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Wearable technologies for assessing the effects of nature on physiological states

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Abstract— **Forest bathing (FB) has been shown to have quantifiable positive effects on human physical and mental health, but few studies have employed non-invasive wearable technologies to monitor autonomic nervous system signals. This study investigated the impacts of a 90-minute Nature Break activity on the physiological response of 10 individuals and the psychological response of 38 (age=43.55± 11.61 years) individuals. Autonomic nervous system response was assessed through continuous measurement of electrodermal activity (EDA), fingertip temperature, and blood volume pulse (BVP) using a wearable fingertip sensor. Psychological distress was assessed using the Profile of Mood States (POMS). Our results showed a decrease in the negative dimensions of POMS and an increase in the positive (vigor) dimension following Nature Break. Moderate evidence for a difference pre-forest and post-forest was found for the mean of the standard deviation of EDA slopes (BF_{10} = 4.179). Significant differences across segments was found for the mean of the standard deviation of EDA slopes ($p<0.05$), mean of the median skin temperatures ($p<0.05$), and average HR ($p<0.001$), but not for the average HRV features or the slopes of the HR. Mean HR was found to decrease throughout Nature Break. Future research should further investigate the use of EDA and skin temperature as measures of autonomic nervous system (ANS) activity in order to develop a better understanding of the changes in these signals in the FB context.**

Keywords— **Forest bathing, nature therapy, autonomic nervous system, Profile of Mood States**

I. Introduction

In 1982, the term Shinrin-Yoku (SY), also known as Forest Bathing (FB), was coined in Japan to describe the practice of immersing oneself in a forest environment using all five senses in order to improve one's mental and physical health [1][2][3]. Since then, accumulating evidence has demonstrated that exposure to nature has quantifiable positive effects on the psychological and physiological health of human beings [1]. In particular, the act of immersing oneself in a forest has been associated with decreased blood pressure in comparison to urban environments [4][2]; significant decreases in physiological markers of stress such as salivary cortisol and alpha-amylase [5][6][7]; and improvements in psychological measures of tension, anger, fatigue, anxiety, confusion, and depression [5][2][8][9]. FB and nature walks have also become increasingly popular for improving overall wellness and have started being prescribed by doctors and recommended by governmental associations [10].

Despite this growing interest, few studies assess the physiological effects of natural environments [11]. Those that do have predominantly measured effects on the cardiorespiratory system, neglecting other measures of sympathetic nervous system arousal, such as electrodermal activity (EDA) or peripheral skin temperature [11][12][13]. This study investigated the in-situ psychological and physiological effects of a 120-minute guided Nature Break activity, monitored with a wearable sensor and mobile application.

II. Methods

A. Nature Break Activity

Nature Break is a 120-minute immersion event in the forest, accompanied by guides (H.M, E.T.M); it is offered by the non-profit organization, L'Universite dans la Nature (UdN), based in Quebec, Canada. This experience aims to educate participants and help them foster personal connections with nature. Nature Break comprises six principal segments in the forest that incorporate themes and exercises surrounding the five senses, as well as education on the scientific findings of the effects of the natural environment. See Table 1 for a detailed description of the segments and exercises.

B. Participants

60 individuals participated in this study through UdN's Nature Break program. Thirty eight filled out the POMS questionnaire (n=38, 24 females, 14 males, mean age=43.55 ± 11.61 years), and 10 participants provided their physiological data. Of these 10, only 3 filled out the POMS questionnaire (n=3, 2 females, 1 male, mean age = 50.33 ± 13.20 years); the rest did not provide demographic information.

C. Procedure

Upon arrival, participants provided ethical consent and completed the pre-forest POMS assessment of their psycho-

Table 1: Description of segments in the Nature Break activity

Segments	Exercises	Length (min.)
Pre-forest segment	Participants fill out pre-forest POMS and don the wearable sensor.	$\sim$ 10-20
Segment 0: Sitting on stumps	The UdN guide invites participants to compare time flow in the city to the forest.	$\sim$ 10-15
Segment 1: Breathing	The UdN guide invites them to do a US Army breathing exercise and to focus on smells.	$\sim$ 10-15
Segment 2: Old tree	Participants are invited to lie down, and to smell and observe a handful of dirt.	$\sim$ 20
Walking barefoot segment	Participants are invited to walk barefoot to the next segment.	$\sim$ 5
Segment 3: Ferns	Participants are invited to do an exercise to observe and listen to their environment.	$\sim$ 20-30
Segment 4: Pine trees	The UdN guide explains the impact of nature on mental health and invites participants to find their own refuge in this clearing. They are invited to taste the resin from the trees.	$\sim$ 10-15
Post-forest segment	Guides lead a group discussion on their forest experience. Participants fill out post-forest POMS.	$\sim$ 15-20

logical state. Participants then donned the sensor on their dominant hand. Baseline assessments of their physiological state were obtained from when the participant put the sensor on to just prior to entering the forest. At the end of Nature Break, participants filled out the post-forest POMS assessment of their psychological state. The guides then led a group discussion about the participants' forest experience.

