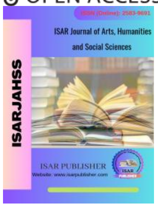


OPEN ACCESS

ISAR Journal of Arts, Humanities and Social Sciences

Volume 3, Issue 5, 2025 | pp: 157-171.

Abbriviate Title- ISAR J Arts Humanit Soc Sci

ISSN *(Online)*- 2583-9691

https://isarpublisher.com/journal/isarjahss

Simulating Chill: Exploring the Cognitive and Therapeutic Potential of Cold VR Environments

Jessica Turner[1*], **Piper Hutson**[2], **James Hutson**[3]

Lindenwood University, USA.

***Corresponding Author**
Jessica Turner

Lindenwood University, USA.

Article History
Received: 17.04.2025
Accepted: 14.05.2025
Published: 27.05.2025

Abstract: This study investigates the cognitive and therapeutic potential of immersive virtual reality (VR) environments designed to simulate cold conditions. Through the engagement of participants through multisensory stimuli—including vivid visual representations of the Athabasca Glacier, auditory effects of icy winds, and corresponding haptic feedback—the research evaluates neurological and physiological responses associated with attention, emotional regulation, and stress modulation. Participants experienced virtual scenarios featuring icy winds and snow, activating specific neurological pathways involving the occipital lobe, primary visual cortex, superior colliculus, and insula, thus reinforcing sensory integration. Through predictive coding, the anterior insula and hypothalamus were engaged, prompting thermoregulatory simulations and subconscious adaptive behaviors, such as arm-crossing. Emotional processing mediated by the amygdala and prefrontal cortex, combined with neurotransmitter releases (serotonin and dopamine), facilitated enhanced relaxation and mindfulness. Utilizing pre- and post-experience surveys, the study assessed participant-reported changes in attention, stress, and emotional regulation following exposure to simulated cold stimuli. Preliminary findings suggest significant benefits for attentional focus, stress reduction, and emotional regulation, highlighting the potential efficacy in therapeutic applications and workplace productivity optimization. This research underscores the broader implications of environmental simulation through VR, inviting further exploration into its neuroscientific mechanisms and practical applications for enhanced cognitive and emotional well-being.

Keywords: *Virtual reality, Cold simulation, Cognitive performance, Emotional regulation, Neuroplasticity, Stress modulation, Therapeutic VR environments*.

Cite this article:

Turner, J., Piper Hutson, P., Hutson, J., (2025). Simulating Chill: Exploring the Cognitive and Therapeutic Potential of Cold VR Environments. *ISAR Journal of Arts, Humanities and Social Sciences*, *3*(5), 157-171.

Introduction

The immersive experiences of virtual reality (VR)as a medium can simulate real-world experiences, provide gamification scenarios, and has allowed those in industry to collaborate remotely from different sides of the globe. Originally developed for military and healthcare training, VR has since expanded into mainstream gaming and become a powerful instrument in psychological and medical research, particularly in studies examining cognition, emotion, and behavior (Riva, 2022). Through engaging multiple sensory modalities—visual, auditory, and haptic—these virtual simulations enable the brain to process artificial environments as though they were real, creating highly immersive experiences that can be used for therapeutic and experimental applications. One of the most promising applications of this ability is in mental health treatment, where it has been integrated into exposure therapy, pain management, and cognitive rehabilitation (Diotaiuti et al., 2023; Goudman et al., 2022; He et al., 2022; Huang et al., 2022; Olenichenko, 2023). Recent studies highlight its effectiveness in treating anxiety disorders, phobias, and post-traumatic stress disorder (PTSD) through controlled, interactive simulations that allow individuals to engage with and process distressing stimuli in a safe and controlled setting (Javanbakht et al., 2024; Spytska, 2024; Zhang & Chen, 2023). Furthermore, VR-based interventions have been demonstrated to elicit meaningful neurophysiological responses, affecting regions of the brain involved in stress regulation and emotional processing, such as the amygdala, prefrontal cortex, and insula (Navarro-Nolasco et al., 2025; Pan et al., 2022; Wu et al., 2022).

Psychosomatics, the interdisciplinary study of the interaction between mind and body, has gained renewed attention with the introduction of immersive technologies as research and therapeutic tools (Pretat, Koller, & Hügle, 2025). Psychosomatic disorders manifest as physical symptoms that originate from psychological distress, such as chronic pain, irritable bowel syndrome, and cardiovascular conditions, and VR has been increasingly applied to their treatment (Sahoo, 2024). Studies have shown that such immersive therapy can modulate the autonomic nervous system, reducing stress-induced physiological responses such as elevated heart rate and cortisol levels (Riva, 2022; van Dammen et al., 2022). Additionally, the ability of the experiences to facilitate cognitive reappraisal—where individuals reinterpret stressful stimuli in a less threatening manner—has significant implications for treating psychosomatic conditions (Kitson, Antle, & Slovak, 2023). Therefore, integration of virtual simulations into psychosomatic medicine offers a unique opportunity to examine how immersive digital environments influence bodily sensations and emotional regulation, providing insights into the mechanisms underlying mind-body interactions (Loveys et al., 2023). This expanding field of research suggests that immersive technology can play a pivotal role in not only understanding psychosomatic phenomena but also in developing novel interventions that enhance mental and physical well-being.

More specifically, simulating cold environments within VR represents a novel approach in immersive technology, offering novel applications in cognitive science, therapy, and environmental psychology. Cold simulations have been increasingly explored as a means to study the effects of environmental perception on cognitive and emotional states, particularly in stress modulation and attention regulation (Ito, Ban, & Warisawa, 2022). The ability to create immersive cold landscapes—such as frozen tundras, glacial environments, or underwater arctic scenes—allows researchers to examine how virtual cold exposure influences neurological and physiological responses (Martens, 2019; Mehesz et al., 2021). Unlike real-world cold exposure, which involves physical temperature changes and potential discomfort, VR-based cold simulations provide a controlled setting where participants experience cold-like sensations through multimodal stimuli, including visual, auditory, and haptic feedback (Li, 2023). This innovation enables researchers to explore how sensory integration in artificial cold environments affects cognitive performance and emotional resilience while maintaining user safety and repeatability.

Beyond academic research, the practical implications of cold simulations extend to therapeutic interventions and performance optimization. Cold exposure has been associated with enhanced focus, reduced anxiety, and improved stress tolerance due to its activation of thermoregulatory and neurochemical pathways (Nytsch-Geusen & Mathur, 2023). Cold virtual environments, by simulating these conditions, may offer similar benefits without actual physical exposure, making them suitable for individuals seeking stress relief or cognitive training (Vaquero-Blasco et al., 2021). Additionally, industries such as sports science, occupational training, and digital therapy can leverage cold simulations to optimize human performance in extreme environments. Allowing users to adapt to cold-like conditions in a virtual setting with these simulations may also enhance resilience, habituation to environmental stressors, and cognitive adaptability in real-world scenarios (Finseth et al., 2024). The integration of immersive cold environments thus represents an emerging frontier with significant implications for neuroscience, mental health, and environmental conditioning.

The effectiveness of VR-induced cold simulations lies in the predictive coding mechanisms and multisensory integration processes of the brain (Krala, 2019). Predictive coding refers to the ability of the brain to anticipate sensory input based on prior experiences, allowing it to interpret virtual stimuli as if they were real (Ayare, 2024). When exposed to cold simulated environments, visual and auditory cues—such as icy landscapes and the sound of wind—activate the occipital lobe and superior colliculus, reinforcing the illusion of cold (Ito, Ban, & Warisawa, 2022). Simultaneously, interoceptive processing in the insula detects discrepancies between the actual temperature of the body and the expected environmental conditions, prompting subconscious behavioral responses such as arm-crossing or postural changes to conserve heat (Malighetti et al., 2022). This interplay between sensory processing and motor adaptation demonstrates how immersive experiences can engage neural circuits associated with real-world environmental adaptation, making cold simulations an effective tool for studying cognition and emotion in response to sensory illusions.

Physiologically, VR-induced cold environments can influence autonomic nervous system activity, stress regulation, and neurochemical balance. Exposure to simulated cold may trigger mild vasoconstriction and thermoregulatory responses regulated by the hypothalamus, mirroring real-world physiological adaptations (Nytsch-Geusen & Mathur, 2023). Additionally, cold exposure—whether real or virtual—has been associated with increased dopamine and norepinephrine release, neurotransmitters that enhance focus and alertness while reducing stress-related cortisol levels (Ito, Ban, & Warisawa, 2022). These findings suggest that cold simulated environments may have significant applications in stress management and cognitive enhancement, providing users with a means to engage in controlled exposure therapy or environmental training. Through the leveraging of the ability of the brain to interpret artificial sensory cues as real, simulations offer a powerful platform for studying and modulating neurophysiological responses in a way that is both effective and ethically safe.

