Virtual Reality Nature Exposure: Exploring the Effects of Mindfulness Meditation and Trail Enrichment on Stress and Presence

by

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Cheers!

ABSTRACT

Stress among university students has increased since the COVID-19 pandemic, due to academic pressures, financial constraints, and limited social support. Nature therapy is an effective method for reducing stress, but many individuals cannot access natural environments. This study investigated the effectiveness of virtual (VR) nature therapy in reducing stress. Specifically, it examined the role of mindfulness meditation and visual enrichment in creating an immersive, stress-reducing VR experience. Participants were randomly assigned to one of four conditions: (1) no mindfulness meditation and no enriched environment, (2) enrichment only, (3) mindfulness meditation only, and (4) both mindfulness and enrichment. Stress levels were measured before and after the session using the State-Trait Anxiety Inventory (S.T.A.I), and presence was assessed with the Spatial Presence Experience Scale (S.P.E.S). We hypothesized that the combination of mindfulness meditation and an enriched environment would lead to the greatest stress reduction. Data from 12 participants revealed a significant within-subjects decrease in stress and a significant interaction effect for participants in the combined condition. A significant interaction between mindfulness and enrichment was also found for presence, though neither factor had a main effect alone. This research supports VR nature therapy as a potentially accessible and cost-effect intervention for managing stress in populations with limited access to natural spaces.

Keywords: Virtual Reality, Nature Therapy, Mindfulness Meditation, Stress Reduction, Enriched Environment, Presence

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Since the COVID-19 pandemic, there has been a significant increase in stress levels and negative affect among individuals, particularly university students (Alkhawaldeh et al., 2023). University students often face both short-term and long-term stressors, which may vary in frequency and intensity depending on factors such as their living situation, social support, access to campus resources, and financial pressures (Alkhawaldeh et al., 2023). The World Health Organization (WHO) highlights that "one in five college students grapples with mental health issues, primarily linked to stress." (as cited in Olasz et al., 2024, p. 2347). Recent research has revealed the prevalence of stress among university students to further emphasize the importance of this issue. For instance, Alkhawaldeh et al. (2023) reported that in a sample of approximately 300 students, around 37% experienced environmental-based stress, while 45% faced severe academic-related stress. This underscores the urgent need for effective interventions for stress reduction and to enhance relaxation and mental health (Alkhawaldeh et al., 2023; Bratman et al., 2012).

Stress is commonly assessed with the Spielberger (1983) *State-Trait Anxiety Inventory* (S.T.A.I.), a widely validated tool for measuring stress (Barnes et al., 2002). The inventory describes trait anxiety as the "frequency and intensity with which anxiety manifests itself over time." (Barnes et al., 2002, p. 604). High levels of stress can exacerbate feelings of helplessness, hopelessness, and distress

(Kaplan, 1995). For the purpose of this study, stress will be operationally defined as the subjective level of stress measured by the S.T.A.I. Higher scores on the State Anxiety subscale indicate greater levels of perceived stress at a specific moment in time. Applying the S.T.A.I allows researchers to evaluate stress levels accurately and determine the efficacy of interventions in reducing these levels (Evans et al., 2018).

Nature and natural environments are described as “areas containing elements of living systems that include plants and non-human animals” or species (Bratman et al., 2012, pp. 121-122). Experiencing nature can include spending time physically in a natural setting like a park, or by watching videos or looking at images of natural scenes or landscapes (Bratman et al., 2012). Nature provides numerous health benefits, such as a reduced heart rate, increased positive thoughts, and a sense of contentment and relaxation (Bratman et al., 2012). Interventions involving natural environments may provide university students with tools and experiences to manage and reduce their stress, thereby improving their overall quality of life and mental well-being (Bratman et al., 2012; Alkhawaldeh et al., 2023).

In recent years, virtual reality (VR) has emerged and continuously advances (Browning et al., 2020). It has started to be used to simulate nature experiences for individuals who may not have easy access to outdoor environments (Browning et al., 2020). The technology offers therapeutic benefits similar to those of real-world nature exposure and allows users to immerse

themselves in simulated natural landscapes (Browning et al., 2020). There has been recent work on maximizing the effectiveness of VR in therapeutic settings by incorporating elements like presence, visual enrichment, and mindfulness techniques (Browning et al., 2020). The components—presence, visual enrichment, and mindfulness—within VR nature therapy can improve its effectiveness in reducing stress, thus offering an immersive and innovative intervention for individuals, like students, dealing with stress.

Nature Therapy

Nature therapy is a widely recognized psychological intervention that involves exposure to or contact with natural environments (Bratman et al., 2012). Some researchers indicate that nature therapy provides a variety of physical and psychological benefits, including reductions in cortisol levels and improvements in stress management (Bratman et al., 2012; Kobayashi et al., 2019). For instance, Grassini (2022) found that "nature walk interventions… [can alleviate] depression and anxiety." (p. 12).

Further investigating nature walks, Ma and colleagues (2024) conducted a systematic review that focused on the therapeutic benefits of physical exercise in natural settings. Their findings showed that physical activity in nature not only enhances cognitive functions like memory but also significantly promotes overall mental well-being (Ma et al., 2024). Ma et al. (2024) also emphasized the importance of *nature connectedness* in nature therapy, which refers to the relationship between humans and the natural world. Individuals experience these

benefits in nature because of this connectedness, and the relationship between an individual and nature grows as they engage in nature therapeutic approaches (Ma et al., 2024).

With the rapid growth of urbanization today, there's a concern for access to natural environments (Bratman et al., 2015). As urban areas expand, opportunities for nature exposure decrease (Bratman et al., 2015). In a study by Bratman et al. (2015), participants assigned to nature walks showed improved memory performance and positive attributes compared to participants who walked in urban environments. Similarly, Kobayashi et al. (2019) found that walking in forest area resulted in lower cortisol levels, measured through salivary concentrations. These findings highlight the stress-reducing benefits of nature exposure, why nature therapy is influential on mental health, and the need to incorporate natural spaces into urban planning (Bratman et al., 2015; Kobayashi et al., 2019; Van den Bosch et al., 2015).

Nature therapy incorporates both natural components and therapeutic approaches designed by psychologists. Nature therapy promotes physical activity, social interaction, and "opportunities for personal develop and sense of purpose." (Mayer et al., 2009, p. 609). It can help people strengthen pre-existing abilities or concepts such as behavioural regulation, self-esteem, and *resilience* (Marselle et al., 2019). Marselle and colleagues (2019) argue that resilience—the "ability to 'bounce back' from adversity"—is an essential skill, especially when individuals face stress or trauma (p. 2). Nature-based interventions, such as wilderness camps,

or outdoor group walks, can enhance resilience by fostering a sense of confidence and self-esteem (Marselle et al., 2019). Marselle et al. (2019) found that regular walks in nature were associated with lower stress and negative emotions, further demonstrating the mental health benefits of nature therapy.

Theories Supporting Nature Therapy

There are a few theories that support the effectiveness of nature therapy, including *Attention Restoration Theory* (ART) (Kaplan, 1995), *Stress Reduction Theory* (SRT) (Ulrich et al., 1991), and the *Biophilia Hypothesis* (Keppert & Wilson, 1995 as cited in Mayer et al., 2009).

ART (Kaplan, 1995) suggests that exposure to natural environments help restore cognitive processes or resources by reducing mental fatigue (Browning et al., 2020). This theory explains why nature therapy tends to be an effective approach—people tend to spend time outdoors to minimize cognitive strain and to increase feelings of relaxation (Browning et al., 2020). SRT (Ulrich et al., 1991) explains that humans have an inherent connection to nature. As Browning and colleagues highlight, "natural landscapes promote wellbeing in part because of the human's unconscious identification with these landscapes for their evolutionary needs." (2020, p. 9). Historically, nature has provided shelter, food, and safety for people (Browning et al., 2020). Therefore, people experience comfortability and a reduction in stress levels when exposed to nature (Browning et al., 2020). The Biophilia Hypothesis shares a similar idea and suggests that "people have a biologically based need to affiliate with and feel connected to the broader world."

