Effect of Relaxation-Based Virtual Reality on Psychological and Physiological Stress of Substance Abusers under Detoxification: A Randomized Controlled Trial

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Abstract

Substance abuse is a widespread problem, with high rates of treatment dropout. Stress plays a crucial role in this problem, so innovative interventions with stressed patients can assist them in completing treatment. This study is a randomized controlled trial with 60 participants who have substance abuse disorder undergoing detoxification at a residency facility in Tehran, Iran. Participants were randomly assigned to one of three groups: watching a 360-degree video of nature, a 360-degree video of a city environment, or no virtual experience. The intervention was performed only for one session. Psychological stress was measured using the Positive and Negative Affect Scale and Perceived Stress Scale before and after the intervention. Physiological stress was assessed through respiratory rate, skin conductance, and heart rate recordings during the virtual reality experience. Data analysis was performed using R software (version 4.2). Paired t-test results indicated significant psychological differences before and after virtual nature experiences, but not in the control and city groups. The repeated measure ANOVA showed a significant reduction in skin conductance ($p < 0.01$) and respiratory rate ($p < 0.01$) scores in the nature group. The findings suggest that virtual reality relaxation could be potentially beneficial intervention for reducing stress in patients during detoxification.

1- Introduction

Substance abuse is a major global concern that involves excessive use and addiction to drugs or other substances (Chie et al., 2016), which is accompanied by a high dropout rate during the treatment process (Şimşek et al., 2019), especially during detoxification (Gossling et al., 2001). Detoxification is an essential part of recovery methods (Bergenstrom & Abdul-Quader, 2010), and the primary objective of that is to manage withdrawal symptoms safely and enhance the effectiveness of treatment. Withdrawal symptoms typically subside within five to fourteen days, depending on the drug's half-life (Di Patrizio et al., 2022).

Patients during residential treatment experience severe distress in the first few days after discontinuation, such as difficulty inhibiting inappropriate behaviors, delayed reinforcement, and stress linked to a lack of impulse control (Hyman et al., 2007; Sinha, 2008a). Patients who are unable to handle emotional distress are at a higher risk of leaving the program. The major theories of addiction suggest that stress plays a critical role in addiction processes. Psychological models propose that drug use is a coping strategy to deal with stress, while neurobiological models explain how neuroadaptations in reward, learning, and stress pathways may enhance craving, loss of control, and compulsion, leading to addiction (Baker et al., 2004; Hyman & Malenka, 2001; Sinha, 2008b). Furthermore, stress-induced vulnerability is even more significant than the vulnerability induced by drug cues when it comes to relapse and dropout. As a result, substance users may require additional help to complete the discontinuation process successfully and remain in treatment (Jarvis et al., 2018; Mattick et al., 2014).

Studies have demonstrated that being in natural surroundings can positively impact both physical and mental well-being. Spending time in nature can promote relaxation, reduce stress levels, and contribute to

a sense of calmness and rejuvenation (White et al., 2021). Attention restoration theory (ART) by Kaplan suggests that exposure to nature can reduce stress, improve mood, and restore work productivity (Berto, 2014; Kaplan, 1995; Van den Berg et al., 2003). Exposure to environments that provide psychological distance from routine mental concerns combined with effortless, interest-driven attention and supported by an environment of substantial scope can restore mental resources. Each of these three mechanisms that lead to mental restoration is found in natural settings (Hartig et al., 2003). Research on real-life nature exposure supports that immersing in natural environments can be crucial in obtaining environmental advantages (Antonelli et al., 2019). However, urban life and residency in some conditions like rehabilitation centers for substance abusers reduce patients access to natural environments, depriving them of the benefits of being in natural environments.

Virtual reality (VR) is a revolutionary medium that can replicate extremely realistic virtual environments, providing an opportunity to deliver health benefits through simulated natural settings (Mattila et al., 2020). Various studies have revealed that using VR technology for nature immersion can have a positive impact on the psychological well-being of individuals. A single session of VR is capable of reducing physiological stress, negative thoughts, and anxiety while promoting relaxation (Anderson et al., 2017). In particular, VR can be helpful in reducing stress and anxiety among individuals with mental health disorders (Hyewon Kim et al., 2021; Malbos et al., 2020; Riches et al., 2023).