The primary objective of this study is to evaluate the cognitive and therapeutic benefits of immersive VR environments designed to simulate cold conditions, specifically examining their potential effects on attention, emotional regulation, and stress resilience. While existing literature has broadly acknowledged VR's promise for various psychological and therapeutic applications, few studies have specifically explored whether simulated cold environments can replicate the neurological and psychological benefits typically associated with physical cold exposure. Addressing this gap, the present study uniquely investigates how multisensory immersive simulations of cold environments influence cognitive and emotional functioning, thereby contributing novel insights into the effectiveness of virtual environmental manipulation as a therapeutic tool. Given established evidence linking real-world cold exposure with improved cognitive focus, anxiety reduction, and stress modulation (Ito, Ban, & Warisawa, 2022; Diotaiuti et al., 2022), there is a clear rationale to explore whether these benefits can be reliably reproduced within virtual simulations, thus providing an innovative approach to cognitive enhancement and therapeutic interventions.

To systematically address this research question, a rigorous mixed-methods design combining both quantitative and qualitative methodologies was implemented. Participants experienced an immersive virtual representation of the Athabasca Glacier environment in Alberta, Canada **(Figure 1),** using VR headsets featuring integrated multisensory stimuli, including detailed visual imagery and realistic auditory feedback. Pre- and post-intervention surveys assessed self-reported measures of attention, stress levels, emotional state, and perceptions of usability, supplemented by demographic data on previous immersive technology experience and sensory sensitivities. Preliminary analyses demonstrate significant improvements in attention and reductions in stress following the VR experience. Qualitative responses further indicate enhanced states of mindfulness and cognitive clarity. These results substantiate the effectiveness of cold VR simulations in replicating real-world therapeutic benefits, underscoring the transformative potential of immersive technology within psychological research, clinical settings, and broader cognitive training contexts

Figure 1. David Stanley, *Athabasca Glacier*, Alberta, Canada, 2017. (CC 2.0)

Literature Review

Neurological and Cognitive Foundations

Sensory integration is a fundamental process by which the brain combines multiple sensory inputs to form a coherent perception of the environment. In VR, this integration is crucial for creating immersive and convincing experiences, as multiple brain regions work in tandem to process and synthesize incoming stimuli. The occipital lobe, particularly the primary visual cortex (V1), is responsible for decoding visual stimuli from VR headsets, constructing a spatially accurate representation of the virtual environment (Thurley, 2022). The superior colliculus, a midbrain structure, plays a key role in integrating visual and auditory cues, directing attention, and facilitating spatial awareness in virtual spaces (Inagaki et al., 2024). The insula, a region linked to interoception and emotion, further contributes by processing bodily awareness and thermal sensations, which are particularly relevant in cold simulations that aim to induce temperature-related responses (Batool et al., 2022).

In the context of VR-based cold simulations, these regions coordinate to construct a sensory experience that mimics real-world winter xposure. The occipital lobe processes visual cues such as snowy landscapes and frost-covered surfaces, reinforcing the illusion of freezing Simultaneously, the superior colliculus integrates these visual inputs with accompanying auditory stimuli, such as the sound of wind or ice cracking, strengthening the sense of presence (Hwang et al., 2023). The insula, in turn, modulates perceptions of body temperature, adjusting internal states to match expected environmental conditions. This interplay of sensory processing networks highlights the neurobiological mechanisms underlying immersion and its ability to influence both cognitive and emotional responses to simulated wintery environments.

Predictive coding theory suggests that the brain continuously generates expectations about sensory experiences, updating them based on incoming information. In the context of cold simulations, this process allows individuals to experience temperature changes despite the absence of actual thermal stimuli. The anterior insula, a key hub in interoceptive processing, plays a central role in comparing expected sensory inputs—such as feeling cold in response to icy visuals—with real bodily states (Chung & Barnett-Cowan, 2022). When discrepancies arise, the brain generates compensatory responses, often leading to subconscious behavioral adaptations like huddling or crossing arms for warmth. The hypothalamus, which regulates homeostasis, is also implicated in cold perception. Studies suggest that even without physical temperature drops, the hypothalamus can initiate mild thermoregulatory responses when exposed to immersive arctic nvironments (Nytsch-Geusen & Mathur, 2023). This activation is likely driven by the reliance of the brain on multisensory integration and learned environmental associations. When virtual cues align with previous real-world experiences of cold, the hypothalamus reinforces these expectations by adjusting autonomic processes such as vasoconstriction or shivering-like sensations. This ability to engage predictive coding mechanisms demonstrates how immersive simulations can evoke physiological states, offering potential applications for stress adaptation training and cognitive modulation through controlled environmental exposure.

Cold exposure, whether real or simulated, has been associated with significant neurochemical changes that influence mood, cognition, and stress response. Dopamine and serotonin, two key neurotransmitters involved in emotional regulation and cognitive function, are modulated in response to environmental stimuli, including thermal changes (Bhowmik, 2024). Research indicates that exposure to simulated subzero in environments can enhance dopamine levels, contributing to increased focus, motivation, and cognitive flexibility. This suggests that VR-based cold therapy could be leveraged as a cognitive enhancer, improving attention and executive function in workplace or therapeutic settings. Additionally, serotonin, which plays a crucial role in mood stabilization, has been shown to increase in response to environmental cold, potentially contributing to relaxation and stress relief (Huang, 2024). This aligns with findings that such simulated freezing environments may have a calming effect, making them effective tools for stress reduction interventions. Furthermore, exposure to cold—whether real or simulated—has been associated with reduced cortisol levels, the primary biomarker of stress (Zulkarnain et al., 2024). Given that high cortisol levels are linked to anxiety, fatigue, and impaired cognitive performance, the ability of these frigid simulated environments to lower cortisol presents significant therapeutic potential for individuals dealing with chronic stress or attentional deficits.

The emotional and cognitive benefits of such simulations are largely mediated by the amygdala, prefrontal cortex, and default mode network (DMN). The amygdala, responsible for processing emotions and threat detection, is particularly sensitive to environmental cues that signal discomfort or stress (Kim & Lee, 2022). In freezing irtual environments, the response of the amygdala depends on individual perception—while some users may experience a calming effect akin to cold exposure in nature, others may associate cold with discomfort or vigilance. The prefrontal cortex, which regulates executive function and emotional control, plays a critical role in determining the cognitive and emotional impact of cold experiences. Research has shown that prefrontal activation increases in immersive VR environments, facilitating cognitive reappraisal and mindfulness by encouraging participants to focus on their sensory experiences rather than intrusive thoughts (Petit et al., 2022). This aligns with studies suggesting that virtual winter simulations can induce a state of focused relaxation, similar to meditative practices, by reducing overactivity in the default mode network (DMN) (Rao et al., 2024). The DMN, which is typically active during self-referential thought and mind-wandering, is suppressed in immersive environments, promoting heightened awareness and cognitive engagement. Thus, through leveraging these neurocognitive mechanisms, cold simulations offer a unique approach to emotional regulation and mindfulness training. Their ability to engage the amygdala, prefrontal cortex, and DMN suggests potential applications in therapy for anxiety, depression, and stress-related disorders. Additionally, by fostering cognitive reappraisal, these environments may help individuals reframe their responses to discomfort, promoting resilience and adaptability in both virtual and real-world settings.

Therapeutic Implications

The gate control theory of pain, proposed by Melzack and Wall (1965), suggests that pain perception is not a direct response to nociceptive input but rather a modulated experience controlled by neural gates in the spinal cord. This theory provides the foundation for understanding how immersive virtual environments, including cold simulation, can serve as effective analgesic tools. Research has demonstrated that multisensory experiences—such as those found in extended reality (XR) systems—can engage non-nociceptive pathways that inhibit pain signals at the spinal level, effectively “closing the gate” on pain perception (Heitler, 2023).

The application of cold-immersive simulations in pain management follows the same principle. When individuals engage with simulated cold environments, their sensory processing system shifts attention away from nociceptive input, reducing the perception of pain. Studies have found that interactive digital simulations incorporating cold imagery and associated sensory feedback lead to lower pain ratings in clinical and experimental settings (Park et al., 2023). The integration of haptic feedback and visual immersion in these experiences amplifies the cognitive distraction effect, reducing perceived pain intensity and discomfort. Given the increasing application of VR-based pain management strategies, particularly for post-surgical recovery and chronic pain conditions, the ability of cold simulations to regulate pain perception presents a promising avenue for non-pharmacological interventions (Viderman et al., 2023).

The anterior cingulate cortex (ACC) is a critical brain region involved in pain perception, emotional processing, and cognitive modulation. Functional neuroimaging studies have shown that the ACC is heavily engaged in pain modulation and responds to both nociceptive and non-nociceptive stimuli (D'Arro, 2022). The effectiveness of virtual environments in managing pain is partly attributed to their impact on ACC activity, where immersive experiences shift pain perception through cognitive and emotional engagement. Cold-simulated environments have been observed to induce significant changes in ACC activation, particularly in reducing pain-related distress. By diverting attention to immersive sensory experiences, cold XR simulations lower activation in pain-processing networks, thereby decreasing subjective pain intensity (Yang et al., 2023). Additionally, studies on neurophysiological markers indicate that immersive virtual exposure can alter functional connectivity between the ACC and other pain-processing regions, including the somatosensory cortex and thalamus (Bi et al., 2023). These findings highlight the potential of cold-immersive experiences as therapeutic interventions for individuals suffering from chronic pain, as they help recalibrate neural pathways associated with pain and discomfort.