(Kellet & Wilson, 1995 as cited in Mayer et al., 2009, p. 610). People have a strong sense of belonging and safety when they are surrounded by nature (Mayer et al., 2009).

Mayer and colleagues (2009) conducted a study to examine how nature connectedness "mediates the relationship between exposure to nature and variables of positive affect." (p. 622). Participants were randomly assigned to one of two buses: (1) bus ride that takes participants to an urban area; or (2) a bus ride that takes participants to a nature scenic area (Mayer et al., 2009). After pre- and post-tests were conducted, measuring various personality and cognitive components, the results showed that participants who went on the scenic route had improved problem-solving skills, self-reflection, and overall mental health (Mayer et al., 2009). The study supports the above theories and further emphasizes the importance of accessing natural spaces (Mayer et al., 2009).

As previously mentioned, due to urbanization and other factors, access to natural environments remains limited for some people. So, researchers have begun exploring the potential of virtual reality (VR) as a tool for simulating nature exposure, providing therapeutic benefits without the need for physical access to nature (Browning et al., 2020).

Virtual Reality

VR is a digital space that allows users to immerse themselves in various environments, such as natural settings or fictional spaces (Frost et al., 2022). Specific places that exist in reality can be replicated and created in VR, or it can

be altered and customized in various ways (Frost et al., 2022). Users typically wear a VR headset that allows them to enter this space, fully immersing themselves into the digital world and inducing an effect that makes them feel like they're actually there (Frost et al., 2022). Using wireless head-mounted displays (HMDs), for example, are easy to use for beginner users of VR, and creates "emotionally evocative therapeutic experiences." (Habak et al., 2020, p. 2). Habak and colleagues (2020) used HMDs and created different virtual worlds such as beaches and forests to investigate VR's impact on positive mood and wellbeing. The researchers found that participants' positive moods increased after engaging in the virtual worlds and emphasized the potential of VR in the field of psychology (Habak et al., 2020).

Virtual reality is flexible and customizable—VR spaces can be designed to tailor individuals' needs and preferences (Botella et al., 2017). Since individuals can only access the space via the VR headsets, users "will always be safe and protected in these synthetic worlds," and can remove the headset when they wish to leave the digital space (Botella et al., 2017, p. 1). In psychology, VR has been used as a new way to offer exposure therapy for those with phobias or posttraumatic stress disorders (PTSD) (Botella et al., 2017). VR exposure therapy provides a controlled setting for the individual, and they are able to attend the virtual space in the comfort of their own home, in a private space with a psychologist, and so on (Botella et al., 2017). Psychologists have also taken advance of the ability to 'gamify' a space, which means adding features that are seen in video games to VR, increasing engagement and commitment (Botella et

al., 2017). For example, using a reward system in a VR world can help someone continue their progress and continue participating in their treatment plan (Botella et al., 2017).

One concern that has been raised is the issue of *cybersickness,* which refers to different symptoms that may result from excessive VR usage such as headaches and/or nausea (Botella et al., 2017). However, Woo and colleagues (2023) conducted a study focusing on cybersickness and found that there were no long-term dangers. There was some discomfort experienced by a few participants, but the recovery time "was at least 11.5 [minutes long]." (Woo et al., 2023, p. 7). Although it seems that long-term effects are less likely to occur, it is important that researchers continue to focus on the topic in case new observations arise.

With the rapid development of VR and its effectiveness as VR exposure therapy, there has been an interest in incorporating nature therapy with VR. For people who may not be able to access or participate in nature therapy, they may be able to do so in VR (Botella et al., Habak et al., 2020).

Virtual Reality Nature Therapy

Virtual reality can integrate nature therapeutic approaches to help reduce stress and enhance positive mood for a variety of individuals (Frost et al., 2020). Some people have less opportunities to spend time in nature or partake in nature therapy in the real-world—this may be due to urbanization, mobility issues, phobias, and so on. (Litleskare et al., 2020). VR can produce high levels of presence and engagement, so many researchers investigate the effectiveness of

nature therapy in VR and if real-world nature therapeutic outcomes can be replicated in the digital world (Browning et al., 2020).

Browning and colleagues (2020) conducted a study to observe the effects of VR nature therapy. Participants were randomly assigned to either an outdoor forest condition, which was a 360-degree video; or an indoor space condition (with no nature-related visuals) (Browning et al., 2020). The results showed that VR nature therapy is an accessible option and has potential to be further explored (Browning et al., 2020).

Birenboim and colleagues (2019) also conducted a study to look at the effectiveness of VR nature therapy. Participants were asked to engage in VR cycling sessions—biking in different virtual settings (e.g., mountain bike trail) (Birenboim et al., 2019). Many participants preferred the bike path with the most greenery and showed an increase in positive mood and enjoyment (Birenboim et al., 2019).

A study conducted by Chan and colleagues in 2023 showed that VR nature therapy can benefit both senior citizens and young adults. Some seniors may not be able to go on outdoor walks due to mobility issues, so VR is an effective alternative and showed a decrease in stress levels (Chan et al., 2023). De Jesus and colleagues (2023) found that VR nature therapy also helps participants with PTSD. It can improve cognitive functioning and processes, such as attention, as well as decrease symptoms and characteristics associated with PTSD (De Jesus et al., 2023).

A literature review conducted by Frost et al. (2022) found 21 studies that further support these findings that VR nature environments can enhance psychological well-being. As ART suggests, increased attention in a virtual natural space can help restore different cognitive processes and significantly reduce stress and improve stress management (Frost et al., 2022). It is important to note that the literature review conducted observed short-term results, and it is important that other variables are explored to see how the effects of VR can be further optimized to cause a greater reduction in stress as well as create a longer-term result(s) (Frost et al., 2022).

Based on previous research, for this study, nature therapy in VR will be operationally defined as the exposure to a mountain nature trail scene in a three-dimensional VR environment.

Enhancing the Effects of Virtual Reality

Spatial Presence and Visual Enrichment

According to Litleskare and colleagues (2020), *immersion* describes the technical components of virtual reality, "such as the frame rate, field of view and resolution." (p. 3). Immersion plays a major role in VR and influences one's engagement, interest, and dedication when they are in a space or world (Litleskare et al., 2020). Being immersed and engaged in the space may influence how *present* an individual is when they are in a VR space (Litleskare et al., 2020). Presence can be defined as the psychological sense of *being there*—someone feels they are in that space almost as if its reality (Litleskare et al., 2020). It is the

"subjective feeling… of being transported from the physical location to the virtual one." (Litleskare et al., 2020, p. 4). The higher the level of presence an individual experiences, the more likely they are to experience the desired effects and features of a VR world (Litleskare et al., 2020). For example, if someone is in a VR beach setting, where they are walking along the beach; they may hear the ocean and the wind in the background. The quality of the virtual space may be in high resolution, so it is more realistic, and thus the individual feels more present.

In order to measure presence, the *Spatial Presence Experience Scale* (S.P.E.S) has been commonly used (Hartmann et al., 2016). S.P.E.S consists of 8 Likert-scale questions, measuring one's "conscious experience or feeling" in an immersive VR experience (Hartmann et al., 2016, pp. 2-3). For the present study, presence will be operationally defined as the subjective level of presence measured by the S.P.E.S.—where higher scores indicate greater levels of presence at a specific moment in time.

A study conducted by Pavic and colleagues (2023) found that high levels of immersion were associated with increased positive emotions, increased immersion and presence increases desired effects (Pavic et al., 2023). Ball's (2023) study also investigated spatial presence and found that nature tourism can be incorporated in VR in order to protect the environment and to provide nature tourism in a sustainable way for others. Ball (2023)'s study included two conditions—a VR travel condition and a television condition, in which participants either watched a televised video about nature tourism, or participants

engaged in a VR nature tour. Ball (2023) found a mediating role of spatial presence and suggested further studies on the potential increase in presence depending on how detailed the VR world is, and how it can become more realistic for the user.

