IMPACT OF NATURAL AND URBAN ENVIRONMENTS ON THERMAL PAIN PERCEPTION: EXPERIMENTAL STUDY IN VIRTUAL ENVIRONMENTS

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Abstract

The environment in which an individual resides and observes may play a meaningful role in well-being and related constructs. Prior investigations have highlighted the positive influence of natural environments on individuals, impacting mood and psychophysical sensations, such as pain relief. Conversely, urban settings, dominated by concrete elements, might lead to mood decline and heightened stress levels. Comparable associations concerning affect arise in the context of perceiving virtual natural and urban environments. Nevertheless, this topic has been insufficiently explored by many researchers, particularly in the context of pain associations. The aforementioned studies inspired and guided the design and implementation of the described experimental research in the field of environmental psychology, utilizing emerging technologies, especially virtual reality (VR), increasingly recognized in mental health. The primary objective was to investigate the impact of a simulated virtual environment, mirroring a natural setting abundant in greenery, on the perception of acute pain induced by thermal stimuli (high temperature) – encompassing intensity, unpleasantness, pain tolerance. Comparative analyses were conducted between the virtual natural environment (constructed in the likeness of a therapeutic garden), virtual urban environment and a control group without virtual projections. Secondary objectives aimed to determine the mutual relationships among variables such as positive and negative emotions, virtual environment preferences, sense of presence and restorative experience in the context of the perception of environments and induced thermal pain. The study involved 126 healthy adults, with 42 individuals in each of the three comparison groups. Oculus Rift VR technology and the TSA-II neurosensory analyzer facilitated the experiment. Alongside demographic data, participants' subjective feelings concerning VR and pain were evaluated using: *Visual Analogue Scale* (VAS), original *Restorative Experience in the Virtual World* questionnaire, an adapted *Slater-Usoh-Steed* (SUS) questionnaire. Results of psychometric analyses (Kruskal-Wallis tests, Wilcoxon tests and contrast analyses) underscored the positive impact of the virtual natural environment on individual pain perception and mood. The virtual natural environment outperformed the virtual urban environment and the control group, particularly in subjective pain components like intensity or unpleasantness. Variables such as restorative experience, sense of presence and virtual environment preference also proved pivotal in pain perception and tolerance threshold alterations, contingent on specific conditions. This suggests significant potential applications of virtual natural environments in various areas of psychology and related fields, including supportive analgesic method and a post-psychotherapeutic session relaxation form.

Keywords: *Environmental psychology, nature, acute pain, virtual reality, experiment.*

1. Introduction

The environment in which an individual lives and observes can significantly influence their well-being and broadly understood psychophysical health. The type of environment plays a non-trivial role in this regard. Previous studies indicate significant differences in the impact of natural environments, with a preference for natural greenery over typical urban or concrete landscapes (Hartig et al., 2003; Nutsford et al., 2016). Explanations for these differences can be traced to evolutionary psychology and the embeddedness of the human species in nature. Therefore, due to their species affiliation, humans prefer natural environments (Wilson, 1984), perceiving them (subconsciously) as sources of stress reduction (Stress Reduction Theory, Ulrich, 1983). Moreover, the specific properties of natural environments contribute to easy, involuntary attention focusing on non-taxing, soothing stimuli, leading to restoration of affective-cognitive functions (Attention Restoration Theory, Kaplan, 1995).

Previous studies have emphasized the positive impact of natural environments, particularly on an individual's mood, contributing to the reduction of anxiety symptoms and decreasing the intensity of negative emotions (Robinson, 2018). Contact with nature can also be an effective form of stress reduction – not only conscious contemplation but even being in a natural environment (Richardson et al., 2020). However, there are also indications that the perception of natural environments can positively affect psychophysical experiences (Quick et al., 2017), including pain relief (Gungormus et al., 2024) or faster recovery after medical procedures (Ulrich, 1984).