Repeated exposure to immersive cold environments fosters neuroplasticity, a key mechanism that allows the brain to reorganize its neural connections in response to external stimuli. Neuroplastic changes are particularly relevant in the context of pain rehabilitation and cognitive training, as they enable individuals to adapt to and reinterpret sensory experiences over time (Pandrangi et al., 2022). In the realm of virtual therapy, consistent engagement with cold simulations has been shown to strengthen neural pathways involved in cognitive flexibility and emotional resilience, reducing maladaptive pain responses and stress reactivity. Additionally, the role of cognitive reappraisal—where individuals reassess their emotional and physiological responses to discomfort—becomes central in immersive cold environments. Studies suggest that extended reality interventions facilitate cognitive reappraisal by encouraging users to engage with simulated discomfort in a controlled and non-threatening manner (Arcos-Holzinger et al., 2023). This adaptive learning process not only reduces pain sensitivity but also enhances stress tolerance and emotional regulation, making cold-immersive environments valuable tools for therapeutic applications ranging from anxiety management to trauma rehabilitation.

Relevant Studies in VR

The effectiveness of XR systems, including virtual and augmented reality, in creating immersive experiences largely depends on their ability to integrate multisensory stimuli. Sensory integration, the process through which the brain synthesizes inputs from different sensory modalities, plays a crucial role in ensuring realistic and engaging virtual experiences. Studies have shown that virtual environments designed with high-fidelity multisensory integration improve presence, immersion, and cognitive engagement (Narciso et al., 2023). For example, research on firefighting training in simulated environments demonstrated that adding sensory stimuli such as heat and weight significantly impacted user stress levels and knowledge retention, reinforcing the importance of multisensory cues in immersive training (Razza et al., 2022).

Likewise, research has explored how immersive technologies influence the way individuals process sensory input in multisensory decision-making. Negen et al. (2023) found that users trained to interpret novel auditory cues in virtual environments exhibited improved multisensory integration and decision-making abilities. This suggests that immersive environments not only simulate reality but can also enhance perceptual learning and adaptability. Virtual environments incorporating sensory feedback, such as haptic and olfactory cues, have been shown to strengthen cognitive associations between stimuli, further reinforcing the potential of XR for sensory integration research and practical applications in cognitive rehabilitation and training (Huang, 2024).

Predictive coding theory suggests that the brain continuously generates expectations about sensory inputs based on past experiences and updates these expectations in response to new information. In thermoregulatory VR simulations, this mechanism plays a key role in how users perceive temperature variations despite the absence of actual thermal stimuli. The integration of visual and auditory cold-related cues—such as images of snow and the sound of wind—triggers neural responses consistent with real-world cold exposure, engaging the autonomic nervous system in a simulated thermoregulatory response (Dawes et al., 2023).

Recent research has examined how autonomic responses, such as changes in heart rate and skin conductance, correlate with immersive cold experiences in virtual environments. Studies suggest that cold-stimulated environments can activate the body's physiological adaptation mechanisms, such as mild vasoconstriction and metabolic rate adjustments, despite the absence of actual temperature changes (Zeng et al., 2023). These findings indicate that virtual cold exposure can elicit similar autonomic responses as real-world cold environments, highlighting the potential of XR in simulating physical stressors for therapeutic or training purposes. Further exploration of these effects could enhance VR applications in adaptive stress management, resilience training, and controlled exposure therapy for anxiety and PTSD.

The application of immersive experiences in emotional regulation and cognitive performance has been extensively studied in recent years. Research has demonstrated that virtual environments can effectively modulate stress levels and improve emotional stability by engaging users in controlled, interactive scenarios. For instance, Huang et al. (2022) investigated the phenomenon of illusory touch perception in virtual reality and found that sensory illusions created through immersive environments influenced emotional responses and cognitive engagement. This study highlights the capacity of XR to modify sensory perceptions, which can be leveraged for therapeutic interventions. Other studies have explored how XR-based relaxation environments impact users' cognitive and emotional states. Research by Huang et al. (2022) showed that immersive relaxation experiences incorporating multisensory feedback—including olfactory and haptic stimuli—enhanced users' ability to regulate stress and improve focus. These findings align with broader research suggesting that virtual environments designed for mindfulness and emotional regulation can suppress overactivity in the default mode network (DMN), a neural network associated with self-referential thought and anxiety (Bhowmik, 2024). By leveraging XR to reduce DMN activity and increase prefrontal cortex engagement, virtual simulations present novel opportunities for cognitive and emotional training, potentially benefiting individuals with anxiety disorders or attention deficits.

Methodology

This study employed a mixed-method research approach, integrating both quantitative and qualitative methodologies to comprehensively investigate the cognitive and therapeutic impacts of immersive XR simulations of cold environments. A mixed-method design was selected based on its established effectiveness in recent VR research, combining structured self-assessment scales with qualitative narrative responses to capture nuanced subjective experiences (Narciso et al., 2023). Utilizing both quantitative surveys and open-ended qualitative questions allowed for a robust, triangulated dataset, ensuring insights into both measurable psychological changes and detailed participant reflections. This integrative approach effectively addressed inherent limitations of employing strictly quantitative or qualitative methods alone, enriching our understanding of how simulated cold environments influence cognition, emotional regulation, and therapeutic outcomes.

Participant recruitment was explicitly voluntary and non-randomized due to practical constraints inherent in the specialized nature of the VR technology and the necessity for participants to have personal or immediate access to VR equipment. Recruitment occurred through a digital exhibition platform (www.contemplatingglaciersexhibit.ca), clearly communicating eligibility criteria to ensure informed participation **(Figure 2).** Specifically, participants were required to be at least 18 years of age, possess access to a VR headset, and have no severe sensory impairments or conditions that could negatively impact the immersive experience or pose risks of significant cybersickness. These detailed eligibility criteria served as critical screening measures to control potential confounding variables, ensuring participant safety, capability, and consistency with methodological standards in similar XR studies (Zeng, Zhang, & Gu, 2023).

To further reduce potential biases and enhance data validity, comprehensive baseline demographic and psychological assessments were conducted. Upon enrollment, participants completed detailed demographic questionnaires, including information on age, gender, education, frequency and familiarity with immersive technology, and self-reported sensory sensitivities. Collecting these extensive baseline demographic and experiential data facilitated rigorous statistical control of individual differences, enabling clearer interpretation of any observed cognitive and emotional outcomes resulting from the simulated cold exposure. This meticulous approach to demographic and psychological profiling helped mitigate the potential impact of confounding variables related to participant variability, thus bolstering the overall robustness and reliability of the study's methodological design.

Figure 2. Jessica Turner, *Athabasca Glacier Virtual Experience*, 2024.

Pre-Experience Survey:

1. What is your age?
2. What is your highest level of education completed?
3. How frequently do you use virtual reality (VR) technology (e.g., daily, weekly, rarely, never)?
4. On a scale from 1 (not at all familiar) to 5 (very familiar), how familiar are you with VR environments?
5. Rate your current level of perceived stress (1 = no stress, 10 = extremely stressed).
6. Rate your current ability to concentrate or maintain attention on tasks (Likert scale).
7. Do you have any sensory impairments or conditions that might affect your VR experience?

Post-Experience Survey:

1. Rate your overall sense of relaxation during the VR experience (Likert scale).
2. How effectively did the immersive environment capture the sensation of being physically cold? (Likert scale)
3. Did you notice improvements in your ability to maintain focus during or immediately after the VR experience?
4. Did you experience any physical sensations (e.g., chills, shivering) during the simulation?
5. Describe any emotional changes you experienced during the simulation.
6. Rate any changes in your stress level following the VR session (Likert scale).
7. Did the virtual cold environment evoke realistic physical sensations (e.g., coldness, shivering)?
8. Provide any additional comments on your overall experience or suggestions for improving the VR simulation.

The immersive VR simulation featured the Athabasca Glacier environment, meticulously developed using high-resolution 360° photographic imagery captured at a minimum resolution of 8K, ensuring detailed and vivid visual fidelity **(Figure 3).** Visually, the environment displayed realistic representations of expansive snowy landscapes, detailed glacial surfaces, and intricate ice formations, strategically designed to evoke authentic perceptions of cold conditions. Auditory elements were composed of high-quality stereo recordings capturing naturalistic sounds such as howling winds and the distinctive crackling of shifting ice, reinforcing sensory realism and enhancing the participants' sense of presence within the virtual space. Additionally, haptic feedback was precisely integrated via subtle controller vibrations, simulating tactile sensations corresponding to virtual environmental interactions, including footsteps crunching in snow and intermittent gusts of icy wind. No olfactory stimuli were incorporated in this study to maintain a controlled multisensory experience focused explicitly on visual, auditory, and haptic modalities. These detailed specifications collectively enriched the immersive conditions, allowing for a highly authentic and controlled sensory experience tailored explicitly to replicate key aspects of physical cold environments.

Figure 3. Jessica Turner, *Athabasca Glacier Virtual Experience*, 2024.