Audio sounds, such as wind; animals, or navigational signs are visual enrichment components that can optimize presence and create more significant results (Anderson et al., 2017). Adding signs, such as the name of a body of water in the VR world, creates a deeper sense of realism for the user (Anderson et al., 2017). Environmental enrichment (*EE*) will be operationally defined as the inclusion of visual trail signs within VR nature walk scenes, for this study. The signs display navigational information and names related to the VR environment. By adding visual enrichment and other components, such as mindfulness, researchers can fully optimize the effects of VR nature therapy and discover new findings (Anderson et al., 2017).

Mindfulness

Mindfulness stems from Buddhist psychology, emphasizing an intentional state of awareness and reflection through a holistic framework (Baer, 2003). The concept has since been Westernized and is commonly defined as “the awareness that arises through paying attention, on purpose, int eh present moment, non-judgmentally.” (Kabat-Zinn, 2019 as cited in Giraldi, 2019, p. 14). The concept has been incorporated in therapeutic approaches, such as nature therapy, to help individuals accept their current thoughts, feelings, sensations, without the need to

evaluate or critique them (Baer, 2003). For example, Mindfulness-based Cognitive Therapy focuses on detaching thoughts and preventing relapse of depressive episodes, unhealthy urges, and with a focus on emotional and behavioural regulation (Baer, 2003). Mindfulness provides psychological benefits such as stress reduction and self-management, as well as biophysiological benefits (Baer, 2003). For instance, mindfulness improves quality of sleep, and it's associated with brain thickness—enhancing sensory processes such as attention and decision-making (Baer, 2003; Keng et al., 2011).

As the concept of mindfulness originates from Buddhist psychology and traditions, it is important to recognize that the concept has been slightly Westernized and through the field of psychology, it emphasizes psychological health and incorporates therapeutic methods (Keng et al., 2011).

According to Brown et al. (2007), there are two categories of mindfulness: *trait mindfulness and state mindfulness.* Trait mindfulness refers to an individual's ability to be mindful—it is a trait they can strengthen through mindfulness exercises (Brown et al., 2007). Whereas state mindfulness, refers to the condition or act of being present, reducing one's stress levels and improving overall mood (Brown et al., 2007). State mindfulness can be developed and strengthen through frequent use of mindfulness tasks (Brown et al., 2007). Slota and colleagues (2024) investigated the effects of mindfulness practices on university students and found a significant decrease in stress and an increase in self-compassion. The students participated in a 12-week mindfulness intervention in which they learned

various mindfulness practices (Slota et al., 2024). This intervention allows students to learn about mindfulness and then integrate the practices they prefer into their day-to-day routine.

Mindfulness in Virtual Reality

Since mindfulness enhances sensory awareness, it can be integrated with visual enrichment in VR and create a more immersive experience for users (Arpaia et al., 2022; Brown et al., 2007). Mistry and colleagues (2020) investigated the effectiveness of mindfulness meditation in VR for stress reduction among undergraduate students. Participants' stress levels and positive affect were measured before experiencing a VR meditation and a non-VR meditation (Mistry et al., 2020). The students' stress levels and positive moods were measured again after the conditions (Mistry et al., 2020). Mistry and colleagues (2020) found that the VR meditation induced a positive 'awe' effect among all participants and increased their mood and feelings of life satisfaction. Modrego-Alacron et al. (2021) conducted a similar study with university students and found that a mindfulness-based program significantly reduced stress and increased engagement and interest among the participants compared to their controlled relaxation program. These studies illustrate the effectiveness of mindfulness meditation in VR and how that can be accessible and engaging for post-secondary students (Modrego-Alacron et al., 2021; Mistry et al., 2020).

For the context of this study, mindfulness will be operationally defined as a *mindfulness meditation (MM) audio* aimed at helping individuals maintain

moment-to-moment awareness of their thoughts, feelings, and surroundings while engaged in a VR experience (Shapiro et al., 2008). Incorporating mindfulness in VR allows participants to embrace the state of awareness and presence while reducing stress (Keng et al., 2011).

Present Study

The current study aimed to investigate the effectiveness of virtual reality [VR] nature therapy on reducing participants' stress levels. Specifically, we aimed to assess whether the inclusion or exclusion of mindfulness meditation and visual enrichment will create a more immersive, stress-reducing experience in VR. The study will address the following research questions:

1. Overall, will VR nature exposure with a mindfulness meditation and enriched environment reduce stress levels?
2. Do the conditions with the guided mindfulness meditation have a greater reduction in stress than the conditions that don't have a guided mindfulness meditation?
3. Do the conditions with an enriched environment have a greater reduction in stress than the conditions that don't have an enriched environment?

We hypothesized that VR nature exposure paired with a mindfulness meditation would reduce stress levels overall, with conditions including a guided meditation having greater stress reduction than those without it. Similarly,

conditions with an enriched environment were expected to show a greater reduction in stress than those without enrichment.

By combining a virtual nature walk with a guided mindfulness meditation and environmental enrichment, we aimed to create a more immersive experience for individuals and significantly reduce stress levels. Optimizing VR nature therapy could provide a more accessible and affordable alternative for individuals who might benefit from in-home use (Frost et al., 2022). It may also be more affordable in terms of its reusability and the ability to access natural environments virtually rather than through travel (Frost et al., 2022).

Method

Participants

The Mount Royal University (MRU) Ethics Board approved this research on December 4, 2024, as shown in the HREB Ethics Approval Letter (see Appendix B). Participants were MRU students enrolled in an introductory psychology course (PSYC 1103, 1104, 1005) and were recruited through MRU's SONA system (see Appendix C). Participants received 0.5% course credit toward their final grade for their participation.

To participate, individuals needed to have normal or corrected-to-normal vision (e.g., glasses or contact lenses). The study was conducted at the Centre for Psychological Innovation (CPI) in EA 2020 at Mount Royal University.

A total of 15 adults were recruited, and 12 participants' data was included in the analysis. Three participants' data were removed—one was removed as they did not complete the VR nature trail, another due to technical issues during their session, and one removed to ensure an even number of participants among all four conditions.

Materials

Apparatus

Participants were tested in a private room equipped with a Meta Quest 3 VR HMD VR headset (2064 x 2208 pixels per eye, 110° field of view, 90 Hz refresh rate) with standard hand controllers as well (see Appendix D). A Meta Quest 2 VR HMD (1832 x 1920 pixels per eye, 96° field of view, 90 Hz refresh rate) with its paired controllers was also in the lab as an alternative option. While there are slight differences in the visual field of the Meta Quest 2 and 3, it was not expected to affect the experience for the participants.

There was also a computer in the room (see Appendix E for images) with secure access to a Google datasheet, which recorded data and managed program stimuli.

Stimuli

The present study utilized *Spatial* (2025), an online gaming platform designed for creating, exploring, and interacting within digital virtual worlds. Spatial allows users to develop and publish games while engaging with others'

games and designs. It is powdered by Unity, a game engine used to create VR environments.

Five virtual environments were developed using Unity and then uploaded onto Spatial. One environment included a condensed version of the nature trail with multiple portals, called the "Participant Lobby World" (see Appendix F). The four environments featured the same nature trail (see Appendix G) but varied in two elements: the mindfulness meditation audio and enriched environmental components. Specifically, one condition included both elements, one only had the mindfulness meditation, one only had the enriched environments, and one had neither.

Measures

State Anxiety Inventory (S.A.I)

The Spielberger State-Trait Anxiety Inventory (S.T.A.I) is a common tool used to measure stress among individuals (Barnes et al., 2002). It has demonstrated stable internal consistency across studies, with the state anxiety subscale exhibiting high variability as it measures current anxiety levels (Barnes et al., 2002).

The inventory describes stress as the "frequency and intensity with which anxiety manifests itself over time." (Barnes et al., 2002, p. 604). It assesses experiences related to worry, nervousness, and tension while differentiating between long-term and short-term stress (Spielberger, 1983).

The current study used 20 Likert Scale items from the state anxiety subscale (S.A.I) to assess participants' stress levels before and after the VR experience (e.g., "I feel calm;" "I feel nervous;" "I feel self-confident."). Participants rated each statement on a four-point scale: *not at all; somewhat; moderately so; very much so.*

Spatial Presence Experience Scale (S.P.E.S)

The Spatial Presence Experience Scale (S.P.E.S) was used to measure participants' sense of presence—the subjective experience of "being there" in the virtual environment (Hartmann et al., 2016). It evaluates how immersed participants feel and their perceived ability to interact in the space (Hartmann et al., 2016).

