20,891.87 ± 2521.6) and control groups (20,530.21 ± 2984.9) (Fig. 3D). Attention and relaxation scores were significantly higher when touching grass than during the control condition (relaxation score: grass: 63.1 ± 6.7 and control: 55.7 ± 4.4; attention score: grass: 68.1 ± 11.7 and control: 60.2 ± 9.04; Fig. 4). Furthermore, significant differences in SDM and STAI scores were observed between the two conditions. SDM results indicated that participants felt moderately comfortable and very relaxed after touching grass, relative to the control condition. Significantly higher scores were observed for items related to relaxation and comfort after touching grass. However, no significant differences in natural feelings were observed between the two conditions (Fig. 5). Finally, we observed significant differences in STAI scores between the conditions. Participants exhibited lower anxiety scores after touching grass than after touching wood (grass: 40.1 ± 5.2 and control: 42.5 ± 3.8; $P < 0.01$, Fig. 6). Moreover, no significant difference before in STAI scores was observed between the experimental and control groups.

Discussion

In the present study, we investigated the stress-reducing effects of touching grass with the toes of both feet for 10 min based on psychological and physiological responses in Chinese adults. Our results indicated that systolic and diastolic blood pressures significantly decreased after 10 min of touching grass, relative to levels observed under control conditions, suggesting that touching grass exerted positive effects on relaxation. These findings are in accordance with those of previous studies, which reported that engaging in horticultural activities significantly reducedsystolic and diastolic blood pressures compared with levels observed during a mental task (Hassan et al. 2018b). Similar findings were obtained in a previous study in which participants engaged in plant-based activities (i.e., transplanting an indoor plant) (Lee et al. 2015). The advantages of physical activity in the treatment and prevention of high blood pressure have been well documented (Alsairafi et al. 2010): Individuals who regularly engage in physical activity have lower systolic and diastolic blood pressures than those who rarely engage in such activity (Knowles et al. 2013). Taken together, these findings suggest that physical activity that involves touching grass with the toes of both feet may decrease the risk of future hypertension in young adults. To determine whether touching grass effects brain activity, we recorded EEG activity in the present study. EEG offers an innovative and modern scientific approach to examining stress and can reveal changes in normal brainwave patterns during contact with external stimuli (Jing and Takigawa 2000). Higher alpha activity was observed in the experimental group than in the control group, indicating that participants who touched grass were more relaxed than those who touched wood (Başar 2012). In contrast, decreases in alpha activity in the control group indicated that participants were under stress during the task. Increased alpha brain power is known to reflect conditions of relaxation, euphoria, an increased ability to recall memories, and reductions in anxiety or stress. Our results are consistent with the findings of a previous study, which reported that certain antianxiety medications (i.e., benzodiazepines) also reduce alpha activity. The fact that interaction with grass exerted effects similar to those of an antianxiety medication has interesting implications for the treatment of psychological disorders (Puri et al. 2013). Previous studies have reported that alpha waves are associated with relaxed wakefulness (Klemm 1966). Feelings of happiness are associated with increases in alpha activity, while feelings of unhappiness are associated with decreases in alpha activity. Research has indicated that humans begin producing alpha waves at the start of sleep and upon waking early in the morning (Keefe et al. 1971). Interestingly, the intake of some plants has similar effects on the production of alpha waves (e.g., cannabis) (Struve et al. 2003). Similarly, overall beta wave activity was higher after 10 min of touching grass than after 10 min of touching wood, suggesting that concentration was stronger in the experimental group than in the control group. In the control group, participants experienced a sharp increase in beta activity soon after they began touching the wood. Beta brainwaves dominate during states of alertness (Neuper and Pfurtscheller 2001), relaxation (Vijayalakshmi et al. 2010), and during highly mental activities, decreasing during states of drowsiness (Hauri 1981). Naturally, beta brainwaves are prominent