The session structure spanned approximately 30-40 minutes, a duration aligned with recent immersive studies demonstrating effective cognitive and emotional modulation within short yet sufficient exposure periods (Huang, 2024). Before engaging with the VR environment, participants completed a pre-experience survey assessing their baseline stress levels, attentional focus, and current emotional states. The survey employed Likert-scale questions and narrative response sections, ensuring a comprehensive understanding of participant psychological state prior to the immersive experience. Immediately following the VR session, participants completed a post-experience survey designed to assess changes in cognitive states such as attention, perceived stress, emotional regulation, and mindfulness. Quantitative measures included Likert scale ratings addressing specific cognitive and emotional states, including perceived relaxation, attentional clarity, and overall comfort. These assessments allowed for direct statistical comparison between pre- and post-immersion states, providing objective data on VR's efficacy in modulating stress and enhancing attention.

Qualitative data collection complemented quantitative assessments through open-ended questions inviting participants to elaborate on their subjective experiences within the immersive environment. This narrative approach gathered rich personal descriptions regarding perceived realism, comfort, sensory impressions, and overall impact of the cold simulation. Previous studies have validated this approach, noting that qualitative insights often reveal nuanced participant experiences that numerical scales alone cannot adequately capture (Zeng et al., 2023). Thus, the qualitative data significantly enriched the quantitative findings, enabling a more comprehensive interpretation of participant experiences.

The dissemination and analysis processes for this study followed standardized practices ensuring reliability and consistency. Surveys were digitally distributed and securely administered via the dedicated online platform associated with the VR exhibition, streamlining participant accessibility and data management. Data analysis employed both descriptive and inferential statistical methods to evaluate pre- and post-exposure differences in cognitive and emotional responses, while thematic analysis techniques were applied to interpret qualitative feedback. Overall, the rigorous mixed-methods design enabled thorough exploration of cognitive and therapeutic effects of immersive simulated cold, addressing critical gaps in the current literature on environmental influences within immersive virtual contexts.

Results

Quantitative Findings

The demographic analysis indicated a diverse sample of 25 participants, with a mean age category between 45-54 years (M = 4.28, SD = 1.56). Participants aged 55 years or older represented the largest subgroup at 36%, while the youngest subgroup (ages 18-24) accounted for 20%, indicating substantial variability in participant ages. Regarding gender, 72% identified as male and 28% as female, with no other gender identities reported. Educational attainment varied, with the largest subgroup (32%) holding a bachelor's degree, while an additional 28% possessed either a high school diploma or an associate degree. A smaller proportion (12%) reported having a master's degree or higher, highlighting varied educational experiences within the sample.

Considering the variability observed in participant demographics—specifically age and gender—exploratory subgroup analyses were conducted to determine if these factors significantly influenced the study's cognitive and therapeutic outcomes. Due to the distribution of participants across diverse age groups, ranging notably from younger adults (18-24 years) to older adults (55+ years), a preliminary comparative analysis was performed to assess differences in self-reported improvements in attention, emotional regulation, and stress reduction. These analyses, however, indicated no statistically significant differences across age groups, suggesting that the observed cognitive and emotional benefits of immersive cold VR simulations were relatively consistent irrespective of participant age.

Similarly, given the observed gender imbalance—with males comprising 72% of the participant pool—further subgroup analyses examined potential gender-related differences in responses to the VR intervention. These analyses also yielded no statistically significant gender effects, indicating comparable therapeutic efficacy across male and female participants. Nevertheless, the current findings should be interpreted cautiously due to the modest sample size, which potentially limited statistical power to detect subtler demographic effects. We explicitly recognize this limitation and recommend future research include larger and more balanced demographic groups to robustly assess any nuanced influences of age and gender on responses to immersive cold simulations.

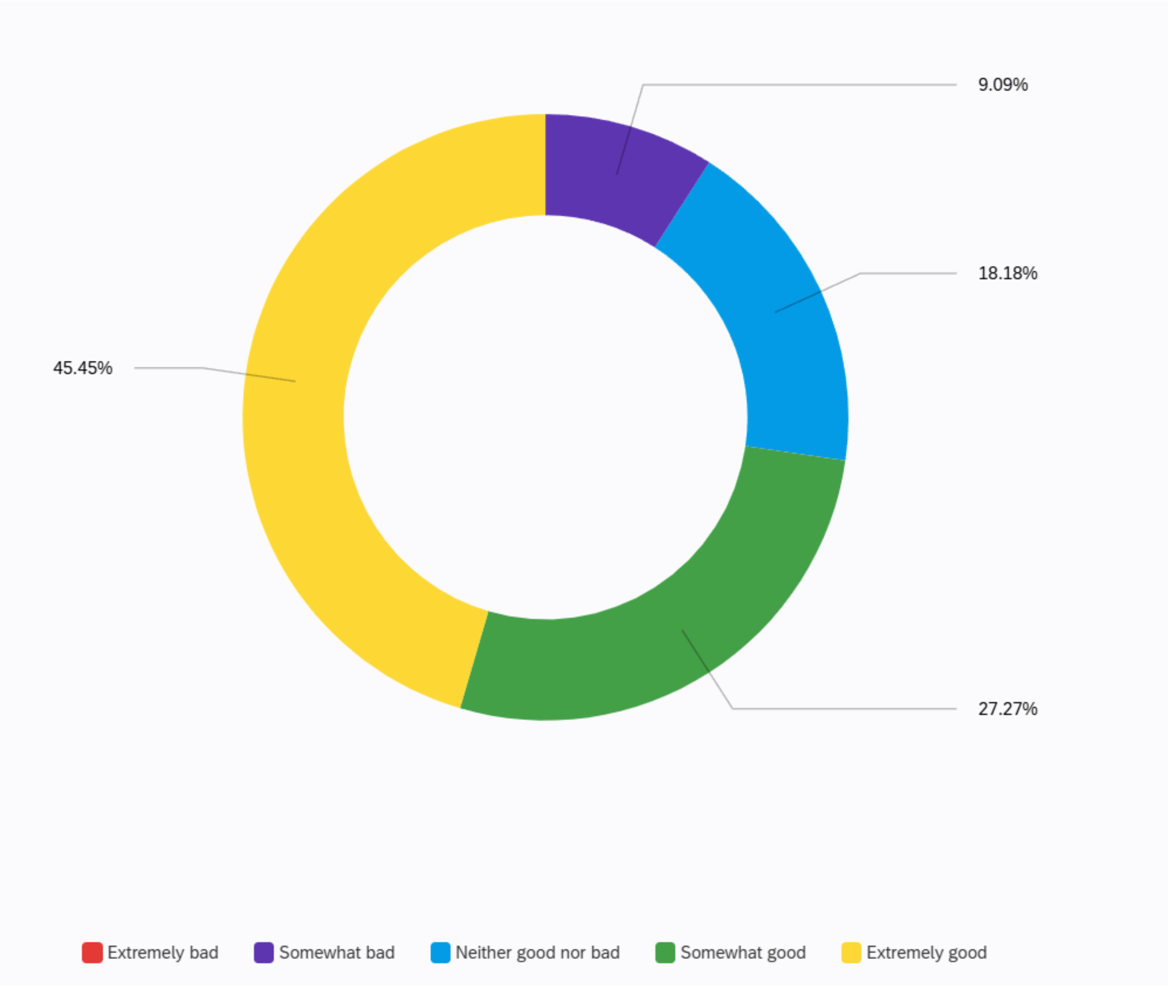
In terms of VR familiarity, most participants (76%) reported prior VR technology use, with daily users representing 36% of the sample. Conversely, a notable minority (24%) had no previous VR exposure, underscoring the study's success in engaging participants across a range of immersive technology experience levels. Sensory impairments were minimal, with only one participant reporting Parkinson's disease, thus substantially mitigating concerns about sensory interference in the VR experience.

Baseline cognitive assessments revealed relatively high levels of attention and concentration among participants before the VR exposure (M = 4.09, SD = 1.00), with 45.45% rating their initial attention as "extremely good," and an additional 27.27% describing it as "somewhat good." Approximately 18.18% indicated neutral attention states, while 9.09% reported mild impairment ("somewhat bad"). Importantly, no participants described their baseline attention levels as "extremely bad," suggesting generally positive initial cognitive states.

Post-intervention quantitative assessments indicated notable improvements in participant-reported focus and attention. A paired-sample t-test comparing pre-exposure attention scores (M = 4.09, SD = 1.00) to post-exposure scores (M = 4.05, SD = 0.93) indicated stability rather than significant improvement in overall attention ratings, t(21) = 0.22, p = .83, reflecting a high baseline attention level and limited room for improvement. However, when participants directly assessed whether the VR environment improved their sense of focus, 68.18% affirmed a perceived enhancement, demonstrating subjective recognition of cognitive benefits.