The scale demonstrated high validity and correlates positively with engagement in virtual environments (Hartmann et al., 2016). It consists of eight Likert scale items, such as "I felt like I was actually there in the environment of the presentation;" I felt as though I was physically present in the environment of the presentation."

Participants completed this measure after their VR experience.

VR Experience

One question was asked to assess participants' previous experience and familiarity with VR. The following question was asked in the post-test phase: "How regularly do you use VR?" Participants answered using a five-point Likert

scale ranging from 1 = “This is my first time” to 5 = “I use VR every day.” (see Appendix H).

Demographics

The only demographic data collected was participants’ gender identity, which was provided through a “fill-in-the-blank.” This question, like all others in the study, was optional (see Appendix H).

Procedure

There were two independent variables, each with two levels. The first independent variable was a mindfulness meditation (*MM*). The condition had two levels, one in which participants listened to a guided mindfulness meditation audio recording as they followed the nature path, and one in which participants did not have the guided meditation audio. The mindfulness meditation was written and recorded by Jane Fix, a registered psychologist and expert in mindfulness interventions in Alberta. The mindfulness audio encouraged participants to focus on the sensory experience they were having in the moment. The second independent variable was the enriched environment (*EE*). This variable also has two levels, one where participants were exposed to the *EE*, and the other in which participants weren’t exposed to the *EE*. In the enriched environment, participants saw a series of six signs along the path, providing information about the environment and walking trail (see Appendix I). The variable was intended to encourage participants to focus on specific aspects of the environment, such as lakes and mountains. As a result of these independent variables, the study had

four independent groups or conditions: (1) No Mindfulness Meditation & No Enriched Environment; (2) No Mindfulness Meditation & Enriched Environment; (3) Mindfulness Meditation & No Enriched Environment; (4) Mindfulness Meditation & Enriched Environment.

Each participant was randomly assigned to one of the conditions and completed the VR nature walk.

Upon arrival at EA2020, participants were welcomed into the lab. Each participant was scheduled for a 30-minute session. They were given time alone to read and complete the consent from (see Appendix J) and were encouraged to ask any questions. After completing the consent form, the participant was directed to a secure Google Form and were left alone to complete a pre-test questionnaire consisting of 20 Likert scale questions from the S.A.I.

After completing the pre-test, the researcher demonstrated how to put on and use the VR headset and navigate within the virtual world. Participants were instructed on how to move forward using the left joystick on the hand controller. To navigate and turn their avatar, they were taught to rotate their body and head in the desired direction by using their feet to turn the 360° swivel chair. This movement allowed them to physically rotate their body while keeping the head aligned with the avatar's direction, minimizing the risk of nausea. The participant was then seated in the swivel chair at the center of the room and was instructed to put on the VR headset, with assistance available if needed. They were reminded that they could remove the headset and discontinue participation at any time if

they experience nausea or discomfort, and they would still receive their SONA credit.

Once the headset was adjusted for comfort, participants found themselves in the VR environment called the "Participant Lobby World," a nature scene where they could practice movement controls. The researcher, using the desktop computer, also entered the virtual world and monitored the participant's movements. The researcher then guided the participant toward an area with four numbered portals (1-4), instructing them to enter one. Each portal corresponded to one of the four experimental conditions. As the participant entered the assigned portal, the researched left the room to allow them to complete the experience alone.

Inside the assigned condition, the participant followed a path in the virtual world. The experience lasted 10-12 minutes, in which they then encountered a sign indicating the end of the walk (see Appendix K). The sign also instructed the participant to remove the headset when ready. The researcher then knocked, re-entered the room, and asked the participant to return to the seat in front of the computer to complete a post-test questionnaire via a new Google Form. The post-test questionnaire included the same 20 Likert S.A.I questions from the pre-test, 8 Likert scale items from the S.P.E.S to assess presence in the VR environment, 1 Likert scale question on VR experience level, and 1 fill-in-the-blank question for gender identity.

After completing the questionnaire, the participant was debriefed (see Appendix L) and given an opportunity to ask questions about the research. The participant was able to take a copy of the consent and/or debriefing form by scanning a QR code for a digital copy or by taking a physical printed copy. Finally, the researcher walked the participant out of the lab and thanked them for their time and participation.

Results

Stress Reduction

A three-way repeated measures mixed analysis of variance (ANOVA) was conducted to examine the effect of the VR nature experience on stress levels. The results showed a statistically significant difference in stress levels from the within-subjects pre-test to the post-test, $F(1,8) = 11.90$, $p = .010$, suggesting that stress significantly decreased over time following the VR nature trail (*NT*) (see Figure 1).

This reduction occurred regardless of the condition, meaning that whether participants received the mindfulness meditation, the enriched environment (trail signs), both, or neither, their stress levels still decreased over time. The within-subjects interactions between stress and enriched environment (*EE*) and between stress and mindfulness meditation (*MM*) were both non-significant, $F(1,8) = 1.28$, $p = .291$. The three-way interaction of stress x *EE* x *MM* was also non-significant, $F(1,8) = 2.45$, $p = .156$. This indicates that the inclusion of mindfulness meditation and/or the enriched environment did not significantly impact stress reduction.

Analysis of the between-subjects effects showed that neither the enriched environment alone ($F(1,8) = 0.981$, $p = .373$) nor the mindfulness meditation alone ($F(1,8) = 2.44$, $p = .157$) significantly affected stress levels. However, there was a significant interaction effect for participants who experienced both mindfulness meditation and the enriched environment, $F(1,8) = 5.27$, $p = .047$. This suggests that the combination of the elements had a meaningful influence on stress reduction. Means and standard deviations for each condition's pre- and post-test S.T.A.I scores are presented in Table 1.

Figure 1

Stress Levels Across All Conditions

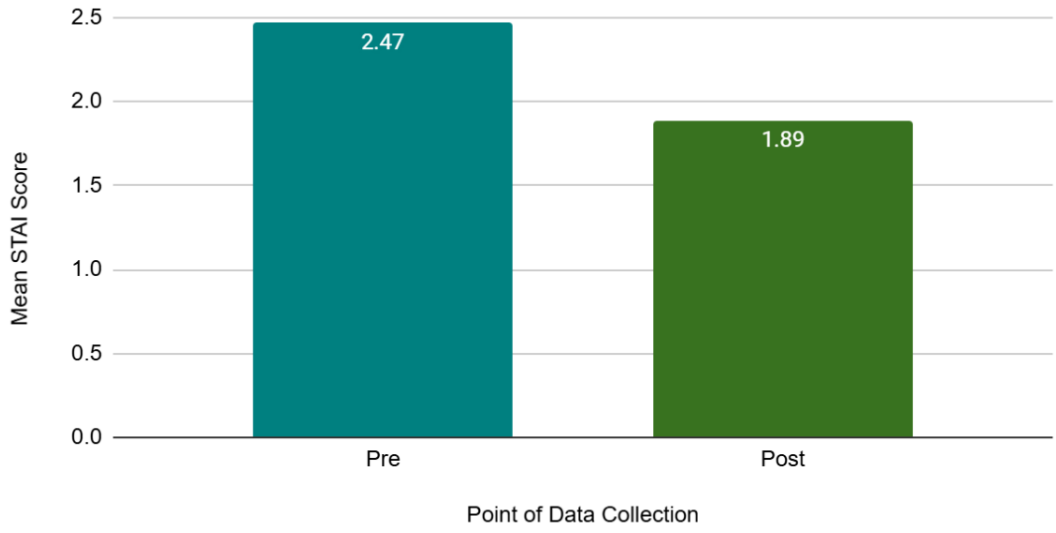


Table 1

Descriptive Statistics for Stress Before and After NT

Condition	Pre-Test			Post-Test			Mean Difference
	N	*M*	*SD*	*N*	*M*	*SD*	*(post)-(pre)*
Control	3	56.3	8.5	3	39.3	8.3	-17.0
EE	3	31.0	18.2	3	32.7	11.2	1.7
MM	3	51.0	2.6	3	37.0	9.6	-14.0
EE-MM	3	59.3	12.5	3	42.3	0.6	-17.0

Presence Levels

A 2 x 2 mixed ANOVA was conducted to examine the effects of the enriched environment (EE) and mindfulness meditation (MM) on perceived presence. The analysis revealed no significant main effects for *EE*, $F(1,8) = 1.01$, $p = .345$, or *MM*, $F(1,8) = 0.11$, $p = .753$. However, a significant interaction effect was found between the *EE* and *MM* conditions on S.P.E.S scores, $F(1,8) = 5.90$, $p = .041$, suggesting that the combination of the two variables influenced participants' sense of presence in the VR environment (see Figure 2). The means and standard deviations for each condition's S.P.E.S scores are presented in Table 2.

