

Nat(UR)e: Quantifying the Relaxation Potential of Ultra-Reality Multisensory Nature Walk Experiences

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Abstract—Stress and anxiety are increasingly present in society, contributing to many chronic diseases and decreasing quality of life. Non-pharmacological therapies to relieve these symptoms and promote relaxation have been developed, including immersing oneself in nature (so-called ‘forest bathing’). Access to nature, however, is not available to many around the world, due to mobility issues, increasing urban spaces, or pollution, to name a few factors. As such, the use of virtual reality tools or digital nature walks have emerged as a possible alternative that can be done at the comfort of one’s home. While promising results have been reported, existing solutions are not completely immersive as they only stimulate the hearing and vision senses. Here, we propose a multisensory (ultra-reality) immersive experience termed *Nat(UR)e*, where in addition to audio-visual stimuli, users are also exposed to nature smells and somatosensory stimuli, including wind, heat and vibrations. An experiment was conducted on 16 participants that experienced virtual nature under two conditions: audio-visual only and ultra-sensory. Wearable devices were used to track changes in the participants physiological states. Significant changes in relaxation were achieved with the proposed system and changes in physiological parameters were also observed, suggesting the potential of the *Nat(UR)e* framework for stress and anxiety treatment.

Index Terms—Nature walk, relaxation, digital shinrin-yoku, ultra-reality multisensory, olfaction, haptics.

I. INTRODUCTION

Generalized anxiety disorder is one of the most prevalent mental health problems around the world [24]. Recently, the COVID-19 pandemic has affected the daily routine of many people around the world, affecting people’s lives, from reduced socialization to lost of jobs and family members. The global pandemic has caused a never-before-seen surge in mental health disorders. Statistics are showing significant increases in anxiety symptoms from young children to seniors [6], [18].

While pharmacological treatments exist to treat anxiety and stress, many prefer non-pharmacological interventions. To this end, walks in nature have been shown to be calming and to reduce anxiety and stress. In Japan, for example, such multisensory nature immersion has existed for many years and is termed ‘forest bathing’ (shinrin-yoku) [15]. Research has shown an impact of forest bathing on several neurophysiological signals, including reduced blood pressure and heart rates [12], as well as reduced stress levels. Notwithstanding,

while the mental health benefits of nature interactions are well known [20], these outdoor activities may not be accessible to many around the world. For example, as societies have been forced into lockdown with the COVID-19 pandemic, access to nature has been restricted, especially for those most vulnerable (e.g., patients in nursing homes). Moreover, it is known that today roughly 55% of the world’s population lives in urban settings where access to nature may be challenging; and these numbers are expected to grow to 68% by 2050 [1]. Lastly, the World Health Organization estimates that 15% of the world’s population has some sort of mobility issue, which could limit the use of nature walks as non-pharmacological treatments for stress. As can be seen, alternate solutions are needed.

To this end, recent research has explored the use of virtual reality (VR) to simulate immersive nature walks [32], a tool called ‘digital shinrin-yoku’ or digital nature walks. Typical VR systems today, however, offer only audio-visual stimuli, thus provide the user with a limited sense of presence and immersion, which could limit the true potential of nature walks. According to shinrin-yoku principles, it is the stimulation of all senses and full immersion into nature that brings health benefits. As such, existing digital shinrin-yoku tools may not be optimal. For example, it is known that aromatherapy has a positive effect in the treatment of stress promoting relaxation [11], [31]. More recently, incorporation of smells into virtual experiences showed to improve the level of relaxation and reduce stress [2], [3], [5], [28]. Moreover, incorporating the sense of touch has also shown to improve the sense of presence and immersion of virtual experiences [33], thus incorporating haptic feedback into the experience could be beneficial. In this paper, we aim to explore this hypothesis.

In particular, we propose *Nat(UR)e*, an ultimate reality (UR) nature walk experience in which a digital shinrin-yoku environment is enhanced with olfactory, vibroacoustic, and somatosensory stimuli, in addition to the usual 360-degree audio and visual stimuli. Experiments with 16 participants were conducted where each participant experienced an audio-visual only nature walk and an ultra-reality version while using two wearable devices to track several physiological signals. Comparisons are described herein between the relaxation levels reported by the participants between the two experienced conditions, and the differences in physiological responses.