Therefore, VR has been considered a promising technology for virtual nature (Li et al., 2021). Due to reduced costs and increased portability, VR technology has emerged as a viable approach for healthcare and recovery (Wren et al., 2021). Relaxation is the primary function of virtual nature, including psychological and physiological relaxation (Riches et al., 2021). These relaxation effects can be detected through physiological indices (e.g., heart rate variability, electrodermal activity, and saliva cortisol) and self-reported questionnaires (e.g., the Positive and Negative Affect Schedule and the State-Trait Inventory) (Blum et al., 2019; Browning et al., 2020).

This study aims to examine the effects of VR on both affect and perceived stress, along with objective stress variables like heart rate, respiratory rate, and skin conductance in substance abusers undergoing detoxification. The participants in this study experienced 360-degree nature scenes, while the control group did not. By comparing the results of both groups, the study aims to provide insights into the potential benefits of using VR technology to alleviate stress and provide a more calming environment for individuals undergoing detoxification. Moreover, to determine whether the observed effects are due to nature or novelty, we included a group that experienced a 360-degree video of complex city scenes without natural elements.

2- Method

This randomized, controlled, single-blinded trial was conducted in 2023 with a 3-arm design at a single center conducted in 2023. Participants were recruited from a recovery center in Tehran, IRAN. The flow chart of the trial is visualized in Fig 1.

2-1- Participants

The study focused on patients with substance dependency and undergoing detoxification at a rehabilitation facility for a duration of 10 to 14 days. All participants were men between the ages of 20 and 60, undergoing detoxification, and without a history of psychotic or neurological disorders, epilepsy, or seizures. Patients were excluded if they did not complete questionnaires or sessions or experienced unusual symptoms like headaches. The sample size for this study was determined using GPower v3.1.1, with an effect size of 0.40, power of 0.8, and 3 groups. The calculated minimum sample size was 52 patients; ultimately, 60 patients (20 patients in each group) were included in the study.

2-2- Procedure

All patients in the center were given a unique number based on their name and then randomly assigned to one of three groups using a number generator app. The researcher explained the study procedure to each patient, but they were not informed about the different scenarios in each group. Prior to the study, written consent was obtained from all participants. A trained clinical psychologist conducted all procedures in a quiet room.

Initially, the participants completed self-reported questionnaires, which included the perceived stress scale (PSS) and positive and negative affect scale (PANAS). Subsequently, participants in the experimental group were asked to wear a Meta Quest 2 VR (Meta Technology, LLC) headset and watch 360-degree videos for 12 minutes while seated in a chair in a room devoid of any external visual or auditory distractions. The headset featured a 5.5" fast-switching LCD at an 1832 x 1932 pixel per eye resolution. Group one, also known as the nature group, watched 12-minute 360-degree high-definition nature scenes. These nature scenes featured expansive views of water, jungle, and beach, but did not include any animals or human elements. Sounds of nature and soothing music accompanied the scenes. Group two, the control group, did not receive VR. They sat in the same room as the other groups and had their physiological data recorded, like the nature and city groups. Group three, the city group, watched 12-minute 360-degree high-definition scenes of cities. These scenes included large and expansive views of outdoor and indoor cityscapes with city sounds. Throughout the VR experience, respiratory rate, skin conductance, and heart rate were measured, and scales were filled out again after the VR experiences.

2-3- Tools

The study recorded demographic information of the participants, such as their age, education level, and marital status.

Psychophysiological measures

During the experiment, a Procomp-5 Infiniti system (Thought Technology Ltd. Quebec, Canada) was used to obtain heart rate, skin conductance, and respiration data. An SC Flex/Pro sensor was used to measure skin conductance. It works by applying a tiny electrical voltage through two electrodes strapped to two fingers of one hand, creating an electric circuit where the subject becomes a variable resistor. As the

subject becomes more stressed, the skin's conductance increases proportionally, and vice versa (Choudhary et al., 2016). The heart rate was measured with a BVP sensor, where a higher heart rate indicates higher stress levels (Choudhary et al., 2016). In order to measure abnormal respiration rates, a Resp-Flex/Pro sensor was employed. When a person is highly aroused, their respiration rate increases; conversely, when they are relaxed, it decreases (Omata & Tanabe, 2015).