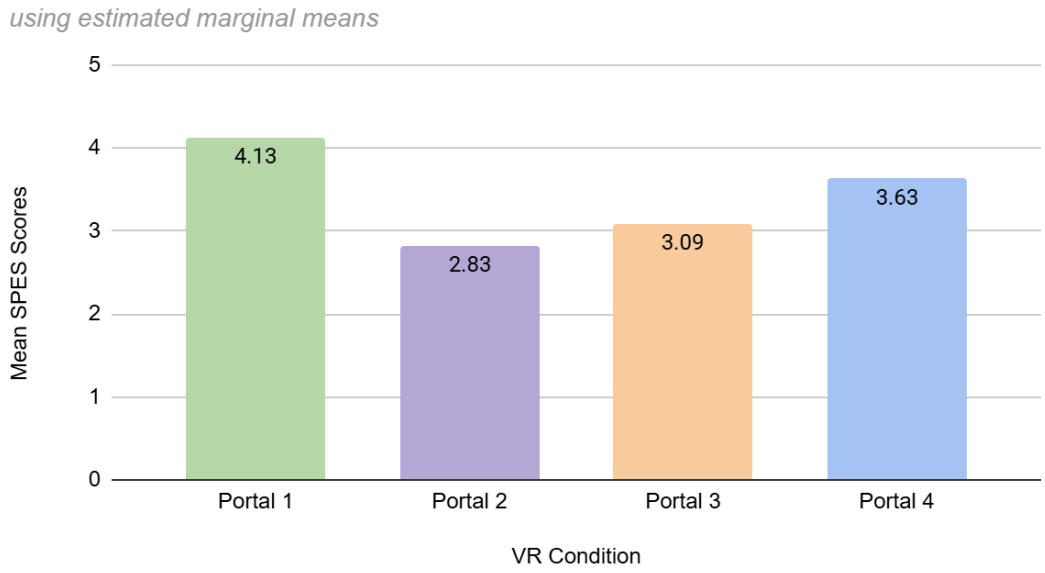
Table 2

Descriptive Statistics for Presence

Condition	*N*	*M*	*SD*
Control	3	33.0	3.61
EE	3	22.7	2.08
MM	3	25.7	10.60
EE-MM	3	29.0	3.00

Figure 2

EE x MM Presence Levels



VR Experience Levels

A one-way ANOVA was conducted to examine whether participants' prior VR experience influenced their sense of presence (S.P.E.S) during the VR nature experience. The results indicated that there was no significant effect of VR experience on presence scores, $F(1, 10) = 0.004$, $p = .949$. This suggests that prior experience with VR did not impact participants' reported presence levels (see Table 3).

Estimated marginal means revealed that participants without prior VR experience (M = 3.40, SE = 0.36, 95% CI [2.60, 4.20]) and those with experience (M = 3.43, SE = 0.30, 95% CI [2.76, 4.10]) reported similar levels of presence during the VR experience. This similarity in group means, as well as the overlap in their confidence intervals, further supports the lack of a significant difference—suggesting that regardless of prior exposure to VR, participants experienced a comparable sense of presence in the virtual nature trail.

Table 3

VR Familiarity Comparison with STAI and SPES Scores

VR Familiarity	STAI Scores			SPES Scores		
	N	*M*	*SD*	*N*	*M*	*SD*
1	5	-12.8	10.8	5	27.9	8.3
2	7	-10.7	15.2	7	22.7	3.3

Note. VR Familiarity is rated 1-5, no participant selected above a level 2.

Discussion

Stress Reduction & Presence

The present study investigated the impact of a VR nature experience on stress reduction and presence, specifically examining the effects of mindfulness meditation and an enriched environment. Results indicated a significant overall reduction in stress from pre- to post-test, suggesting that VR nature exposure is effective in promoting relaxation over time. This finding aligns with previous research supporting the use of virtual natural environments as a tool for stress relief (e.g., Frost et al., 2020). These results suggest that simply immersing oneself in a virtual nature setting may be sufficient to reduce stress, regardless of additional features.

Contrary to our hypotheses, there were no significant main effects for either mindfulness or environmental enrichment individually. This may suggest that these features do not offer substantial benefits beyond the baseline effects of VR nature exposure. However, possible explanations for this outcome—such as sample size—are discussed later in this paper (see *Limitations* section).

Importantly, a significant interaction effect was found, indicating that the combination of mindfulness and enrichment enhances the stress-relieving benefits of the VR experience. Prior research suggests that mindfulness increases attentional focus and emotional regulation (Baer, 2003), while enriched environmental components can enhance perceive realism and presence (Litleskare et al., 2020). This is consistent with our study's findings, as the interaction effect

also extended to presence—the combined condition fostered a more immersive and engaging virtual experience. While presence was not a primary focus of our hypotheses, it is an important factor to consider, as greater presence is associated with increased user engagement and a greater likelihood of experiencing the intended therapeutic effects, such as stress reduction (Litleskare et al., 2020).

VR Experience

The current study found that participants with minimal or no prior VR experience reported similar levels of presence in the virtual environment as those with more experience. This may be due to the intuitive and accessible nature of the VR nature trail used in this study, suggesting that previous exposure to VR was not necessary to experience a strong sense of immersion. These findings align with previous research (e.g., Anderson et al., 2017; Litleskare et al., 2020), suggesting that presence in VR is often more strongly influenced by the quality and design of the simulation—such as ease of navigation and visual appeal—than by the user's previous (or lack thereof) VR experience.

It is also possible that participants' general curiosity contributed to their comfort and engagement, allowing even those unfamiliar with VR to enjoy the experience and develop a similar sense of presence. That being said, future research should consider assessing participants across a broader range of VR experience (e.g., frequency and type of us) to better determine if and how prior experience may shape perceived presence in VR-based interventions.

Future Implications

Incorporating mindfulness meditation and environmental enrichment within VR nature therapy highlights the potential of combining immersive elements to enhance therapeutic outcomes. Although these features did not individually lead to a significant reduction in stress, the combination of the two suggests a promising direction for future VR design aimed at promoting psychological well-being. Future research should continue to explore how these components interact and examine their influence on other outcomes such as emotional regulation, relaxation, and contentment.

There is also notable potential for applying VR nature therapy in real-world contexts, such as clinical settings, schools, workplaces, and wellness programs. VR environments that integrate nature, mindfulness, and enrichment could become powerful tools for stress management and overall well-being.

Importantly, VR offers unique advantages in terms of accessibility. Since the experience can be delivered from a seated position, it may be especially beneficial for individuals with limited mobility or those facing barriers to accessing outdoor environments due to geographic location, physical disability, weather conditions, or other factors. Expanding research in this area could help extend the benefits of nature-based therapy to populations who may otherwise be excluded from such experiences.

Limitations

Samples

It is important to recognize that the smaller sample size and low statistical power influenced the results of the analysis. The current study aimed to recruit a total of 30 participants per condition, for a total of 120 participants; achieving this goal would have increased the study's statistical power. Additionally, pilot data collected from one participant was not included in the analysis, which further reduced the total sample size. The sample may also not be representative of the broader population due to demographic homogeneity—according to the post-test, the majority of participants identified as female. The recruitment process also heavily relied on convenience sampling, which impacts external validity. It is important that future research looking to contribute to VR-based mental health interventions, aim for a larger and more diverse sample to improve validity.