D. Data Collection

An adapted version of the Profile of Mood States (POMS) was used as a measure of psychological distress. This version consisted of 18 adjectives which measure six dimensions: tension-anxiety (T), depression-dejection (D), anger-hostility (A), fatigue-inertia (F), vigor-activity (V), confusion-bewilderment(C) [14]. Each adjective is rated using a 5-point scale from 0 to 4.

Three physiological parameters reflective of ANS activity were collected from the Triple Point Sensor (TPS) (Thought Technology Ltd. ©), which is worn on the fingertip. It collects three signals that reflect the state of the individual's ANS: (1) EDA, (2) skin temperature, and (3) blood volume pulse (BVP), which is used to derive HR and HRV.

E. Data Analysis

The difference in psychological and physiological measures was assessed before and after the Nature Break activity. Changes in physiological signals were also assessed across all segments within the forest.

For the pre-post psychological assessment, the mean POMS score for each dimension was taken across all participants. Pre-post significance was computed using Wilcoxen signed-rank paired t-tests. Results were tested against the Bonferroni-Holm adjusted-alpha levels of 0.05 and 0.01.

Each of the ANS signals were pre-processed to remove non-physiological artifacts by applying smoothing filters (1D median filter, moving average filter), cubic spline interpolation, and modality specific filters [15]. The signals were then segmented by forest segment and the following features were extracted across a 60 second sliding window: 1) average EDA slope; 2) average skin temperature slope; 3) average HR; 4) average low-frequency to high-frequency (LF/HF) ratio for HRV; 5) average HF component for HRV. For each segment, each of these features was characterized as follows: 1) The standard deviation of the slopes of the EDA was used to determine skin conductance responses (SCR), which are evoked by internal or external arousal stimuli, such as emotional thoughts or memory recall [16]; 2) The median of the slopes of the skin temperature was used to determine its general increasing/decreasing trend; 3) The median of the slopes of HR was used to determine its general increasing/decreasing trend; 4) The mean of the HR in the segment; 5) The mean HRV LF/HF was used to assess sympathetic nervous system activity; and 6) the mean of the HF HRV component was used to assess parasympathetic activity [7].

For the pre-post physiological assessment, we performed a Bayesian paired t-test on the physiological features. A Friedman test followed by Conover's post hoc test was performed for each physiological measure to determine significance across segments.

III. Results

A. Effect of forest exposure on psychological responses

The average POMS scores for the negative mood states significantly decreased following Nature Break ($p < 0.01$), while the average POMS score for the positive mood state (V) significantly increased following Nature Break ($p < 0.05$).

(Figure 1)

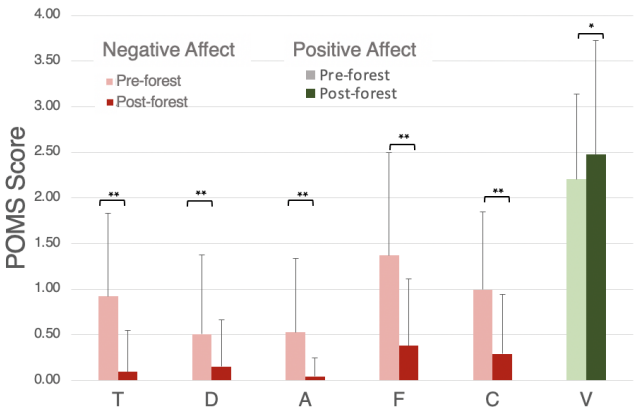

Fig. 1: POMS results pre-forest and post-forest. T tension and anxiety, D depression and dejection, A anger and hostility, F fatigue, C confusion, V vigor. Significant differences are marked with ** for $p < 0.01$, * $p < 0.05$.

B. Effect of forest exposure on physiological responses

Across participants, the average of the standard deviation of the EDA slopes was higher after the forest than before (Bayes factor BF_{10} = 4.179), indicating moderate evidence that forest bathing stimulated the sympathetic nervous system. The other features reported insufficient evidence to reject the null hypothesis ($0 < BF_{10} < 0.7$).

The FB segments had significant effects on several physiological features, including the mean standard deviation of the EDA slopes (p=0.023), mean of the median skin temperature slopes (p=0.022), and mean of the average HR values (p<0.001). Figure 2 shows the mean value with 95% confidence interval of these three measures across all segments.