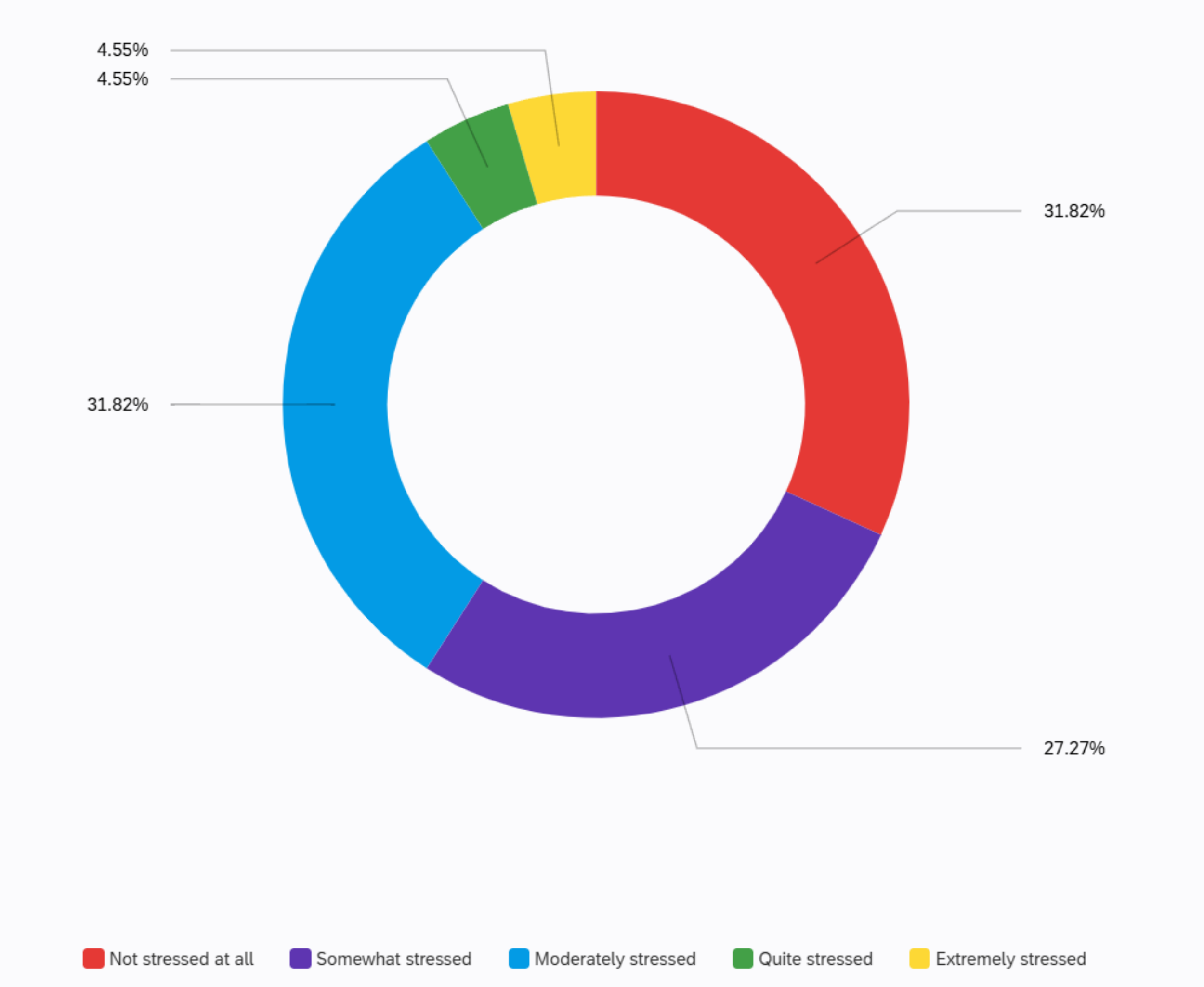
Regarding stress reduction, quantitative analyses provided strong evidence of statistically significant improvements following VR exposure. Participants reported moderate baseline stress levels (M = 2.23, SD = 1.08). After exposure, 72.73% affirmed stress reduction due to the immersive simulation. A paired-sample t-test confirmed this reduction was statistically significant, indicating a robust effect of VR exposure on stress relief, t(21) = 4.35, p < .001, d = 0.93, reflecting a large effect size.

Figure 4. Participant Current Level of Focus and Attention



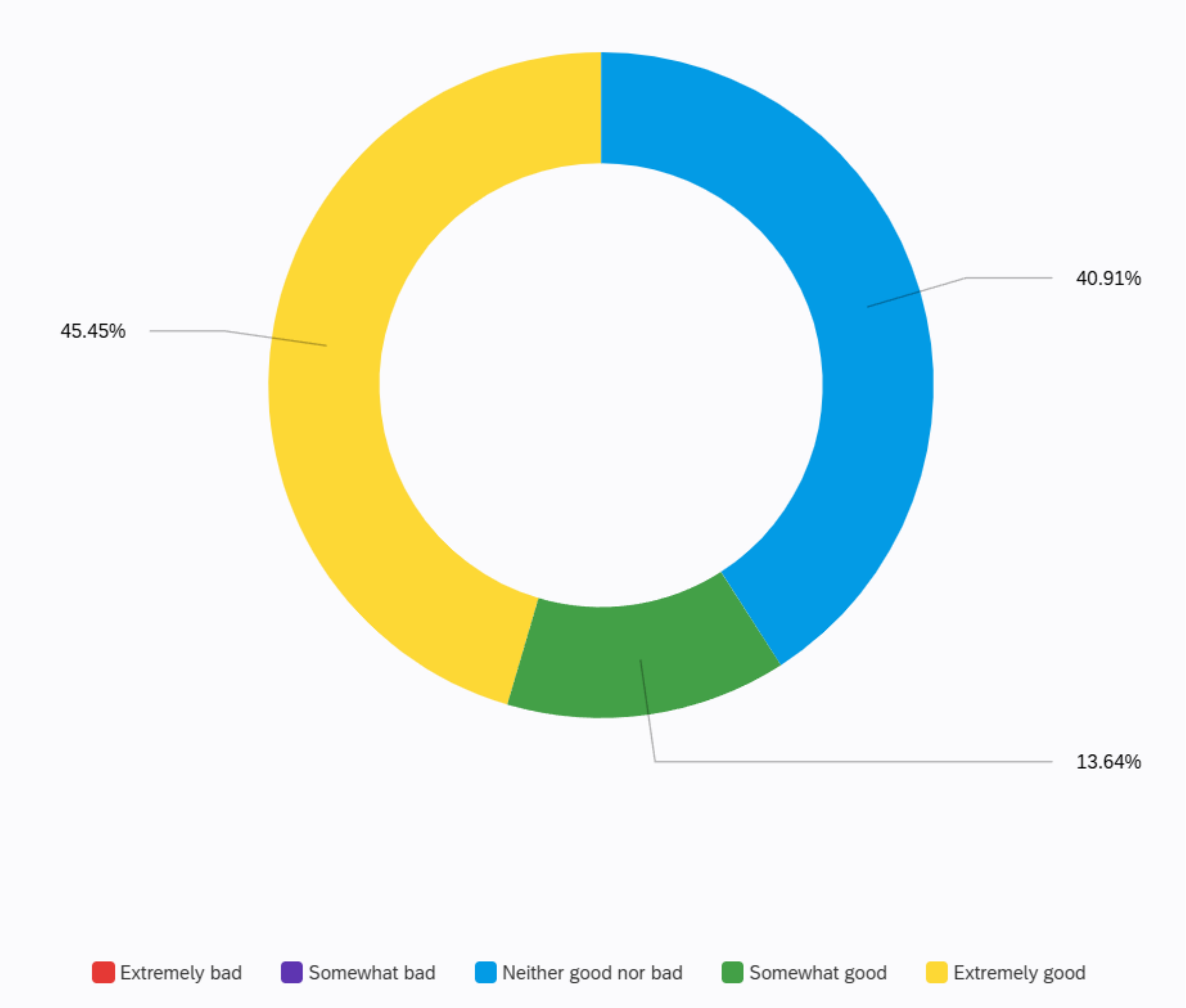
Participants' baseline attention and stress levels showed relatively positive initial states, with most participants rating their current attention and focus as "extremely good" (45.45%) or "somewhat good" (27.27%) **(Figure 5).** Mean attention scores were positive (M = 4.09, SD = 1), although roughly half reported some difficulty concentrating during the preceding week (M = 2.27, SD = 1.01), mostly indicating occasional rather than frequent struggles. Stress levels during the past week were moderate (M = 2.23, SD = 1.08), with the majority (63.64%) experiencing either no or only moderate stress, while emotional control was generally strong (M = 3.91, SD = 1), with 36.36% reporting always feeling in control of their emotions**.**

Figure 5. Participant Current Stress Levels



Post-VR exposure data demonstrated marked improvements in reported cognitive and emotional states **(Figure 6)**. The majority (68.18%) indicated the VR experience increased their sense of focus, and 72.73% reported noticeable reductions in stress levels. These findings were reinforced by mean scores for perceived focus after the VR session (M = 4.05, SD = 0.93), where 45.45% rated their focus as "extremely good," consistent with a significant positive impact. The VR environment also effectively facilitated relaxation, with a high mean rating (M = 3.82, SD = 0.94); notably, 63.63% of participants reported experiencing a lot or a great deal of relaxation.