Self-reported Measure

The study relied on a subjective self-reported measurement (S.T.A.I) for the pre- and post-test. Future studies should incorporate a physiological measurement in addition to self-reported measure to increase reliability and validity. For instance, researchers can measure heart rate and/or blood pressure during the pre- and post-tests when observing stress levels.

Nausea & Technical Difficulties

There were a few technical difficulties and feelings of nausea or discomfort that affected some participants during the study. One participant was unexpectedly disconnected from the VR nature trail due to a network error, which interrupted their experience and rendered their data unusable. There were also a

few moments when a researcher experienced delays in setting up the virtual environment due to technical slowdowns, which resulted in some participants waiting a few minutes longer than others, thus entering the virtual world later. These delays could have impacted participants' stress levels as they would have had to wait a little longer before beginning their experience. Technical issues with VR HMD can be common, which is why it's important that researchers use up-to-date technology, such as the Meta Quest 3, while also ensuring proper troubleshooting procedures to minimize disruptions.

Two participants reported feeling nauseous or slightly uncomfortable during the experience and were unable to complete the full virtual session. However, both participants were eager to continue and completed the post-test questionnaire, suggesting that their discomfort was temporary and did not interfere with their ability to finish the study or remain in the lab. To note, one of these participants was a designated pilot, and their data was already intended to be excluded from the final analysis.

As previously mentioned in the procedure, the study incorporated a comfortable swivel chair to reduce the likelihood of nausea associated with the VR headset. Additionally, the nature trail was designed to be simple and non-threatening, minimizing the risk of triggering fear of heights or other common discomforts.

Conclusion

This study demonstrated that VR nature therapy can effectively reduce stress, particularly when mindfulness meditation and environmental enrichment are combined. These findings emphasize the value of incorporating multiple immersive elements to enhance virtual experiences and points to promising directions for future therapeutic applications. As VR technology continues to evolve, its potential to support mental well-being in accessible and inclusive ways becomes increasingly relevant.

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Appendix A

TPCS 2 Certificate

Appendix B

HREB Ethics Approval Letter

MOUNT ROYAL UNIVERSITY
1910

Human Research Ethics Board
t: 403.440.8470 | f: 403.440.6299
e: hreb@mtroyal.ca
research.mtroyal.ca

December 4, 2024

Tony Chaston, Signa Lauf
& Emma Radford
Psychology
Mount Royal University

Dear Dr. Chaston, Ms. Lauf and Ms. Radford:

Re: Application Number #104227
Virtual Reality Nature Exposure: Exploring the Effects of Mindfulness Meditation and Trail Enrichment on Stress and Presence

The above-noted honours thesis project was reviewed by the Human Research Ethics Board (HREB) and was found to be ethically acceptable on ***December 2, 2024.*** I am pleased to advise you that ethical clearance for this proposal has been granted *to* ***December 2, 2025.*** You may request an extension if you wish to collect data beyond this date.

Please note that this clearance is contingent upon adherence to the limits of the project as outlined in your application, including the restriction of the student projects to minimal risk, and the appropriate education being provided to students regarding ethical conduct of research involving human participants. Prior permission must be obtained from the Board before implementing any substantive modification(s) to the submitted documentation.

Researchers are required to notify the Mount Royal University HREB immediately if any untoward or adverse event occurs during the student projects, or if data analysis or other review reveals undesirable outcomes for participants or the students. HREB and Mount Royal University adhere to the Tri-Council Policy Statement, "Ethical Conduct for Research Involving Humans".

You are required to submit a brief project completion report in **December 2025**. Completion report templates can be assessed through ROMEO.

Please accept the Board's best wishes for success with this project.

Yours sincerely,

Lynne Lafave, PhD
Chair, Human Research Ethics Board

Appendix C

SONA Recruitment Poster

Study Name	Virtual Reality Nature Exposure: Exploring the Effects on Mindfulness Meditation & Trail Enrichment
Study Type	 **Standard (lab) study** This is a standard lab study. To participate, sign up, and go to the specified location at the chosen time.
Percent	0.5 Percent
Duration	30 minutes
Abstract	Participants will participate in a VR hike.
Description	This research will take place in the Center for Psychological Innovation (CPI) Virtual Reality (VR) lab (EA2020). Participation is divided into 3 stages: 1) Pre-test: you will complete a 20-question questionnaire to assess your current stress level. 2) You will explore a nature hike in virtual reality. During the virtual reality nature hike some participants will be exposed to a mindfulness audio recording. 3) Post-test: you will complete a 20-question questionnaire to assess your current stress level and an 8-question questionnaire to assess your sense of presence during the VR nature hike
Eligibility Requirements	Participants must have normal or corrected-to-normal vision (e.g., glasses, contacts)