Participants experienced the largest sympathetic arousal, as manifested by their EDA, during the barefoot walking segment and post-forest segment, and the lowest sympathetic arousal during focused breathing and the pine tree refuge segments. The pine tree refuge segment also had the lowest level of sympathetic arousal in comparison to all other segments, with the largest significant difference compared to the post-forest segment ($p < 0.01$). Skin temperature demonstrated the largest rate of increase during the breathing activity, likely indicating relaxation, and the largest rate of decrease during the barefoot walking activity, likely reflecting focus and attention. Heart rate was highest during the breathing activity and lowest after the forest bathing experience. The breathing activity induced significantly higher heart rate compared to all other segments apart from sitting on stumps ($p < 0.001$). This segment had significantly higher heart rate compared to four other segments: barefoot walking, ferns, pine trees, and

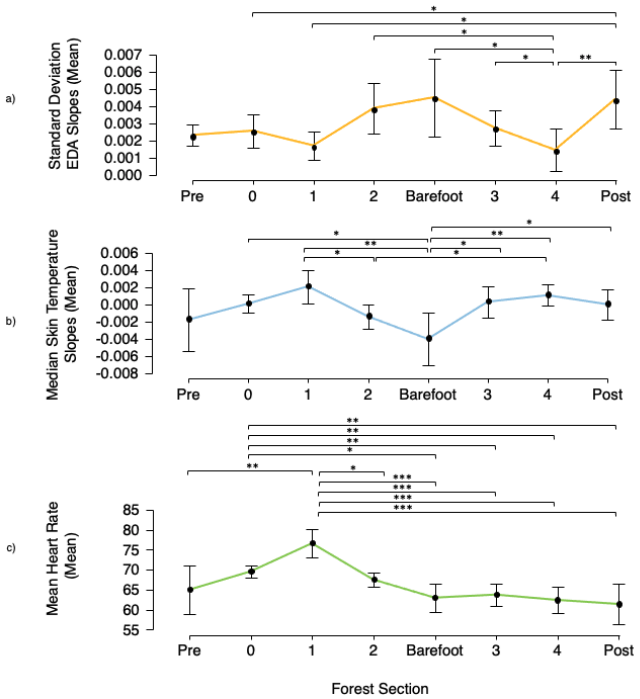

Fig. 2: . Mean values and 95% CI for: a) Standard deviation of EDA slopes. b) Median of temperature slopes. c) Mean value of the median heart rate slopes across participants with 95% CI. d) Mean HR. Significant differences are marked with * for $p < 0.05$, ** for $p < 0.01$, and *** for $p < 0.001$

post-forest ($p < 0.01$). After segment 1, there is a downward trend of the mean HR. Both HRV features (LF/HF ratio and HF component) and median HR slopes showed no significant differences across segments.

IV. Discussion

FB and nature walks have been shown to benefit the physical and mental health of human beings, such as reducing cortisol levels, HR, and blood pressure[1][3][17][10][5][18]. We found that the Nature Break activity significantly lowered heart rate after the forest experience, and that there was a general decreasing trend in mean heart rate following segment 1, which supports previous findings [1]. Previous studies have found that FB and nature walks significantly increases parasympathetic activity (HF component of HRV) and decreases sympathetic activity (HRV LF/HF ratio) [2]. Our study did not find significant differences in the HRV LF/HF ratio or HF component due to Nature Break. One potential reason for this is the interactiveness of the segments, which could stimulate both sympathetic and parasympathetic systems. Participants also had the ability to interact with one another both during pre-forest and post-forest segments.

EDA and peripheral skin temperature have received little attention in the context of FB and nature walks. Reeves et al. found no significant effects on EDA after exposure to urban wetlands [11]. In contrast, we found a significant difference before and after Nature Break. In particular, walking barefoot in the forest induced the largest sympathetic activation, likely due to the various activities of touching, smelling, walking on dirt at this segment [16]. Skin temperature also reflected changes in ANS activity across segments, with higher rate of increases indicating relaxation (e.g. during breathing) and higher rates of decrease indicating focus (e.g. walking barefoot). Decreasing skin temperature may be associated with psychological stressors, but only when the starting fingertip temperature is approximately 32°C [19][16]. Further analysis should be done to assess the effects of the ambient temperature and starting fingertip temperature on the results.

Previous studies using the POMS questionnaire found that negative mood states improved and positive mood states increased following a forest bathing and nature walk activity [17][8][2][20]. Our findings support this trend as well.

V. Conclusion

FB and nature walks improve psychological states and decrease physiological indicators of stress, such as average HR. This study also provides preliminary evidence indicating the EDA and skin temperature are effective markers of physiological changes induced by FB activities, and that it is feasible to collect these signals from wearable sensors in a forest setting. Further research should investigate these signals for measuring ANS response in a FB context to provide complementary evidence on their response to such activities.

Conflict of Interest

The authors declare that they have no conflict of interest.

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