Similar relationships, especially concerning emotions, arise in the context of virtual natural and urban environments (Yin et al., 2019) thanks to the occurrence of phenomena such as effective distraction and a sense of presence (the feeling of actually being in a virtual environment; Tack, 2019) combined with the perception of potentially restorative environments (McAllister et al., 2017). Nevertheless, many studies, especially in the case of impact on pain sensations, have not sufficiently delved into this topic, only pointing to the significant potential of using virtual natural environments in a psychological context (Tanja-Dijkstra et al., 2018).

2. Objectives

The above-mentioned studies served as inspiration and guidance for designing and conducting an experimental study in the field of environmental psychology, utilizing modern technologies, specifically virtual reality (VR), increasingly recognized and widely employed in the realm of mental health.

The main goal was to explore how a simulated virtual environment, resembling a nature-rich setting with abundant greenery, influences the perception of acute pain caused by thermal stimuli (high temperature). This involved examining aspects like intensity, unpleasantness, and pain tolerance. Comparative assessments were carried out among three groups: one exposed to a virtual natural environment (resembling a therapeutic garden; VNE), another to a virtual urban environment (VUE), and a control group without any virtual projections. Secondary objectives aimed to establish the interconnections between and variables such as mainly positive and negative emotions, but also preferences for virtual environments, sense of presence, and the restorative experience in the context of environment perception and induced thermal pain. The main hypotheses in the study were as follows:

1. VNE has a positive influence on pain experiences induced by thermal stimulation.
2. VNE has a more positive impact on pain experiences than a VUE.
3. VNE has a more positive impact on an individual's emotions than a VUE.

3. Methods

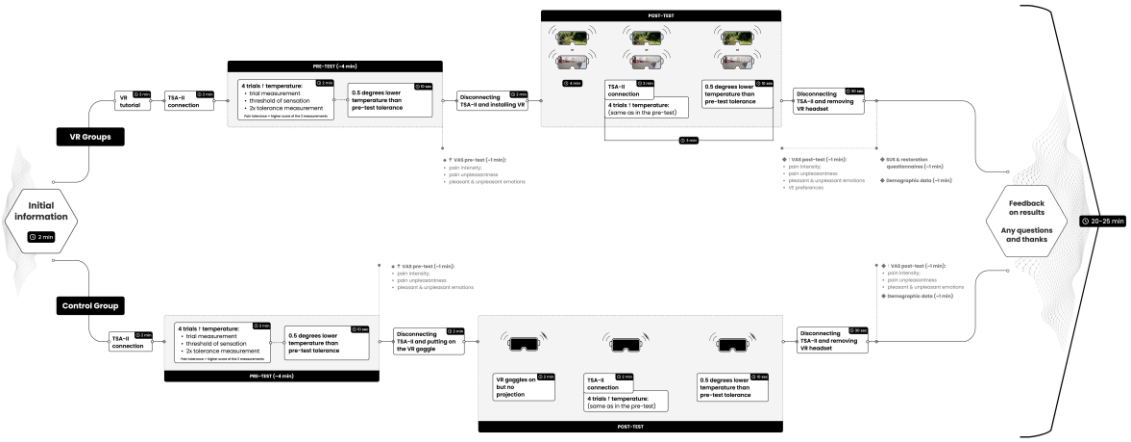
An experimental investigation was designed with the manipulation of the independent variable, aiming to establish causal relationships. The study enlisted 126 healthy adults, with 42 individuals in each of the three comparative groups (VNE group, VUE group and control group – the group wore VR goggles, but were not exposed to a virtual projection). To be eligible for participation, individuals had to fulfill specific criteria e.g., providing informed consent, being of legal age, having no apparent physical conditions, and no prior adverse experiences with VR.

The TSA-II neurosensory analyzer (Medoc) was utilized in an experiment involving Oculus Rift VR technology, enabling pain-related measurements and high temperatures up to 50.5 degrees Celsius. In addition to collecting demographic information, participants' subjective experiences with VR and pain were assessed through tools such as the *Visual Analogue Scale* (VAS), the original 6-item *Restorative Experience in the Virtual World* questionnaire (α = 0,78-0,86; n = 84), and a linguistically adapted 3-item *Slater-Usoh-Steed* (SUS) questionnaire for sense of presence measurement (original Slater et al., 1994; an adapted version: α = 0,63-0,80; n = 84).