*Both authors contributed equally to this research.

II. MATERIALS AND METHODS

In this section we describe the data collection, experimental setup, and physiological features extracted for analysis.

A. Participants

Sixteen (6 females) healthy participants (27 ± 7.46 years) consented to participate in this experiment which was approved by the INRS Ethics Committee. In particular, special COVID-19 safety measures were followed, including social distancing, masking, sanitizing the VR headset and wearable devices with alcohol wipes and placing the VR headset into an UV-C chamber custom-built for VR headsets (Cleanbox Technology, USA).

B. Experiment Setup

The experiment was conducted inside a SENSIKS (SENSIKS, Netherlands) multisensory booth (see Fig. 1a), where four fans surround the participants (shown as ‘A’ in the figure), heating elements surround the sides, back and front of the users (‘B’), high definition speakers provide immersive audio, a subwoofer under the seat provides vibroacoustic feedback, and a scent device diffuses up to six different aromas (‘C’). All of these stimuli were time-synchronized with the 360-degree video, which was presented via an Oculus Quest VR headset (Fig. 1b). The multisensory nature walk synchronized i) fans to coincide to parts of the video in which leaves were blowing and wind noise could be heard, ii) the heaters with the sun shining through the trees, iii) vibroacoustic feedback as the user walked through nature and stepped on crackling leaves, and iv) smells comprised of dirt, forest, grass, and mist freshness, which were presented subtly in the background.

Moreover, to measure physiological information, participants wore a BioHarness3 (Zephyr, USA) chest-strap (Fig. 1c), which measured electrocardiogram (ECG) at a 250 Hz sample rate, breathing signals at 18 Hz sample rate, as well as an E4 (Empatica, USA) wristband (Fig. 1d) to measure skin temperature, electrodermal activity (EDA), and blood volume pulse (BVP).

C. Experiment description

The experiment itself comprised four sessions/conditions: video only (VO), audio-visual (AV), audio-visual-olfactory (AVO), and UR where audio, visual, olfactory, somatosensory, and vibroacoustic feedback was enabled. The ordering of the conditions was counterbalanced across participants to avoid any ordering biases. At the end of each session, a modified Relaxation Rating Scale (RRS) questionnaire was used [22] where each participant rated their current level of relaxation state from 1 (“Not relaxed at all”) to 5 (“Very much relaxed”). The psychological instrument most used to measure the perception of stress is the Perceived Stress Scale (PSS) [10], however this is a long-term measure based on the experience of the last month. Here, we will focus only on comparisons between the AV and UR conditions to test the benefits of the proposed Nat(UR)e framework with conventional digital nature systems.