Appendix D

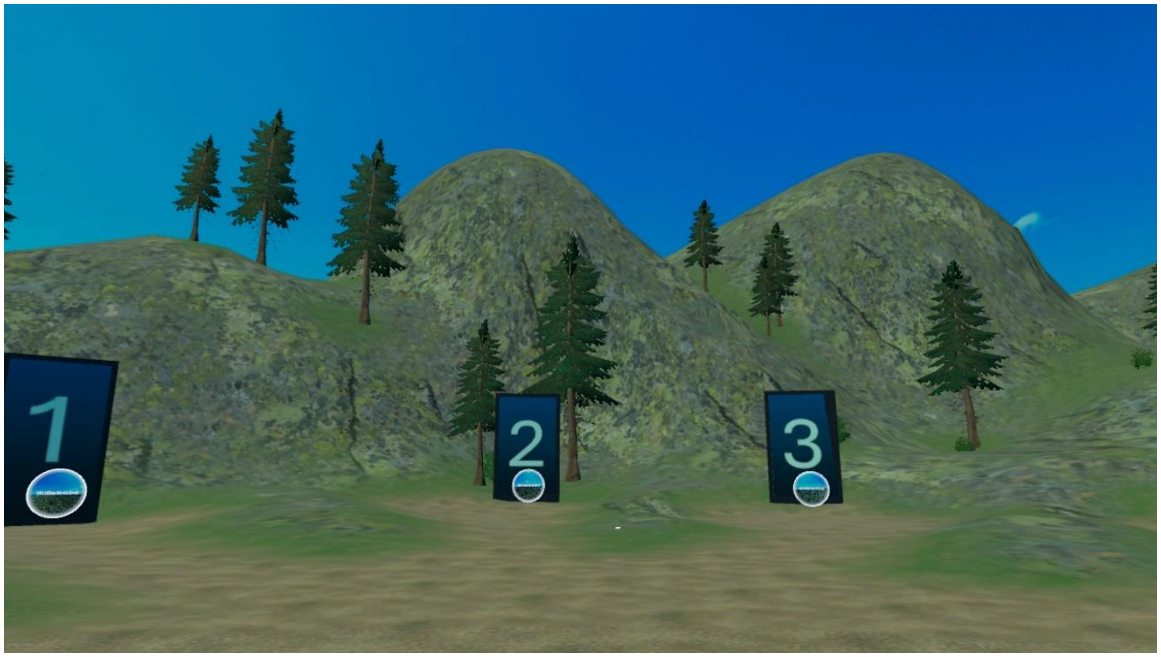
Head-Mounted Display and Controllers

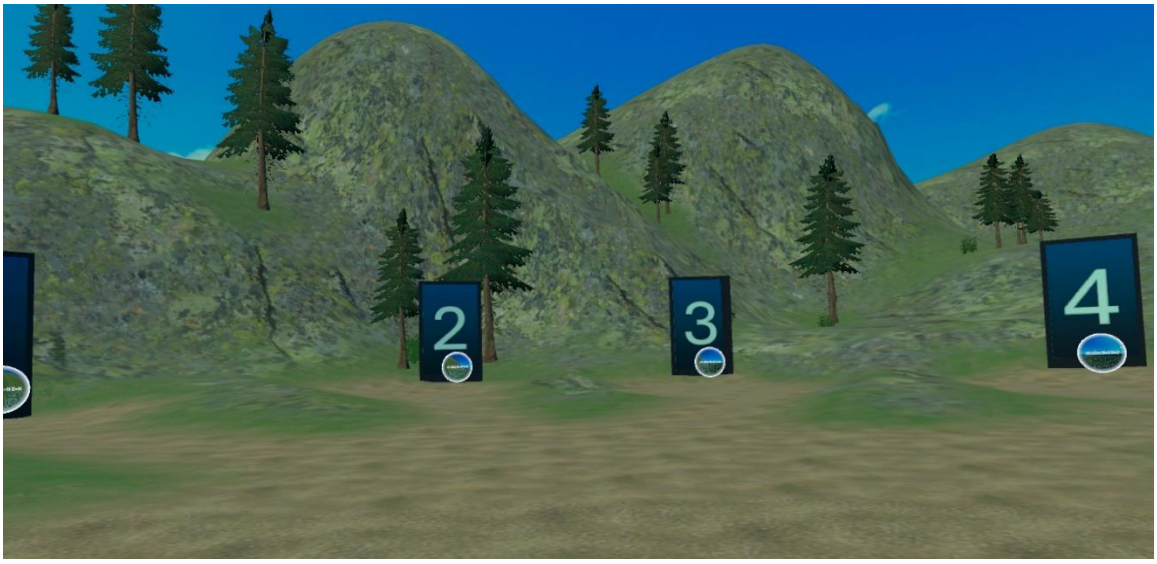
Appendix E

Pre-test & Post-test Lab Room

Appendix F

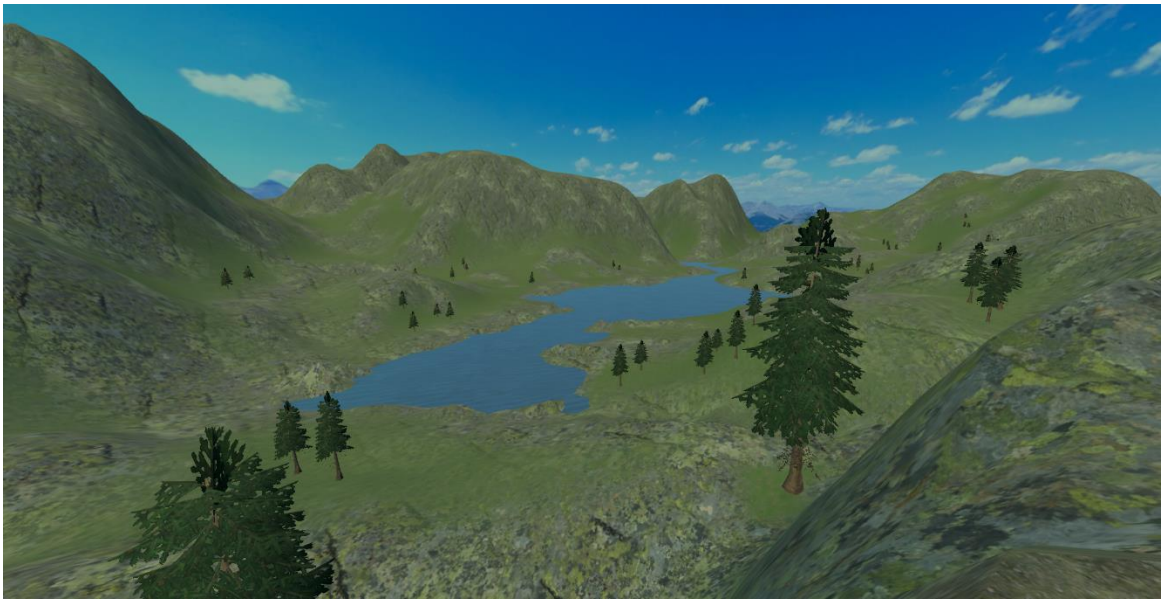
VR Participant Lobby World





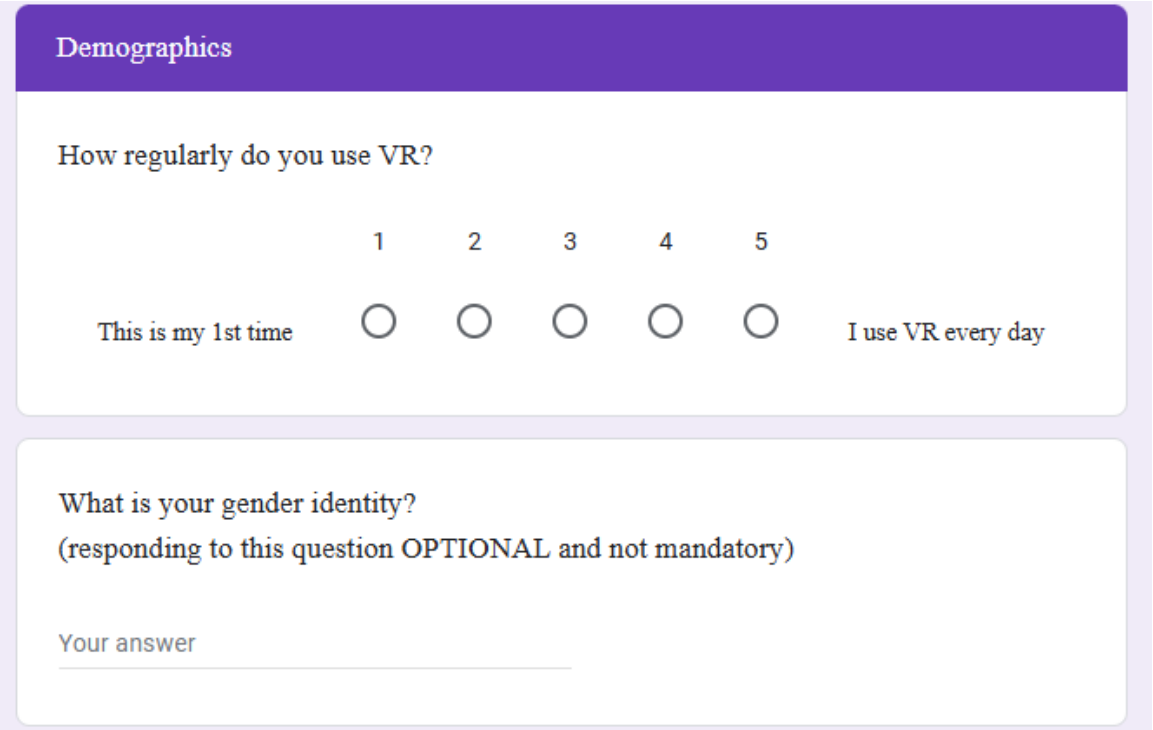
Appendix G

VR Nature World



Appendix H

Demographic Questions



Appendix I

Enriched Environment – Trail Sign Examples

Appendix J

Consent Form

Project Title: *Virtual Reality Nature Exposure: Exploring the Effects of Mindfulness Meditation and Trail Enrichment on Stress and Presence*

Investigators: Dr. Anthony Chaston, Emma Radford and Signa Lauf

Contact Information: achaston@mtroyal.ca

You are being invited to participate in a research project, as described in this consent form. Please note this consent form serves to provide an overview of what the research in question is about and what your participation would entail; it is only one part of the consent process. Read this consent form carefully. You should understand the accompanying information. If you have any questions, please ask for help. You will receive a copy of this form.

Summary of the Study: Participation in this experiment will take place in the Center for Psychological Innovation (CPI) Virtual Reality (VR) lab (EA2020). Participation is divided into 3 stages: 1) Pre-test: you will complete a 20-question questionnaire. 2) You will explore a nature hike in virtual reality 3) Post-test: you will complete a 20-question questionnaire and an 8-question questionnaire.

Participant's Involvement/ What would my involvement entail?