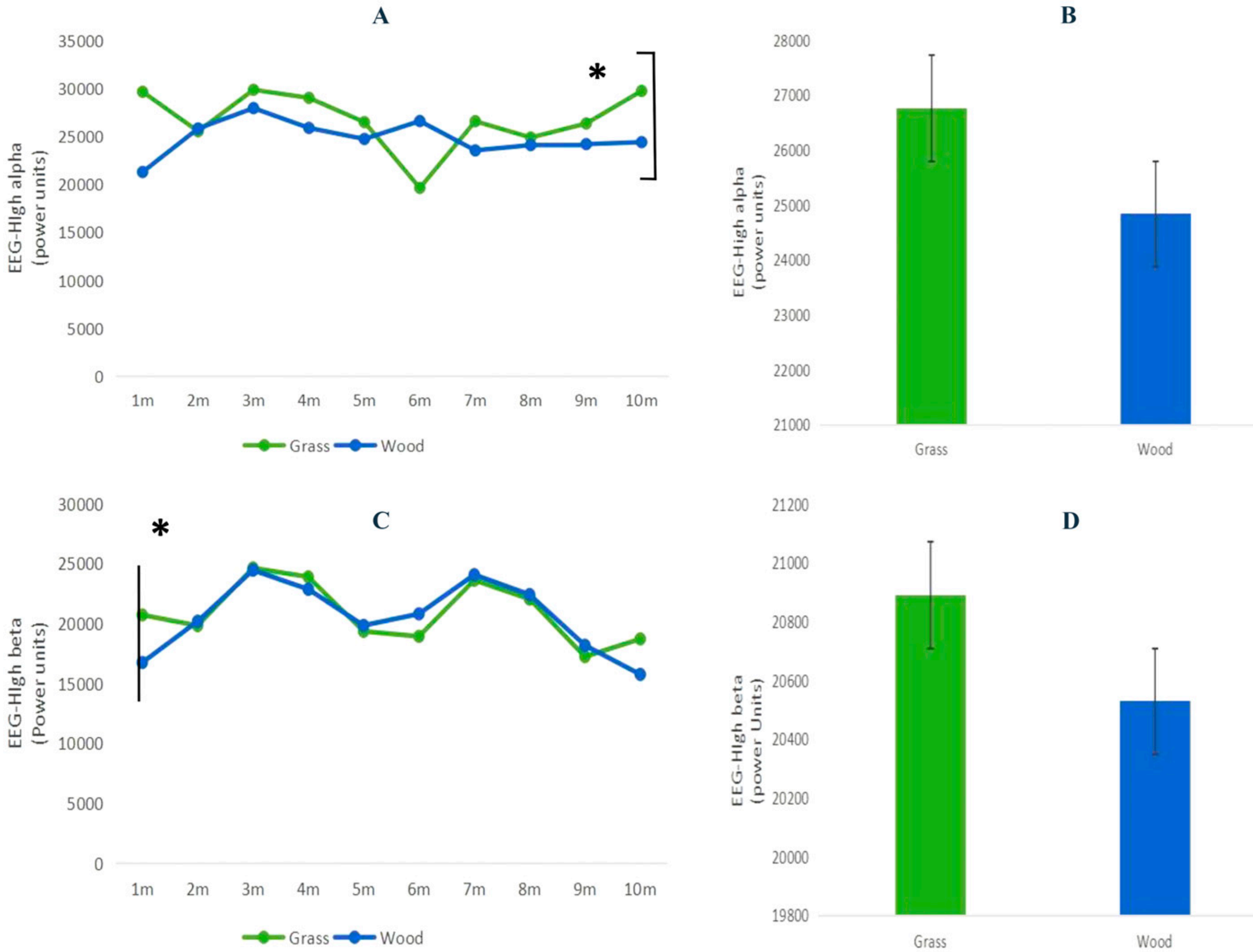

Fig. 3. (A) Changes in mean high alpha wave activity in the grass and control groups during a 10-min touching protocol. Repeated-measures analysis of variance (ANOVA) revealed a nonsignificant effect of time ($F_{9,88}$ = 1.52, P = 0.13) and a significant between-group effect ($F_{1,88}$ = 4.11, P = 0.04). (**B**) Overall 10-min high alpha mean value. (**C**) Changes in high beta wave mean values in the grass and control groups during a 10-min touching protocol. Repeated-measures ANOVA revealed a significant effect of time ($F_{9,88}$ = 4.829, P = 0.000) and a nonsignificant between-group effect ($F_{1,88}$ = 0.16, P = 0.68). (**D**) Overall 10-min high beta mean value. EEG = electroencephalogram.