2-4- psychological measures

PSS measures one's perception of life as unpredictable, unmanageable, and troublesome. The scale consists of 10 items, each evaluated on a Likert scale ranging from 0 (never) to 4 (often). A higher score on the scale indicates a greater level of perceived stress (Mazgelytė et al., 2021). The Persian version of this questionnaire has a reliability of 0.90 and a validity of 0.69 (Maroufizadeh et al., 2014). PANAS, on the other hand, is used to evaluate one's immediate affect. It consists of 20 questions, with half of the provided emotion words associated with positive affect (such as interested, alert, attentive, excited, enthusiastic, inspired, proud, determined, strong, and active) and the other half with negative affect (including distressed, upset, guilty, ashamed, hostile, irritable, nervous, jittery, scared, and afraid). Each question is answered on a 5-point Likert scale ranging from "very slightly" to "very much." The score for each emotion is calculated and combined to generate separate measures for positive affect (PA) and negative affect (NA), which are independent of each other (Anderson et al., 2017). The Persian version of this questionnaire has a reliability of 0.87 and a validity of 0.77 (Ghorbanshiroudi & Abbas Ghorbani, 2012; SHARIFI et al., 2012).

2-5- Statistical analysis

The data are presented as mean with standard deviation (SD), and categorical data are reported as numbers with percentages. The normality of the data was assessed using the Shapiro-Wilk test. Demographic data were compared using One-way ANOVA or the Kruskal-Wallis H test. The paired t-test was used to compare approximately normally distributed continuous variables, while the repeated measure ANOVA was used to analyze continuous data. A P-value of less than 0.05, two-sided, was considered significant. The statistical analysis was conducted using R version 4.2.1 (R Foundation for Statistical Computing Vienna Austria).

3- Results

3-1- Participant’s background

All participants were men and reported mean age of 36.95 (5.62) in the nature group, 38.05 (6.74) in the city group and 40.10 (6.76) in the control group. The results of ANOVA show there is no significant difference between the mean age of groups (F=1.24, p=0.29). In groups city and control 15% have college education compared to the nature group which 20% of participants have a college education, according to Kruskal Wallis test there was no significant different between them (H=0.236; p=0.88); in nature and city groups 30% and in control group 45% participants were married (H=1.29; p=0.52).

3-2- psychological scales

At baseline

Scores of patients at baseline compared with each other. As the results of ANOVA with the Bonferroni test showed there was a significant difference between the nature group and control in pretest of positive affect (PANAS) (F=4.00; mean difference =-3.30; p=0.02; Eta=0.12). There was no significant difference between the other pretest scores between groups.

Table 1 displays the result of paired t test for comparing the mean score of patients before and after treatment for each group. Paired t test assessing before and after VR experience indicated positive affect (p<0.01), negative affect (p<0.01), and stress perception (p<0.01) significantly change after exposure to a nature environment. There was no significant difference in city and control groups before and after a session.

Table 1. Results of paired t test for PSS and PANAS

Groups		Mean difference	95% Confidence interval of the difference		t	P	Cohens D
			Lower	Higher			
Nature	PA	-2.65	-4.396	-0.903	-3.17	0.004	-0.71
	NA	1.50	0.137	2.862	2.30	0.032	0.51
	PSS	2.45	0.676	4.223	2.89	0.009	0.64
City	PA	-0.10	-0.468	0.268	-0.56	0.577	-0.12
	NA	0.25	-0.227	0.727	1.09	0.286	0.24
	PSS	0.30	-0.785	1.385	0.57	0.569	0.12
Control	PA	0.30	-1.815	2.415	0.29	0.769	0.06
	NA	1.10	-0.603	2.803	1.35	0.192	0.30
	PSS	-0.71	-2.399	0.971	-0.88	0.380	-0.19