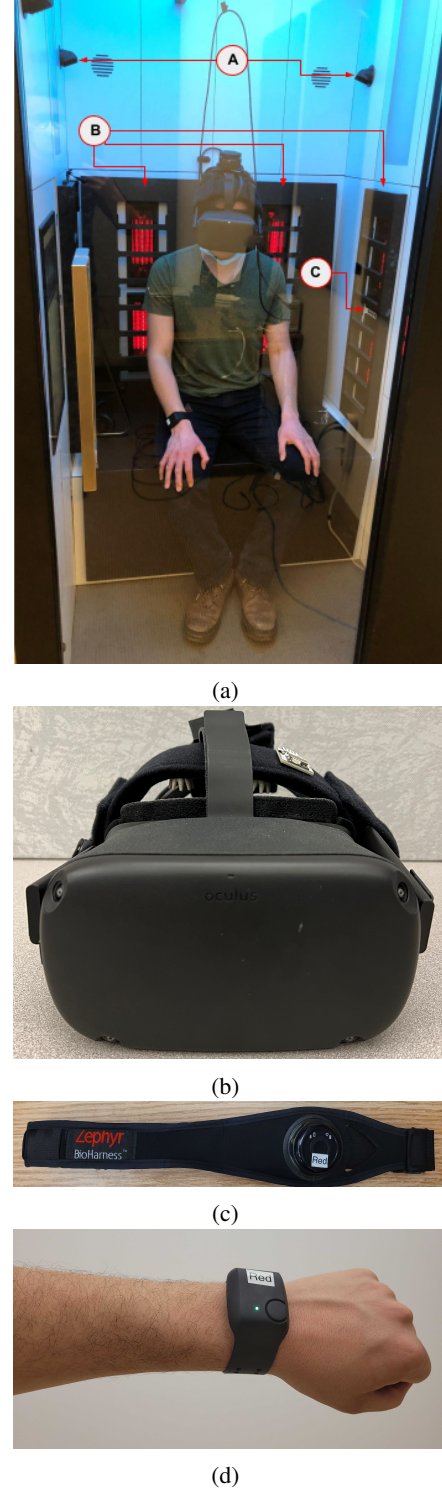


Fig. 1: (a) Multisensory pod showing A-fans, B-heating elements, and C-scent diffuser, (b) Oculus Quest VR headset, (c) Zephyr BioHarness3 chest-strap and (d) Empatica E4 wristband.

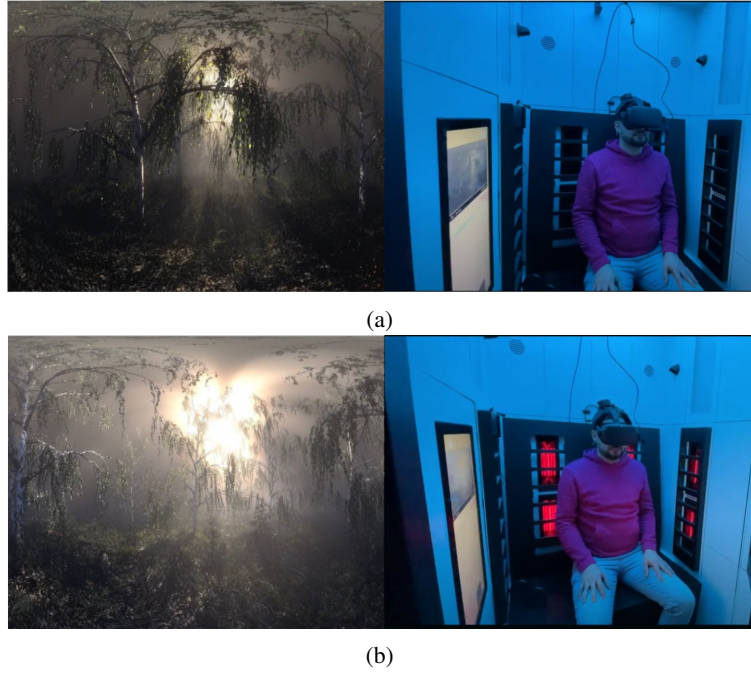


Fig. 2: Nat(UR)e scenes (left) and view inside the booth (right) as (a) sunlight was blocked by the tress (heating elements in low settings) and (b) sunlight appearing and heating elements on high settings.

The experience comprised participants immersed in a forest environment for roughly one minute (see Fig. 2). In the AV session, in addition to the main surround sound track, participants could hear the voice of a young woman whispering in the background, encouraging self-reflection on existence and awareness throughout the video experience. Participants could see and hear the leaves blowing and see sunshine passing through the trees. In the UR session, the same female background voice was present, but additionally, participants could smell different aromas in the background, such as the scent of dirt, forest and grass. When the sound of wind appeared and leaves blew, airflow would be produced by built-in fans to simulate the wind. As the person moved and stepped on leaves, crackles were translated into vibrations in the seat. Lastly, as sun rays emerged from the trees, various heating elements around the sides, back, and front of the participant would come on at varying intensities to match the intensity of light observed. Fig. 2a, for example, shows the heating elements on low intensity when the sun was hidden by the leaves, whereas Fig. 2b shows the increased heating intensity as light intensity increased.