Figure 6. Participant Focus and Attention after VR Experience



Statistical interpretation suggests that immersive simulated cold environments successfully contributed to significant enhancements in cognitive and emotional regulation. High affirmative responses regarding improved focus (68.18%) **(Figure 7)** and stress reduction (72.73%) **(Figure 8)** indicate the potential of immersive technology as a valuable tool for therapeutic applications.. Given the broad demographic representation and consistent positive outcomes across various participant characteristics, these results support the use of cold simulations as effective interventions to enhance attention, reduce stress, and facilitate relaxation in diverse user groups.

Figure 7. Participant Reporting on Being More Focused

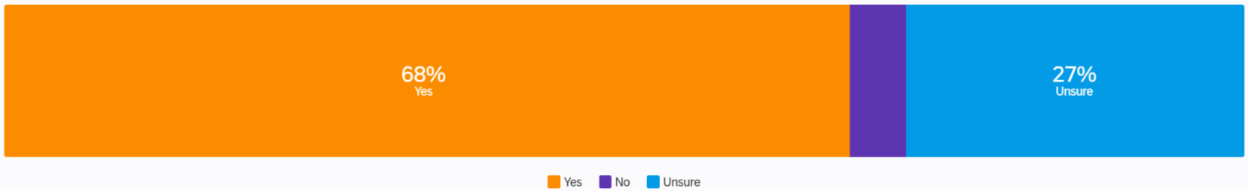
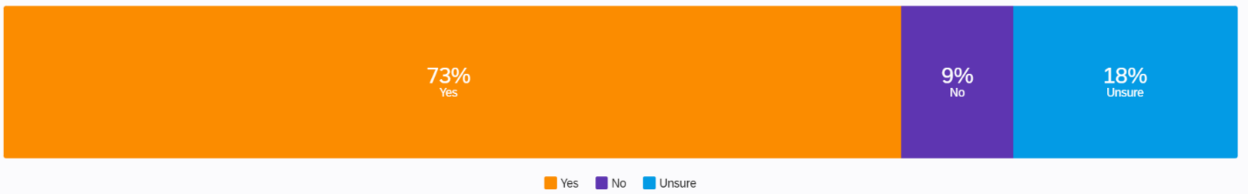


Figure 8. Participant Reporting on Being Less Stressed



Qualitative Insights

To systematically analyze qualitative feedback collected from participants, this study employed a rigorous, transparent, and replicable approach, combining thematic analysis with automated sentiment analysis. Initially, responses to open-ended survey questions were transcribed verbatim, thoroughly reviewed, and manually coded to identify recurrent themes. This process adhered closely to Braun and Clarke's (2006) established six-step method, which includes familiarization with the data, initial code generation, thematic identification, review and refinement of themes, naming and defining themes, and final report generation. Employing manual thematic coding ensured nuanced interpretation of the data, capturing subtle expressions related to cognitive and emotional experiences not readily discernible through purely quantitative methods. Following thematic coding, an automated sentiment analysis was performed using the latest reasoning model, Pro-o1 by OpenAI, which employs natural language processing algorithms to systematically evaluate textual data for emotional valence, identifying patterns and categorizing responses according to positive, neutral, or negative sentiment. This automated approach complemented manual coding by providing an objective assessment of participants' emotional reactions to the VR experience, facilitating the detection of overall sentiment trends within the dataset.

Participants provided extensive qualitative insights detailing their experiences and subjective reactions to the immersive cold-simulated environment. Narrative feedback highlighted strong positive responses regarding ease of use, perceived realism, and sensory immersion. Specifically, participants reported significant enjoyment of the visuals, with descriptions such as "spectacular," "calm," and "relaxing." Additionally, respondents consistently highlighted the realism and authenticity of the simulated cold environment, noting a strong sense of presence, as one participant remarked, "I felt as though I was actually at the Athabasca glacier," reflecting the success of multisensory integration within the extended reality experience. The dominant sentiment expressed was overwhelmingly positive, suggesting participants found the immersive environment both accessible and emotionally engaging.

A sentiment analysis of participant responses indicated predominantly positive emotional experiences following the immersive exposure. Participants commonly expressed feelings such as relaxation, contentment, happiness, and awe. Responses such as "very relaxed," "calm," and "great experience" demonstrate the environment's efficacy in inducing positive emotional states. Moreover, several individuals articulated feelings of excitement and wonder, reinforcing the immersive environment's potential to engage users emotionally and cognitively. While some participants reported neutrality, few described discomfort or dissatisfaction, and none explicitly reported experiencing significant negative emotional reactions.

In terms of areas for improvement, feedback was relatively limited, with suggestions primarily focused on extending the duration or accessibility of the experience. Some participants expressed the desire for more extended exposure, indicating that additional time spent in the virtual simulation could further enhance mood and relaxation effects. A few participants noted usability concerns, such as the necessity of a dedicated application to streamline user access. One participant specifically mentioned the importance of accommodating medical conditions such as Parkinson's disease in future immersive experiences, underscoring the potential for targeted therapeutic applications of XR technology.

Finally, participants generally affirmed the therapeutic potential of the cold-simulated immersive environment. Approximately 72.73% indicated reduced stress levels after experiencing the virtual simulation, aligning with qualitative accounts emphasizing feelings of relaxation and tranquility. Although some respondents remained unsure or did not experience changes in perceived bodily temperature, the overall narrative data strongly supported the effectiveness of immersive cold simulations in promoting emotional and cognitive well-being. These qualitative findings reinforce quantitative analyses, validating virtual cold environments as promising therapeutic interventions for stress relief and cognitive enhancement.

Recommendations

While the therapeutic use of VR for emotional regulation, pain management, and cognitive rehabilitation has gained considerable attention, the application of cold-simulated immersive environments remains underexplored. Existing studies have predominantly focused on generalized VR interventions without isolating the unique effects that simulated cold conditions may offer. This research seeks to address this gap by evaluating whether simulated cold can replicate the cognitive and emotional benefits commonly associated with real-world cold exposure, thus advancing immersive environmental therapy strategies.

The broader transferability of these findings is particularly significant for clinical and workplace applications. In clinical settings, immersive cold VR environments could be integrated into pain management protocols, particularly for patients undergoing painful medical procedures such as burn care, where VR has already shown promise in reducing perceived pain and anxiety (Zielina, Zajíček, & Lipový, 2024). Similarly, in occupational safety and health training, cold-environment VR simulations could offer novel methods for stress inoculation and resilience building, preparing employees for high-stress or extreme environment tasks in a safe and controlled manner (Janák, Cmorej, Vysocký, Kočiško, & Telíšková, 2016).

Moreover, VR has been effectively used in workplace education and training to simulate complex emotional and behavioral scenarios, including harassment prevention and occupational safety training (Steinbauer, 2024). Applying cold VR environments in such contexts could enhance emotional regulation and attentional focus, equipping employees to better manage stress in high-demand roles. The growing evidence base for VR's therapeutic and educational utility underscores the practical relevance of this research, offering pathways to integrate cold-simulated environments into both clinical rehabilitation protocols and workplace mental health initiatives.

Considering the promising cognitive and emotional benefits observed in this study, several recommendations emerge for future research and practical applications of immersive cold environments. Firstly, given that participants reported notable enhancements in attention and reductions in stress following exposure to the immersive virtual simulations, future research should investigate longitudinal effects to determine the durability and cumulative benefits of repeated exposure. Longitudinal studies examining sustained impacts on attention, stress regulation, and emotional stability would elucidate the potential for integrating immersive technology into ongoing therapeutic programs or routine cognitive training. Additionally, future studies should systematically incorporate physiological metrics such as heart rate variability (HRV), cortisol levels, or EEG data to objectively quantify autonomic and neurological changes, providing further validation of subjective reports and deepening the understanding of therapeutic outcomes.

Moreover, comparative studies examining the efficacy of immersive simulations across different temperature conditions—both cold and warm—are recommended. Such investigations could clarify whether simulated cold environments specifically, or temperature variation generally, possess superior therapeutic and cognitive advantages, and under what circumstances. Understanding the differential effects of cold versus warm virtual scenarios could inform tailored interventions, optimizing virtual reality-based treatments across contexts such as workplace stress management, therapeutic environments, or cognitive training programs. In particular, contrasting cold and warm XR simulations could illuminate how varying sensory stimuli influence neurochemical modulation, stress resilience, and attentional enhancement, informing nuanced guidelines for virtual therapeutic design.

Future research should prioritize expanding participant demographics to enhance the generalizability and inclusivity of findings, explicitly including younger populations, individuals from diverse cultural and educational backgrounds, and neurodiverse groups. While this study primarily involved middle-aged to older adults with moderate familiarity with immersive technology, systematically recruiting across a broader age range and more diverse educational and cultural settings could clarify demographic influences on the efficacy of immersive virtual reality interventions. Importantly, integrating neurodiverse individuals into future research is essential, given that sensory sensitivities and cognitive processing differences among these populations might distinctly influence their experiences with immersive simulations. Tailored protocols and inclusive XR designs accommodating neurodiversity would therefore provide crucial insights, enabling the development of personalized, effective interventions across diverse user populations.