PA=Positive affect, NA=Negative affect, PSS=Perceived stress scale

3-3- Physiological data

A repeated measures ANOVA with a Greenhouse-Geisser correction determined that mean respiratory rate differed statistically significant between 12 time points in nature group (F(2.65, 50.52))=8.17,P<0.01, np^2=0.29) but not in city group (F(2.81, 53.36))=1.90,P=0.14, np^2=0.09) and control group (F(2.30, 43.78))=1.03,P<0.37, np^2=0.05). Post hoc analysis with a Bonferroni adjustment revealed that respiratory rate was statistically significant decrease from first minute to minute 8 (1.23(95% CI,0.2 to 2.44), p=0.04),

minute 9 (1.36(95% CI,0.11 to 2.61), p=0.02), minute 10 (1.42(95% CI,0.10 to 2.74), p=0.02), minute 11 (1.73(95% CI,0.32 to 3.14), p=0.006) and minute 12 (1.74(95% CI,0.19 to 3.31), p=0.01). Also, there was significant different between minute 2 and minute 11 (1.53(95% CI,0.003 to 3.06), p=0.04). Furthermore time*group interaction revealed significant difference between groups (F (5.93,169.06) =2.61, p=0.02, np^2=0.08)(Fig2).

Furthermore, the results of Skin conductance determined significant different between 12 time points in nature group (F (1.45,27.67)) =4.71, P=0.02, np^2=0.20) but not in city group (F (2.10, 40.03)) =1.72, P=0.18, np^2=0.08) and control group (F (2.99, 56.93)) =0.04, P=0.98, np^2=0.02). Post hoc analysis with a Bonferroni adjustment revealed that no significant different between two time point. Furthermore time*group interaction revealed significant difference between groups (F (5.20,148.76) =3.67, p<0.01, np^2=0.11).

Analyze of hearth rate shows no significant different in nature group (F (1.79, 34.12)) =0.24, P=0.76, np^2=0.01), city group (F (2.00, 38.18)) =0.12, P=0.89, np^2=0.006) and control group (F (4.06, 77.16)) =0.25, P=0.91, np^2=0.01). Also time*group interaction revealed no significant difference between groups (F (4.90,139.68) =0.10, p=0.99, np^2=0.004).

4- Discussion

Participants were exposed to a virtual natural environment created by a VR device. The virtual environment consisted of both nature and city settings, each lasting 12 minutes. The findings revealed that participants who experienced the natural setting had a significant decrease in scores on the PSS and negative affect as well as significant increase in scores on the positive affect. Furthermore, physiological measures such as respiratory rates and skin conductance decreased significantly in the nature group but with small effect size.

Notably, none of the subjects reported any unusual symptoms, such as dizziness, nausea, vomiting, headache, or visual disturbances. Although the study did not assess the implementation of VR, patients are likely to use it for relaxation and enjoyment on their own accord. Given the time constraints, VR could be a viable solution to alleviate stress as it reduces stress levels by providing an immersive video of natural settings, making the subjects feel like they are in a peaceful and calming environment (H. Kim et al., 2021).

The study found that virtual reality experiences in natural environments can reduce psychological stress in detoxifying patients, as demonstrated by significant differences in self-reported measures. This approach is consistent with previous research (Calogiuri et al., 2022; Ho et al., 2023; Li et al., 2021; Spangenberger et al., 2022) and the findings of other researchers in attention restoration theory (Berto, 2005; Hartig et al., 2003). Looking at natural scenes was found to be more effective than looking at city scenes in reducing stress and improving affect during withdrawal. This study builds upon previous research on the impact of virtual nature on substance abuse. Like other studies using 360-degree videos

of virtual nature, this study indicates that virtual reality nature scenes can help substance abusers divert their attention from negative thoughts and withdrawal symptoms (Wilson & Scorsone, 2021).

The findings show that similar to other studies using 360-degree videos of VR nature (Anderson et al., 2017), participants experienced an increase in positive affect and a decrease in negative affect when viewing virtual reality nature scenes. Stress reduction theory suggests that natural landscapes promote well-being because humans unconsciously identify with these landscapes for their evolutionary needs (Ulrich, 1983). Simulated nature might primarily benefit from reducing negative affect, according to previous research (Van den Berg et al., 2003) and attention restoration theory (Kaplan, 1995), nature can provide an escape from everyday demands and help interrupt cognitive demands and maladaptive patterns of thought, potentially reducing negative affect without necessarily increasing positive affect (Golding et al., 2018; Van den Berg et al., 2003).

Unlike other studies, our findings indicate that simulated nature exposure can have a positive impact on the overall affect rather than just reducing negative affect. This information could be important for future research and interventions aimed at improving mental health and well-being. This aligns more with the findings from outdoor nature research than with simulated nature research (McMahan & Estes, 2015; Neill et al., 2019). Minimal variation in positive affect after a simulated natural encounter can be attributed to factors such as boredom or disconnection when viewing pictures or videos of environments (Brooks et al., 2017; Kjellgren & Buhrkall, 2010). However, it is important to note that this study kept the session time brief, which may have prevented participants from becoming bored.