D. Feature Extraction

From the physiological signals, several features were extracted from each modality, namely skin temperature, BVP, and EDA from the Empatica E4 wristband, and ECG and breathing curves from the Bioharness 3 cheststrap. Table I summarizes all of the extracted features per signal modality.

TABLE I: List of extracted features for each signal modality.

Modality	Features
Skin temperature	mean, standard deviation, range, mean of 1° difference, minimum, maximum, skewness, kurtosis, delta temperature, spectral energy from 0-0.01 Hz, and 0.1-0.2 Hz.
BVP	maximum, minimum, spectral energy from 0-0.5 Hz, 0.5-1.0 Hz, 1.0-1.5 Hz, 1.5-2.0 Hz, and 2.0-2.5 Hz, spectral energy ratio between 0.04-0.15 Hz and 0.15-0.5 Hz.
EDA	mean, standard deviation, mean of 1st difference, mean of negative 1st difference, spectral energy from 0-0.2 Hz, 0.2-0.4 Hz, 0.4-0.6 Hz, 0.6-0.8 Hz, and 0.8-1.0 Hz from the phasic component of EDA signal.
ECG	mean RR, standard deviation RR, coefficient of variation, RMSDD, pNN50, mean of 1st diff, mean of absolute 1st diff, normalized, standard deviation of absolute 1st diff, low-frequency power (0.04-0.15 Hz), high-frequency power (0.15-0.4 Hz), very-low-frequency power (0-0.04 Hz), normalized low-frequency power, normalized high-frequency power, the ratio of low-frequency power and high-frequency power, total power.
Breathing	mean, standard deviation, range, skewness, kurtosis, mean of 1st diff, spectral energy from 0-0.2 Hz, 0.2-0.4 Hz, 0.4-0.6 Hz, 0.6-0.8 Hz, and 0.8-1.0 Hz, spectral energy ratio between 0.05 - 0.25 Hz and 0.25-0.5 Hz, the frequency with maximum spectral energy, centroids

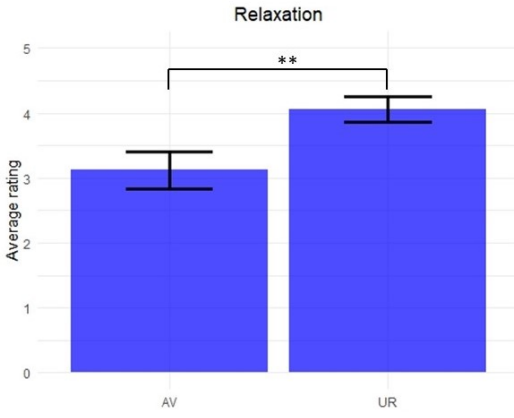


Fig. 3: Average relaxation rating across test conditions.

III. RESULTS AND DISCUSSION

A paired t-test was performed to compare the difference in relaxation ratings between the two test conditions. Figure 3 shows the average relaxation ratings reported for all participants across the two conditions. As can be seen, participants significantly rated the UR condition as more relaxing than the traditional audio-visual condition with $t(15) = -4.04$, $p\text{-value} < 0.01$, thus corroborating the shinrin-yoku principles of improved health benefits with multisensory experiences.

From the analysis of the collected physiological signals, data from three participants had to be removed from the Bioharness 3 cheststrap due to the low quality of the recordings. Additionally, data from the Empatica E4 wristband of one participant had to be deleted, due to device battery issues that resulted in an incomplete recording of the session. For these analyses, we observed biological signatures associated with stress and anxiety reduction previously reported in the literature. For example, Fig. 4 displays the difference in the average (across all participants) high frequency (HF) component of the ECG signal across participants for the condition UR compared with AV. These findings corroborate those reported in [4], [8], [25], which showed increases in HF for during deep relaxation situations such as meditation, or decreases in HF during stressful situations.