4. Procedure

Participants were provided with instructions on using VR equipment, assessing their controller proficiency in a neutral testing environment. They were directed to sit comfortably and shake their non-dominant hands. The thermode of the TSA-II was then applied directly to the skin of the inner forearm. In their other hand, participants held a computer mouse, providing them full control during the examination; pressing the button led to an instant cooling of the thermode. The procedure involved virtual projection, pre- and post-tests measuring pain components and positive and negative emotions, and measurements related to the sense of presence, restorative experience, and preferences for VNE or VUE. Participants also completed a demographic data questionnaire. The study procedure is detailed in Figure 1.

Figure 1. The experimental procedure – diagram.



5. Results and discussion

All statistical and psychometric analyses were performed in SPSS v26.0 for Windows. Due to the non-normal distribution of variables in line with the first research hypothesis, the Wilcoxon test for repeated measurements was employed as an alternative to the Student's t-test. To assess hypotheses 2-3, the Kruskal-Wallis test, chosen for its suitability with non-normally distributed data, was utilized as an alternative to one-way ANOVA. Subsequently, a contrast analysis was performed.

5.1. Research group

Out of the 216 volunteers who expressed interest in participating, 126 individuals were ultimately included in the final sample (M_{age} = 23.28). Within this sample, 71% identified as female, 27% as male, and 2% indicated a different gender identity. 57.1% of participants in the survey had never used VR before, while 92.6% of those who had reported neutral or favorable experiences.

5.2. Virtual reality and pain

5.2.1. Pain intensity. The Wilcoxon test conducted to assess the repeated measurement of pain intensity in the VNE group (pre-test and post-test) yielded statistically significant results (z =2.23; p =.008). The rank-biserial correlation value (rrb = .49) suggests a moderate effect size. As suspected, not only actual nature with a predominance of greenery but also its virtual projection can induce psychologically beneficial effects (cf. Léger & Mekari, 2022), including an analgesic effect. Additionally, the Kruskal-Wallis test was performed to assess the variability in pain intensity measurements, specifically the contrast between pre-test and post-test pain intensity across various comparison groups. The findings revealed statistical significance ($\chi^2(2)$ =7.14; p =.028), indicating a significant difference among groups in the reduction in perceived pain intensity, supporting Tanja-Dijkstra et al. (2018) results.

Examination of descriptive statistics indicated that the VNE group showed the most substantial decline in pain intensity measurements. In the VNE group, the average reduction in pain intensity was .36 points, whereas in the VUE and the control group, the intensity increased by an average of .21 points. A contrast analysis revealed statistically significant distinctions between both the VNE group and the VUE group (t =-2.39; p =.018) and the VNE group and the control group (t =-2.39; p =.018).

5.2.2. Pain unpleasantness. The outcome of the Wilcoxon test, performed to assess the recurrent measurement of pain unpleasantness in the VNE group (pre-test and post-test), reached statistical significance (z =2.32; p =.001). The rank-to-serial correlation value (rrb =.58) signifies a substantial effect size. Being in a natural environment and observing its natural elements may contribute to human psychology and closely related bodily sensations, such as perceiving pain as milder and less unbearable (cf. Quick et al., 2017). The Kruskal-Wallis test was used to compare pre-test and post-test scores of pain unpleasantness across different groups. The results showed statistical significance ($\chi^2(2)$ =10.48; p =.005), indicating a significant difference in the reduction of pain unpleasantness among these groups, highlighting the varied impact on pain unpleasantness observed across the studied groups.

Descriptive statistics concerning the variability in pain unpleasantness measurements highlight the most significant reduction in the VNE group. More specifically, the VNE group demonstrated an

average decrease in pain unpleasantness of .88 points. In contrast, the VUE group experienced a minor increase in unpleasantness by .05 points, while the control group recorded a slight increase of .17 points. Consequently, a contrast analysis was conducted, revealing statistically significant differences both between the VNE group and the VUE group (t =-2.48; p =.014), as well as the VNE group and the control group (t =-2.8; p =.006).