We observed a gradual decrease in skin conductance and respiratory rates with exposure to nature scenes, while no significant change in values was noted for the city scene and control. The respiratory system responds to mental stress by increasing the respiratory rate (Widjaja et al., 2013). The virtual nature experience has been found to lower the respiratory rate of substance abusers, which is a significant physiological stress index (Lin et al., 2011). Skin conductance is a measure of arousal or stress levels. The study showed that patients experienced increased relaxation after viewing natural scenes. Skin conductance is a symptom of the stress response due to sweat secretion by the eccrine sweat glands located all over the body (Westerink et al., 2020). It is widely used to measure the impact of built or natural environments on recovery after stress or cognitive tasks (Frumkin et al., 2017). Recent research has shown that a sudden increase in skin conductance can be a reliable indicator of the occurrence and timing of a stressful event. This increase in skin conductance level is associated with heightened arousal, influenced by cholinergic activity. Mental stress can also cause an increase in skin conductance level, further supporting the use of this measure as a reliable indicator of stress (Westerink et al., 2020). Such findings have important implications for understanding the physiological processes during stress and developing effective interventions to help individuals manage stress in their daily lives. The findings suggest that a decrease in a virtual nature environment compared with a city environment leads to decreased arousal, which may reflect feeling more relaxed and distract participants from their stressful thoughts. This finding shows that the virtual nature environment is beneficial for reducing the physiological stress of substance abusers.

According to our result, VR did not significantly change heart rate. A study conducted by Naylor et al. on healthy individuals demonstrated that heart rate significantly decreased after a VR intervention from pre-test levels. An elevated heart rate is typically a sign of physiological arousal and is often accompanied by feelings of psychological stress and strain (Kao et al., 2014). Research conducted on the correlation between heart rate and stress levels has shown that a lower heart rate may indicate reduced stress or increased relaxation (Naylor et al., 2019). According to a study by Kennedy et al., heart rates were higher when substance abusers reported cravings. It is possible that the high heart rate observed in substance abusers during our study is caused by physiological changes in the body, which may not be decreased after a VR experience.

The potential advantages of using VR as a relaxation technique have been explored through various studies. One of the main benefits of VR relaxation is that it requires minimal effort in terms of attention and concentration, as the immersive nature of VR can help to alleviate stress and anxiety (Riches et al., 2023). Moreover, VR relaxation can be used independently, even in rehabilitation centers, making it a promising option for individuals seeking to manage their stress levels. Additionally, VR relaxation can be used as a standalone intervention, with fewer requirements from staff and less time-intensive than other relaxation techniques. VR has many advantages for use in detoxification centers because it offers stress reduction and relaxation in psychological and physiological stress.

In this study, there are limitations that should be taken into consideration. First and foremost, patients cannot have multiple sessions during the day due to the treatment center's daily schedule. This means that the data collected may not be as comprehensive as it would have been if patients were able to have multiple sessions. Secondly, the number of participants is limited due to recruitment challenges. This can potentially limit the generalizability of the findings. Finally, access to more precise tools to measure physiological status is lacking, which may impact the accuracy of the results. Despite these limitations, this study provides valuable insights into the application of VR in the treatment process of substance abusers.

Conclusion

The study found that a 12-minute VR experience that involves exposure to nature can significantly reduce both psychological and physiological stress levels. This is an important discovery, especially for individuals who may not have access to natural environments or for those who have substance abuse problems. For such individuals, a brief and isolated exposure to a 360-degree video of nature can be a beneficial alternative to visiting natural environments. However, the study emphasizes the need for further research to compare the effects of repeated exposure to virtual experiences with real-life nature experiences in other populations. These findings have significant implications for developing interventions to reduce stress and improve mental health.

Declarations

Data availability statement: The datasets generated and analyzed during the current study are not publicly available to protect patient confidentiality but are available from the corresponding author upon reasonable request.

Competing interest: authors declared no competing interest

Consent for publication: This manuscript has been approved for publication by all authors.