The first step in the study will be to discuss and obtain voluntary and informed consent. If you choose to take part in the experiment, you will provide written consent on this form. Next, you will respond to 20 rating scale questions on the lab desktop computer. Upon questionnaire completion, you will be set up with the VR equipment needed for the experiment (VR headset and controllers). You will then explore a simulated hike in a natural environment. Upon completion of the VR experience, you will remove the VR headset and give it to the experimenter along with the controllers. Now you are ready to complete the post-test questionnaires comprising of 28 rating scale questions. After data collection, you will receive further details about the research study, a debriefing form, and an opportunity to ask any questions. At this point, your participation in the study will conclude. The

whole procedure is expected to take approximately 25 minutes for you to complete.

Collection of Personal Information/ What sort of personal information would be collected and how?

No personally identifying information will be collected as part of the data. All data will be stored anonymously, represented by a numerical code. No personal details, such as names or dates, will be linked to your data.

As part of the study, we will ask for demographic information, including gender identity. This information will be used solely for research purposes and will not be associated with your personal identity in any way. All responses will be anonymized, and no identifying information will be linked to your demographic data.

Your information will be collected and stored using the researchers' Mount Royal University Google account. Google servers are located in California, USA. The information you submit may be subject to laws in force outside of Canada. As with any information transmitted via the internet, there is some risk that this signed consent form and the anonymized data may be intercepted by unauthorized parties and, therefore, privacy cannot be absolutely guaranteed.

Study Risks or Benefits for Participants/What are the risks or benefits involved in my participation?

The risks involved in this research study are minimal. There is a slight chance of experiencing short-term light-headedness or dizziness from the VR display, which will be mitigated by ensuring that participants remain seated during their VR experience. You are free to discontinue your participation or remove the VR headset at any time if you wish. You will be given full credit for your participation. You can take pride in contributing to a research study that holds the potential to benefit others in the future.

Voluntary Participation and Withdrawal of Consent:

You are under no obligation to participate in this research study. You are free to withdraw without penalty or prejudice to pre-existing entitlements. If you choose to withdraw during your participation in the experiment, any data collected up to that point will be deleted from the study and destroyed completely. If you choose to withdraw after the data collection process has been completed, your data cannot be removed as the data is collected

anonymously. You will not suffer any disadvantage or reprisal for withdrawing. The assigned researcher will ensure you are withdrawn as a participant from the study for reasons including but not limited to: re-consideration of research risks being greater than anticipated, to maintain the integrity of the data, and safety concerns. You will be given, in a timely manner throughout the course of the research process, information that is relevant to your decision to continue or withdraw from participation.

What will happen to the results of this research project?

The results of this research project will be presented at the MRU psychology research symposium. The results may also be published in a peer-reviewed journal or presented at an academic conference in the future. As part of the publication process, an anonymized copy of the data may be uploaded to a digital repository.

Compensation: you will be compensated 0.5 credit in SONA for your time and participation in this study.

Who should I contact if I have concerns regarding ethical issues related to this research project?

If you have any questions concerning your rights as a possible participant in this research, please contact the lead investigator Dr. Anthony Chaston achaston@mtroyal.ca or the Research Ethics Officer, at Mount Royal University, 403-440-8470, hreb@mtroyal.ca.

Signature (written consent):

By selecting "I consent and wish to proceed" below, and by providing your name and date, indicates that you:

• are voluntarily consenting to participate in this research project,

• understand to your satisfaction the information regarding your participation in the research project and your agreement to participate,

• have not yet commenced participation in the research project – your participation will only begin once you have provided your consent, and

• have been given adequate time and opportunity to:

- consider the information provided,

- pose any questions you may have, and

- discuss and consider whether you will participate.

If you have further questions concerning matters related to this research, please contact Dr. Anthony Chaston: achaston@mtroyal.ca

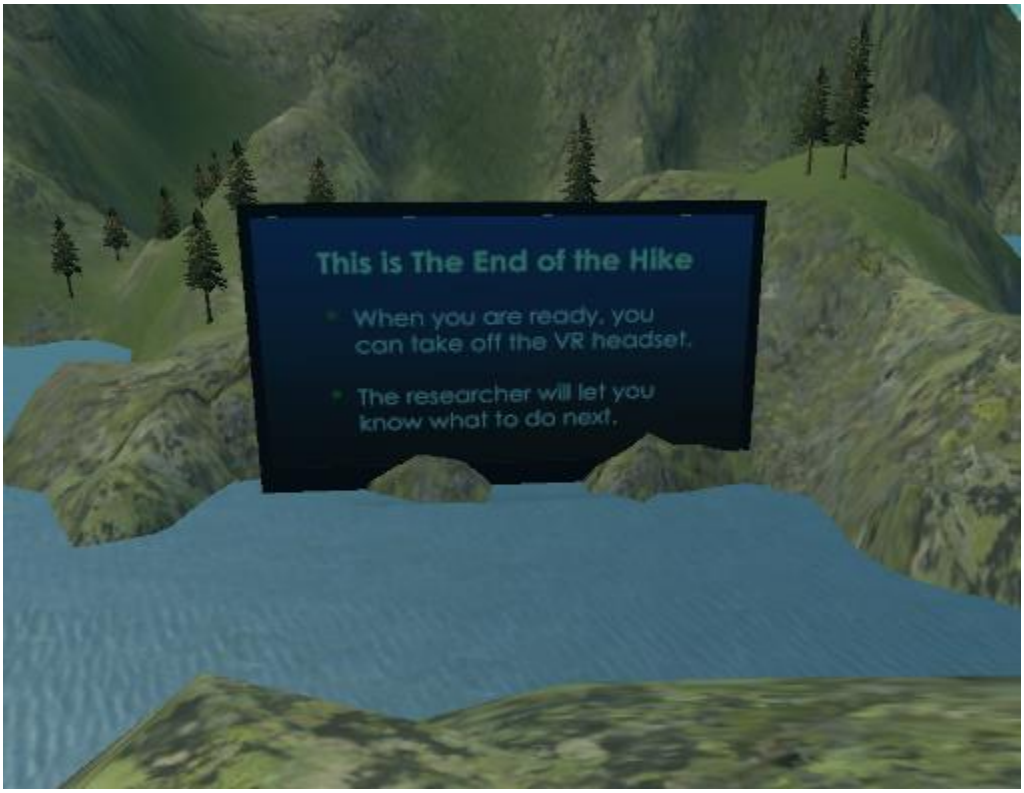
Do you consent to participant in *Virtual Reality Nature Exposure: Exploring the Effects of Mindfulness Meditation and Trail Enrichment on Stress and Presence*?

Participant's Name*

Date* (MM/DD/YYYY)

Appendix K

VR Completion Sign



Appendix L

Debrief Form

Thank you for participating in this research. The objective of this study is to examine the effects of virtual reality (VR) nature exposure on participants' stress levels. Previous research has indicated that exposure to nature promotes an individuals' health and well-being (Silva et al., 2018; Browning et al., 2020). We are trying to understand how to effectively recreate that effect in Virtual Reality. We are looking for any significant differences in participants' subjective feelings of stress before and after experiencing a virtual hike. The prediction is that stress levels will be lower after the VR nature exposure.

This research had two independent variables. 1) During the nature walk some participants were exposed to a mindfulness meditation while others only heard the ambient nature sounds. The prediction is that a mindfulness meditation will work in conjunction with the VR nature exposure to increase the reduction of stress. 2) During the nature walk some participants viewed signs that provided information about the names and natural features of the walk like lakes and mountains, while other participants did not have these signs during their VR nature walk. The prediction is that the signs will work to focus your attention on the VR environment and increase your sense of being "present" in the nature environment. This should work in conjunction with the VR nature exposure to increase the reduction of stress.

The goal of the different exposures is to enhance presence and reduce stress, ultimately helping participants achieve psychological well-being. Building upon the promising findings of previous research regarding nature's stress-reducing potential, our study seeks to further substantiate the effectiveness of VR as a tool for stress reduction, particularly for individuals with limited access to natural environments. Therefore, our research hypothesized that participants' subjective levels of stress would decrease after being exposed to the VR nature hike, regardless of which specific hike condition they experienced. Do you have any questions?

If you would like a copy of the **debriefing** form, please scan the QR code:

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