5.2.3. Pain tolerance. Concerning the assessments of pain tolerance thresholds within the VNE group (pre-test and post-test), the outcome of the Wilcoxon test, though nearing significance, did not reach statistical significance (z =-1.57; p =.059). Furthermore, distinct groups showed no significant differences in pain tolerance threshold measurements, indicating no intergroup variations in the augmentation of pain tolerance, as per the Kruskal-Wallis test ($\chi^2(2)$ =2.44; p =.295).

Based on findings from scientific studies (cf. Ho et al., 2022), it was hypothesized that a VNE might contribute to an increase in individual pain tolerance due to distinctive distraction involving attention engagement with a diverse environmental stimulus (cf. Moran, 2019). Importantly, over 25% of participants reached the tolerance level at the maximum allowable value for safety reasons (50.5 degrees Celsius). Therefore, it is likely that if participants were allowed to continue the measurement, some of them could achieve higher readings, potentially revealing differences. Additionally, participants with a strong sense of presence in the VNE group reported an increase in pain tolerance thresholds (similarly to the restorative experience), unlike participants from the VUE group. This may indicate that other variables are also important for this issue.

5.3. Virtual reality and emotions

5.3.1. Negative emotions. The result of the Kruskal-Wallis test, conducted for the difference in negative emotions measurements (pre-test and post-test) in individual groups, indicates a significant intergroup difference in the reduction of negative emotions ($\chi^2(2)$ =14.16; p <.001). Moreover, the analysis of descriptive statistics for the difference in measurements of negative emotions levels suggests its highest decrease in the VNE group among all groups. To examine whether the difference between the VNE group and the other comparative groups is statistically significant, a contrast analysis was performed. Its results indicate statistically significant differences both between the VNE group and the VUE group (t =-2.16; p =.033), and the VNE group and the control group (t =-3.82; p <.001). The obtained results, akin to previous publications (cf. Yin et al., 2019; Robinson, 2018), indicate a more favorable impact of contact with nature compared to urban environments concerning emotions.

5.3.2. Positive emotions. The result of the Kruskal-Wallis test, conducted for the difference in positive emotions measurements (pre-test and post-test) in individual comparative groups, is statistically significant ($\chi^2(2)$ =19.34; p <.001). Descriptive statistics for the difference in measurements of positive emotions levels indicate its highest increase in the VNE group, what is a similar result to McAllister et al. (2017) conclusions. To examine whether the difference between the VNE group and the other groups is statistically significant, a contrast analysis was performed. The obtained results indicate statistically significant differences both between the VNE group and the VUE group (t =2.23; p =.028), and the VNE group and the control group (t =4.37; p <.001). Moreover, deeper analyses reveal that in the VUE group, increased preference for virtual environments leads to higher positive emotions. This effect is similar, but reversed, to Grahn and Stigsdotter's (2003) study based on real environments, which highlighted the significance of aesthetics in mood mainly in natural environments.

5.4. Answers to the hypotheses

The study partially confirmed Hypothesis 1 that VNE positively impacts pain by reducing its intensity and unpleasantness, but not its pain tolerance. Similarly, Hypothesis 2 showed that VNE has a more favorable impact on pain intensity and unpleasantness than VUE, but no significant differences were observed in pain tolerance thresholds. Hypothesis 3 confirmed that VNE has a more positive effect on emotions than VUE, decreasing negative emotions and increasing positive ones.

6. Conclusions

The results of the study revealed the positive influence of the VNE on pain perception and perceived emotions. VNE outperformed the VUE and the control group, particularly in subjective pain components like intensity or unpleasantness. Variables such as restorative experience, sense of presence, and virtual environment preference may also play a crucial role in pain perception and tolerance threshold

alterations under specific conditions, which, however, requires further exploration. This suggests significant potential applications of VNE in psychology and related fields, including supportive analgesic methods and post-psychotherapeutic relaxation. In the future, it is worth exploring the possibilities of integrating VR-based therapies with traditional treatment methods, particularly in the context of pain management and the potential of VNE to reduce the need for pain medication.

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