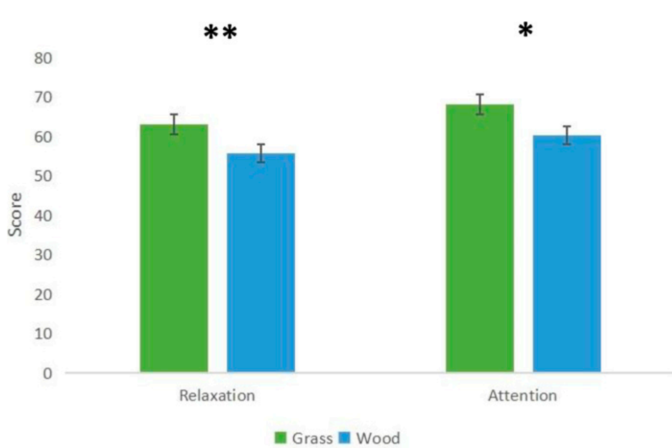

Fig. 4. Comparisons of attention and relaxation scores during the grass and control tasks. N = 90, mean ± SD, paired t test.

during different tasks such as playing sports, during speech, and during attentive listening. Our EEG results indicated that relaxation and attention levels were higher when participants touched grass than in the control condition, consistent with the previous finding that walking in a bamboo forest increased scores for both relaxation and attention (Hassan et al. 2018c). Thus, touching grass significantly alleviated stress levels compared with the control condition. STAI and SDM results indicated that touching grass exerted beneficial effects on mental stress, while touching wood enhanced mental stress. Such findings suggest that touching grass with the toes represents an easy and attainable method for connecting with nature to enhance mental health and quality of life in modern adults. However, the current study possesses some limitations of note, including the fact that only young Chinese adults were involved. Future studies should examine participants of all ages using a more specific control group.

Conclusion

Our findings provide scientific evidence that—relative to a control task—touching grass reduces psychophysiological stress by lowering blood pressure, increasing relaxation, and decreasing anxiety.

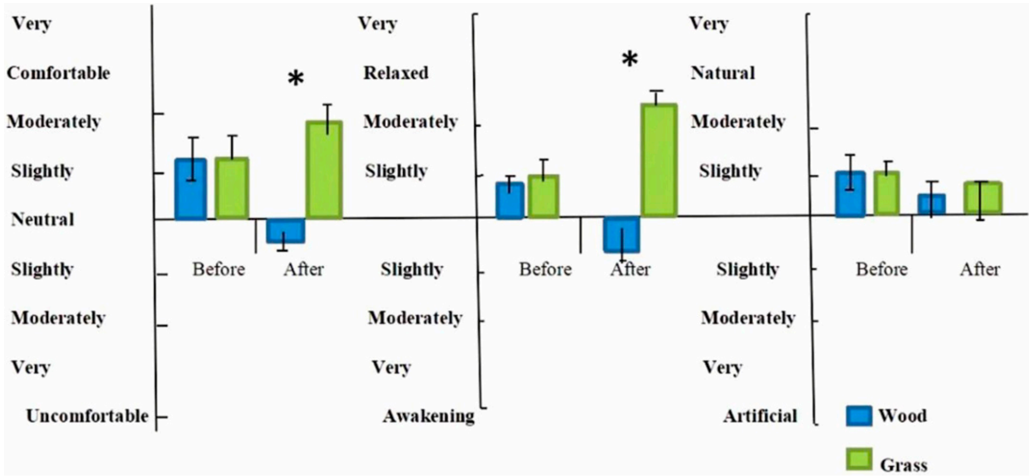

Fig. 5. Participants scoring for comfortable, natural, and relaxed feelings before and after touching grass and control. N = 90, mean ± SD, $*P < 0.01$ by Wilcoxon signed-rank test.

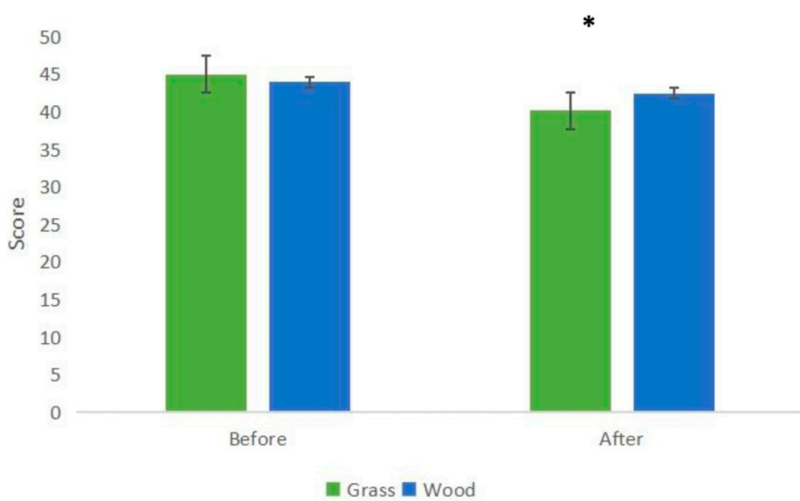

Fig. 6. Comparison of State-Trait Anxiety Index before and after grass and control tasks. N = 90, mean ± SE, paired *t* test.

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