Authors contributions: SHL, AY conceptualized this research and acquired the data. SHL, AY, PJ, FN,JSY and HSH interpreted data. SHL drafted the manuscript with input from all authors. ASK supervised the study.

Ethical approvements: The study protocol was approved by the Ethics Committee of the Shahid Beheshti University of Medical Science (IR.SBMU.RETECH.REC.1402.303) and Iranian Registry of Clinical Trials (IRCT20220316054306N2).

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Figures

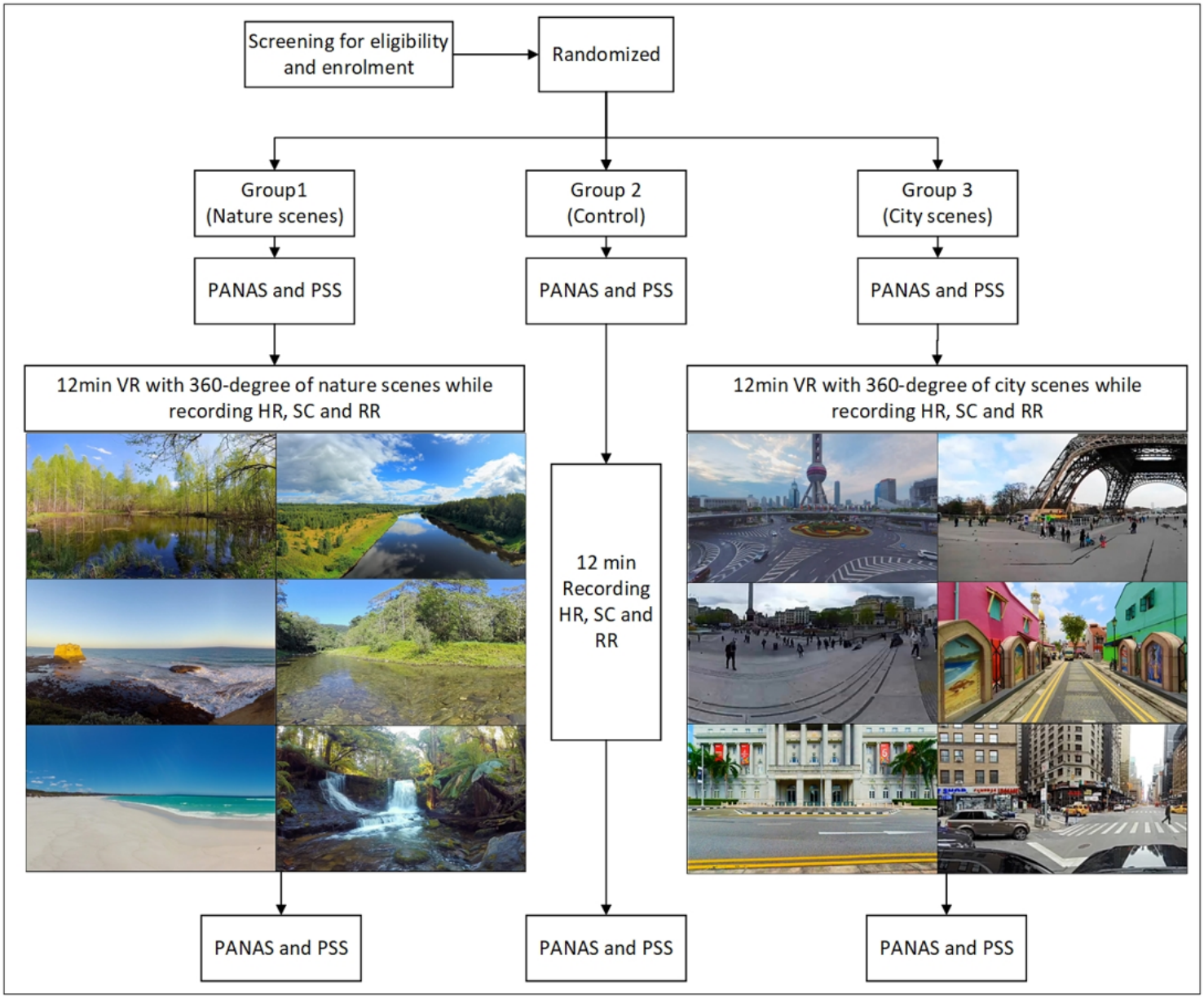

Figure 1

Flow chart of the study and example of 360-degree scenes. PANAS: Positive and Negative Affect Schedule; PSS: Perceived Stress Scale; HR: Heart Rate; SC: Skin Conductance; RR: Respiratory Rate