Moreover, Fig. 5 shows a lower average across participants of the low frequency component of the electrodermal activity signal for the condition UR when compared to AV. Increase of the low frequency component of EDA has been associated with stress [29], thus further corroborating the increased relaxation potential of the Nat(UR)e framework. Similarly, Fig. 6 shows the decrease in (average over all participants) maximum BVP signal for the UR condition relative to AV, thus also corroborating the link with relaxation previously reported in [21]. It is important to mention, however, that despite these observed behaviours, the observed differences did not show a statistically significant difference between the two conditions based on the paired t-test analysis. On the contrary, the mean of the negative 1st difference and the standard deviation of the

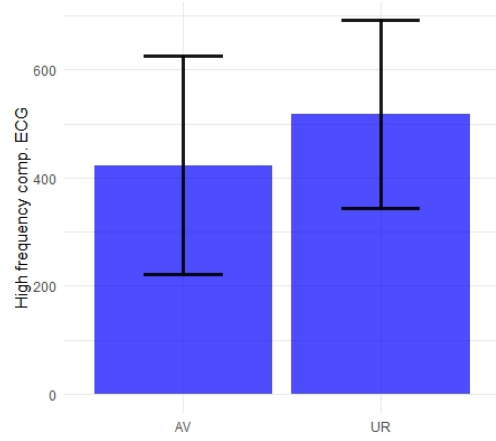


Fig. 4: Comparison of the ECG HF component.

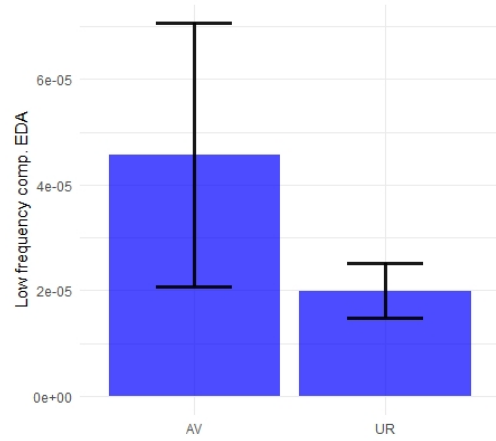


Fig. 5: Comparison of the EDA low frequency component.

electrodermal activity signal presented a significant difference between the two conditions ($t(14) = -2.2$, $p\text{-value} < 0.05$ and $t(14) = 2.52$, $p\text{-value} < 0.05$, respectively). These features have been used in the past to classify stressful versus non-stressful situations, thus corroborating previous findings [17], [19], [26].

Additionally, we explored the differences seen in the physiological features per condition and across the two conditions by determining Pearson correlation between the extracted features and the relaxation rating. Some features, for example, showed significant correlations ($p\text{-value} < 0.05$), including: standard deviation of the absolute 1st difference of the ECG signal, $r = -0.41$; high frequency component of the breathing curve, $r = -0.46$; spectral energy ratio between 0.05 - 0.25 Hz, $r = -0.5$; mean of negative 1st difference of the electrodermal activity signal, $r = 0.42$; and standard deviation of the electrodermal activity signal, $r = -0.43$. Figure 7, for example, depicts the scatter plot of the standard deviation of the absolute 1st difference of the ECG feature along with the respective correlations obtained with the relaxation rating for conditions AV and UR separately. While the feature did not correlate significantly with relaxation in the AV condition AV, a significant negative correlation was seen in the UR condition. This feature has

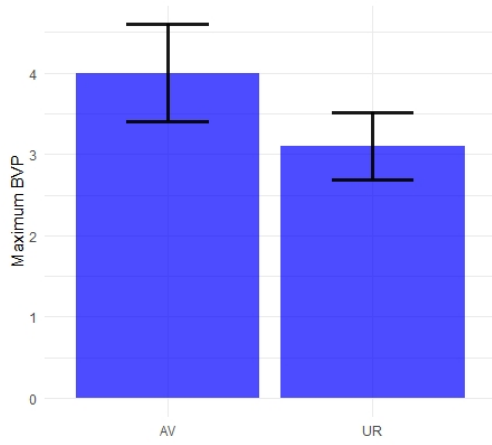


Fig. 6: Comparison of the maximum BVP value.