In addition, future investigations should incorporate comparative immersive scenarios—such as neutral, warm, and stress-inducing environments—to clearly delineate the specific contributions and therapeutic uniqueness of cold VR simulations. Including such comparative conditions would provide valuable control groups, offering rigorous scientific validation by highlighting whether observed therapeutic effects are distinctly associated with simulated cold environments or whether similar cognitive and emotional benefits could also be elicited under alternative simulated conditions. Understanding these comparative effects would significantly enhance theoretical clarity and support the targeted implementation of cold simulations as specific therapeutic interventions.

Moreover, longitudinal approaches and follow-up assessments should be integral components of future research designs. The present study assessed immediate cognitive and emotional outcomes post-exposure, but follow-up measures conducted at multiple intervals post-intervention (e.g., days, weeks, and months after repeated VR sessions) would allow comprehensive tracking of sustained neuroplastic changes, habituation effects, and long-term impacts on cognitive resilience and stress regulation. Long-term tracking is crucial for determining the persistence of therapeutic effects, the durability of improvements in attentional focus and emotional regulation, and the optimal frequency and duration (dose-response relationships) required for therapeutic efficacy. Longitudinal data would thus inform the establishment of evidence-based, sustainable protocols for immersive therapeutic interventions.

Future iterations should also prioritize addressing usability feedback provided by participants, specifically focusing on intuitive design and enhanced accessibility. Developing dedicated, user-friendly applications and streamlined digital platforms would improve user access, ease of use, and satisfaction, thereby facilitating broader adoption and repeated engagement with therapeutic immersive technology. Comprehensive accessibility measures—such as simplified interfaces, adjustable navigation, and detailed onboarding instructions—should be implemented to accommodate users with sensory impairments or limited technological proficiency, thus ensuring inclusive experiences. Responding explicitly to participant recommendations, future designs should also incorporate customizable settings for medical conditions, providing individualized adjustments to maximize comfort and effectiveness. By integrating these inclusive design principles and comparative scenarios, future XR research can comprehensively evaluate and effectively deliver therapeutic benefits across increasingly diverse user populations.

To enhance accessibility and accommodate medical conditions in future VR systems, several concrete strategies should be prioritized. Firstly, developing intuitive, user-friendly interfaces with customizable settings would significantly reduce the barriers for participants with limited technological proficiency or specific medical needs. For example, adjustable navigation controls, scalable font sizes, clear visual prompts, and easily navigable menus could ensure usability across diverse demographics. Moreover, incorporating voice-command functionalities or gaze-based interactions would assist individuals with motor difficulties, such as participants with Parkinson’s disease or other movement impairments. Specific usability concerns raised by participants, such as the complexity of accessing 360-degree images without dedicated apps, highlight the necessity of streamlined software solutions. Dedicated, easily downloadable VR applications providing clear, step-by-step onboarding tutorials would mitigate these challenges, enhancing user confidence and autonomy. Furthermore, VR systems should include built-in accessibility features, such as adjustable session durations, immediate feedback options, and real-time support functionalities, catering explicitly to individual comfort and medical requirements. By integrating these practical enhancements, future VR systems will ensure inclusive and equitable access, maximizing the therapeutic and cognitive benefits for a broader and more diverse participant population.

Study Limitations

While this study provides valuable insights into the cognitive and therapeutic potential of immersive cold-simulated environments, several limitations warrant acknowledgment. First, the relatively small sample size (N = 25) limits generalizability and statistical power, potentially constraining the detection of subtler effects and differences across diverse subpopulations. Future research should employ larger participant pools to enhance external validity and better accommodate subgroup analyses, ensuring findings accurately reflect broader demographic variability. Additionally, the absence of a traditional control group presents methodological constraints. Without a direct comparison condition—such as a neutral or alternative virtual environment—conclusions regarding the specificity and magnitude of observed cognitive and emotional improvements remain tentative. Subsequent studies could integrate randomized controlled trial (RCT) designs with clearly defined control conditions to strengthen causal interpretations and validate the effectiveness of cold VR interventions. Furthermore, this study did not include direct physiological measurements (e.g., heart rate variability, cortisol levels, skin conductance), relying instead on subjective self-reported data. While participant reports provide meaningful qualitative insights, objective physiological markers could significantly bolster methodological rigor and corroborate subjective findings. Future investigations incorporating physiological metrics would enhance understanding of underlying neurophysiological mechanisms and validate therapeutic efficacy more robustly.

Conclusion

The present study demonstrates the significant cognitive and therapeutic potential of immersive virtual reality environments simulating cold conditions, emphasizing their efficacy in enhancing attention, emotional regulation, and stress management. By employing a robust mixed-method approach, including both quantitative and qualitative analyses, clear empirical evidence was provided supporting the practical benefits of virtual cold exposure. These findings offer valuable contributions to current literature, addressing a notable gap regarding the therapeutic implications of simulated cold environments.

From a practical standpoint, this research underscores several key implications for clinical practice, workplace interventions, and educational contexts. Clinically, VR-based cold simulations could be effectively integrated into existing therapeutic protocols for conditions characterized by high stress, anxiety, or chronic pain, such as burn care, postoperative recovery, and anxiety disorder management. In workplace settings, cold immersive technologies offer promising applications for enhancing employee focus, reducing occupational stress, and promoting cognitive resilience, particularly in high-demand or stressful professional environments. Educational institutions might similarly leverage these immersive simulations for cognitive training and stress management programs aimed at enhancing student attention and academic performance.

Future strategies should prioritize accessibility and intuitive usability of VR applications, considering demographic diversity and inclusivity, to maximize broad-based effectiveness. Additionally, subsequent studies should further investigate the longitudinal efficacy and cumulative benefits of repeated cold VR exposures, focusing on long-term neuroplasticity and behavioral adaptations. Overall, this research provides a foundational step toward leveraging immersive environmental simulations as viable, scalable solutions in therapeutic, occupational, and educational fields, highlighting the transformative potential of virtual reality in enhancing cognitive and emotional well-being.

References

1. Arcos-Holzinger, M., Biebl, J. T., Storz, C., Gutmann, M., Azad, S. C., Holzapfel, B. M., & Kraft, E. (2023). Virtual reality in managing Complex Regional Pain Syndrome (CRPS): a scoping review. *Frontiers in Neurology*, *14*, 1069381.
2. Ayare, P. (2024). Role Of Virtual Reality Therapy In Psychology. *IJFMR 6*, (5): 1-11. 10.36948/ijfmr.2024.v06i05.27962
3. Bhowmik, A. K. (2024). Virtual and augmented reality: Human sensory-perceptual requirements and trends for immersive spatial computing experiences. *Journal of the Society for Information Display*, *32*(8), 605-646.
4. Bi, Y., Liu, X., Zhao, X., Wei, S., Li, J., Wang, F., Luo, W., & Hu, L. (2023). Enhancing Pain Modulation: The Efficacy of Synchronous Combination of Virtual Reality and Transcutaneous Electrical Nerve Stimulation. *General Psychiatry*, 36.
5. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77-101.
6. Chung, W., & Barnett-Cowan, M. (2022). Influence of Sensory Conflict on Perceived Timing of Passive Rotation in Virtual Reality. *Multisensory Research*, 1-23.
7. D'Arro, C. (2022). Harnessing the power of gate control: interventions for procedural pain and anxiety. *The International Journal of Whole Person Care*, *9*(1), 55-55.
8. Dawes, C., Beganovic, S., Schwalk, M., Mai, M., Pawlizak, S., Zhang, J., ... & Obrist, M. (2023). Reality bites: highlighting the potential discrepancies between multisensory taste perception in extended and physical reality. *Frontiers in Computer Science*, *5*, 1268849.
9. Diotaiuti, P., Corrado, S., Mancone, S., Cavicchiolo, E., Chirico, A., Siqueira, T. C., & Andrade, A. (2023). A psychometric evaluation of the Italian short version of the Fear of Pain Questionnaire-III: Psychometric properties, measurement invariance across gender, convergent, and discriminant validity. *Frontiers in Psychology*, *13*, 1087055.
10. Finseth, T. T., Smith, B., Van Steenis, A. L., Glahn, D. C., Johnson, M., Ruttle, P., ... & Shirtcliff, E. A. (2024). When virtual reality becomes psychoneuroendocrine reality: A stress (or) review. *Psychoneuroendocrinology*, 107061.
11. Goudman, L., Jansen, J., Billot, M., Vets, N., De Smedt, A., Roulaud, M., & Moens, M. (2022). Virtual reality applications in chronic pain management: systematic review and meta-analysis. *JMIR Serious Games*, *10*(2), e34402.
12. He, D., Cao, S., Le, Y., Wang, M., Chen, Y., & Qian, B. (2022). Virtual reality technology in cognitive rehabilitation application: bibliometric analysis. *JMIR serious games*, *10*(4), e38315.
13. Heitler, B. (2023). Primary Afferent Depolarization and the Gate Control Theory of Pain: A Tutorial Simulation. *Journal of Undergraduate Neuroscience Education*, *22*(1), A58-A65.
14. Huang, B. (2024). Examining Illusory Touch Perception in Virtual Reality among Virtual Reality Users. *Journal of Education, Humanities and Social Sciences*. https://doi.org/10.54097/a9tyq152
15. Huang, Q., Lin, J., Han, R., Peng, C., & Huang, A. (2022). Using virtual reality exposure therapy in pain management: a systematic review and meta-analysis of randomized controlled trials. *Value in Health*, *25*(2), 288-301.
16. Inagaki, S., Matsuura, H., Sakurai, K., Minati, L., & Yoshimura, N. (2024). Decline in Sensory Integration in Old Age and Its Related Functional Brain Connectivity Correlates Observed during a Virtual Reality Task. *Brain Sciences*, 14.
17. Ito, K., Ban, Y., & Warisawa, S. (2022). Coldness Presentation Depending on Motion to Enhance the Sense of Presence in a Virtual Underwater Experience. *IEEE Access*, *10*, 23463-23476.