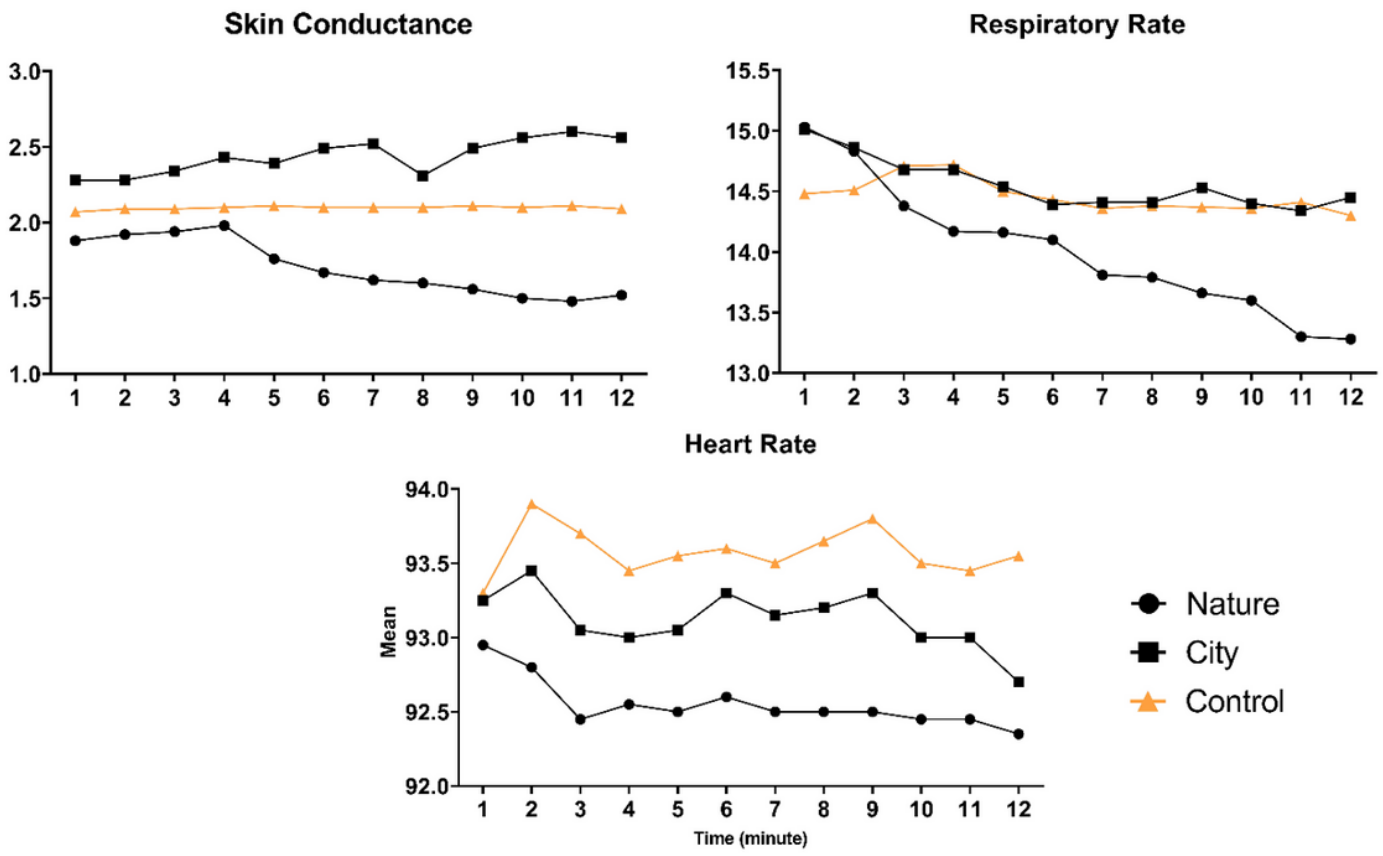

Figure 2

Points and connecting lines show the mean of heart rate, respiratory rate and skin conductance for each group.