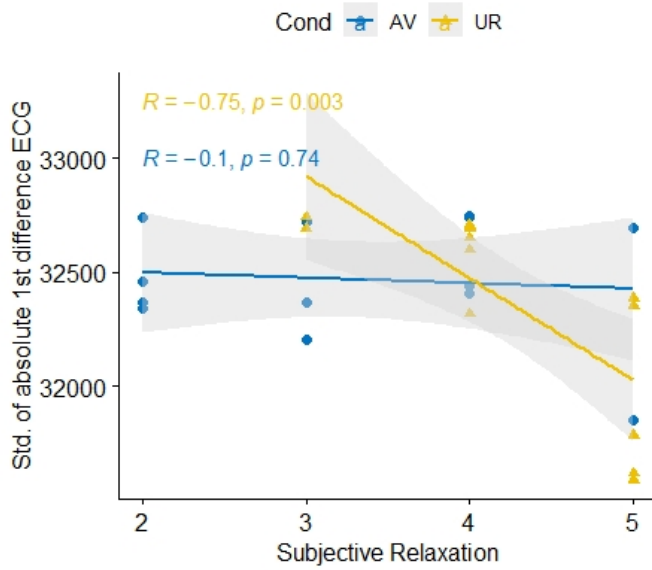


Fig. 7: Scatter plot for standard deviation of the absolute 1st difference of the ECG and the correlation achieved with the subjective relaxation rating for each condition.

been linked to stress and anxiety in the past (e.g., [17], [19], [26], [30], [34], [35]), thus further validating the benefits of the proposed Nat(UR)e framework.

IV. LIMITATIONS AND ONGOING EXPLORATIONS

The results reported in this pilot study were performed on a limited sample size of 16 participants due to restrictions imposed by the COVID-19 pandemic. While the trends seen with many of the extracted physiological signals were in line with those previously reported in the literature for stress and relaxation monitoring, their differences between the two tested conditions showed to be insignificant for many of the features. Future work should focus on increased number of participants to ensure greater statistical power. As well as the use of a baseline as a mean of registering the participants'



Fig. 8: Instrumented VR headset with 16 dry ExG electrodes (EEG, EMG, ECG, EOG) and a wireless bioamplifier.

level of relaxation before the experiment, both subjectively and objectively.

Moreover, the duration of the experiment was chosen to be relatively short, around 1 minute and 15 seconds, motivated by meditation principles for beginners [16]. Such short duration, however, may reduce the effectiveness of ECG based features, especially those based on heart rate variability (HRV) which achieve more accurate results with time windows between 2-5 minutes [34]. In the future, longer duration experiences should be performed to allow for improved HRV analysis.

All the analyses presented herein have focused on each individual modality and feature alone. As shown in [9], [27], however, multimodal analyses allow for improved and more robust stress level prediction and characterization. Future work should focus on the development of multimodal stress/relaxation predictors based on different regression-based machine learning algorithms for real-time evaluation.

Lastly, while wearables have shown promising results to track real-time relaxation states during the Nat(UR)e experience, we are currently expanding our research to also incorporate additional modalities, including electroencephalography (EEG), electro-oculography (EOG), and facial electromyography (EMG) via an instrumented VR headset [7], as shown in Fig. 8. These are important signal modalities that can provide additional insights on the user's stress and anxiety levels (e.g., [13], [14], [34], [36]). Additionally, head movement information obtained from accelerometers embedded into the VR headset could provide information about the users' real-time arousal and valence states [23]. It is expected that access to such augmented biometrics information should lead to improved relaxation state prediction and characterization.

V. CONCLUSION

This study explored the effects of ultra-reality multisensory digital nature walks on user relaxation and compared subjective and objective findings relative to a conventional audio-visual VR experience. Significant improvement in relaxation was found and several biometric features indicative of stress/anxiety/relaxation showed significant changes and correlations with the reported relaxation ratings. Results are

promising as (1) they suggest Nat(UR)e could be used as an alternative to nature walks for those with e.g., mobility issues and (2) that wearables could potentially be used to monitor, in real-time, stress states and allow for biofeedback to change the multisensory scene to customize the experience per user.

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