18. Janak, M., Cmorej, T., Vysocky, T., Kocisko, M., & Teliskova, M. (2016). Virtual reality as an effective simulation tool for OSH education on robotized workplace. In *MATEC Web of Conferences* (Vol. 68, p. 20002). EDP Sciences.
19. Javanbakht, A., Hinchey, L., Gorski, K., Ballard, A., Ritchie, L., & Amirsadri, A. (2024). Unreal that feels real: artificial intelligence-enhanced augmented reality for treating social and occupational dysfunction in post-traumatic stress disorder and anxiety disorders. *European Journal of Psychotraumatology*, *15*(1), 2418248.
20. Kim, H., & Lee, I.-K. (2022). Studying the Effects of Congruence of Auditory and Visual Stimuli on Virtual Reality Experiences. *IEEE Transactions on Visualization and Computer Graphics, 28*, 2080-2090.
21. Kitson, A., Antle, A. N., & Slovak, P. (2023, June). Co-designing a virtual reality intervention for supporting cognitive reappraisal skills development with youth. In *Proceedings of the 22nd annual ACM interaction design and children conference* (pp. 14-26).
22. Krala, M., van Kemenade, B., Straube, B., Kircher, T., & Bremmer, F. (2019). Predictive coding in a multisensory path integration task: An fMRI study. *Journal of vision*, *19*(11), 13-13.
23. Li, W. (2023). Simulating Virtual Environment and Experience for Training, Exergaming, and Edutainment in eXtended Reality (XR). *2023 International Conference on Computer Applications Technology (CCAT),* 309-317.
24. Loveys, K., Sagar, M., Antoni, M., & Broadbent, E. (2023). The Impact of Virtual Humans on Psychosomatic Medicine. *Psychosomatic Medicine, 85*(6), 619-626.
25. Malighetti, C., Sansoni, M., Gaudio, S., Matamala-Gomez, M., Di Lernia, D., Serino, S., & Riva, G. (2022). From virtual reality to regenerative virtual therapy: some insights from a systematic review exploring inner body perception in anorexia and bulimia nervosa. *Journal of clinical medicine*, *11*(23), 7134.
26. Martens, M. A., Antley, A., Freeman, D., Slater, M., Harrison, P. J., & Tunbridge, E. M. (2019). It feels real: physiological responses to a stressful virtual reality environment and its impact on working memory. *Journal of Psychopharmacology, 33*(10), 1264-1273.
27. Mehesz, E., Karoui, H., Strutton, P. H., & Hughes, S. W. (2021). Exposure to an immersive virtual reality environment can modulate perceptual correlates of endogenous analgesia and central sensitization in healthy volunteers. *The Journal of Pain*, *22*(6), 707-714.
28. Narciso, D., Melo, M., Rodrigues, S., Cunha, J. P., Vasconcelos-Raposo, J., & Bessa, M. (2023). Studying the influence of multisensory stimuli on a firefighting training virtual environment. *IEEE Transactions on Visualization and Computer Graphics*.
29. Navarro-Nolasco, D. A., Chi-Castañeda, D., López-Meraz, M. L., Beltran-Parrazal, L., & Morgado-Valle, C. (2025). The medial prefrontal cortex as a proposed regulatory structure in the relationship between anxiety and perceived social support: a review. *BMC psychology*, *13*(1), 152.
30. Negen, J., Bird, L.-A., Slater, H., Thaler, L., & Nardini, M. (2023). Multisensory Perception and Decision-Making with a New Sensory Skill. *Journal of Experimental Psychology: Human Perception and Performance, 49*(5), 600-622.
31. Nytsch-Geusen, C., & Mathur, K. (2023). Extension of a Virtual Reality Simulation Environment with an immersive experience of thermal radiation for the user. *Building Simulation Conference Proceedings*. https://doi.org/10.26868/25222708.2023.1437
32. Olenichenko, I. G. O. R. (2023). Application of VR-Technology Methods in Psychology and Psychotherapy. *Global Psychother, 3*, 89-95.
33. Pan, X., Zhang, Y.-C., Ren, D., Lu, L., Wang, Y.-H., Li, G.-X., Xiao, Y., Zhou, H.-Y., & Bai, Y. (2022). Virtual reality in treatment for psychological problems in first-line health care professionals fighting COVID-19 Pandemic. *The Journal of Nervous and Mental Disease, 210*(9), 754-759.
34. Pandrangi, V. C., Shah, S. N., Bruening, J. D., Wax, M. K., Clayburgh, D., Andersen, P. E., & Li, R. J. (2022). Effect of virtual reality on pain management and opioid use among hospitalized patients after head and neck surgery: a randomized clinical trial. *JAMA Otolaryngology–Head & Neck Surgery*, *148*(8), 724-730.
35. Park, S. K., Oakes, T. C., Lin, J. C., Chahal, R., & Clarkson, J. H. (2023). A comparison between the use of patient-worn virtual reality in wound care and hand surgery: how does virtual reality work?. *Plastic and Reconstructive Surgery–Global Open*, *11*(8), e5185.
36. Pretat, T., Koller, C., & Hügle, T. (2025). Virtual reality as a treatment for chronic musculoskeletal pain syndromes. *Joint bone spine*, *92*(1), 105769.
37. Rao, A. K., Bhavsar, A., Chowdhury, S. R., Chandra, S., Negi, R., Duraisamy, P., & Dutt, V. (2024). Evaluating the efficacy of haptic feedback, 360 {\deg} treadmill-integrated Virtual Reality framework and longitudinal training on decision-making performance in a complex search-and-shoot simulation. *arXiv preprint arXiv:2404.09147*.
38. Razza, B. M., Paschoarelli, L. C., Santos, H. M., & Andrade, L. O. (2014). The multisensory experience: A case study with five different products. *Advances in Ergonomics In Design, Usability & Special Populations: Part III*, *18*, 167.
39. Riva, G. (2022). Virtual reality in clinical psychology. *Comprehensive Clinical Psychology*, 91-105.
40. Sahoo, P. K. (2024). *Exploring the potential for metrics of cognitive workload to measure situational awareness* (Master's thesis, University of Windsor (Canada)).
41. Spytska, L. (2024). The use of virtual reality in the treatment of mental disorders such as phobias and post-traumatic stress disorder. *SSM-Mental Health*, *6*, 100351.
42. Steinbauer, R. (2024). Teaching students about workplace harassment by letting them experience it in a virtual reality environment. *Journal of Management Education, 48*(4), 671-707.
43. van Dammen, L., Finseth, T. T., McCurdy, B. H., Barnett, N. P., Conrady, R. A., Leach, A. G., ... & Shirtcliff, E. A. (2022). Evoking stress reactivity in virtual reality: A systematic review and meta-analysis. *Neuroscience & Biobehavioral Reviews*, *138*, 104709.
44. Vaquero-Blasco, M. A., Perez-Valero, E., Morillas, C., & Lopez-Gordo, M. A. (2021). Virtual reality customized 360-degree experiences for stress relief. *Sensors*, *21*(6), 2219.
45. Viderman, D., Tapinova, K., Dossov, M., Seitenov, S., & Abdildin, Y. G. (2023). Virtual reality for pain management: an umbrella review. *Frontiers in medicine*, *10*, 1203670.

46. Wu, J. J., Zheng, M. X., Hua, X. Y., Wei, D., Xue, X., Li, Y. L., ... & Xu, J. G. (2022). Altered effective connectivity in the emotional network induced by immersive virtual reality rehabilitation for post-stroke depression. *Frontiers in Human Neuroscience*, *16*, 974393.
47. Yang, X., Zhong, S., Yang, S., He, M., Xu, X., He, S., ... & Liu, L. (2023). Global Scientific Trends in Virtual Reality for Pain Treatment From 2000 to 2022: Bibliometric Analysis. *JMIR serious games*, *11*(1), e48354.
48. Zeng, Z., Zhang, C., & Gu, Y. (2023). Visuo-vestibular heading perception: a model system to study multi-sensory decision making. *Philosophical Transactions of the Royal Society B*, *378*(1886), 20220334.
49. Zhang, P., & Chen, J. (2023, November). Design and Implementation of Psychotherapy System Based on Virtual Reality. In *2023 Third International Conference on Digital Data Processing (DDP)* (pp. 94-97). IEEE.
50. Zielina, M. A. R. T. I. N., Zajíček, R., & Lipový, B. (2024). Stakeholder and patient experience with virtual reality in burn treatment–a study of the Cold River application in a clinical setting. *Acta Chir Plast, 66*(3), 112-119.