

# Immersive Mindfulness: The Effectiveness of VR-Based Techniques Compared to Traditional Mindfulness Practices

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## ABSTRACT

This study compared the effectiveness of Virtual Reality (VR) based mindfulness practices with traditional audio-guided mindfulness practices. A 2 × 2 between-subjects experiment was designed to examine the effects of Method (VR vs. Traditional) and Duration (8 vs. 16 minutes). Physiological data (heart rate, heart rate variability, breathing rate, galvanic skin response, stress index) and self-report measures (Perceived Stress Scale, Mindful Attention Awareness Scale) before and after interventions were recorded. Overall, trends emerged and indicated that the traditional audio-guided method was associated with greater reductions in breathing rate, heart rate variability, stress index, and z-normalized galvanic skin response (z-GSR). Specifically, traditional methods produced greater reductions in breathing rate ( $M = -5.84$  vs.  $-2.90$ ), heart rate variability, stress index, and galvanic skin response, while VR showed slightly more substantial decreases in heart rate. VR demonstrated high usability ( $SUS = 77.88$ ). Both modalities achieved comparable physiological effects in brief sessions, with VR offering advantages in engagement and usability. Overall, these findings suggest that while VR provides an immersive and engaging mindfulness experience, its physiological effects in the present study were comparable to, or marginally weaker than, those observed with conventional audio-guided approaches. Future research should explore longer-term interventions and larger samples.

**Keywords:** Mindfulness practices, Guided meditation, VR-based interventions

## INTRODUCTION

Mindfulness practices reduce stress and promote emotional well-being through guided breathing and meditation. Traditional delivery via in-person sessions or smartphone apps has proven effective, but VR's immersive environments may enhance engagement and outcomes. Previous research demonstrates that VR produces higher feelings of presence and emotional reactions (Seabrook et al., 2020), yet few studies directly compare VR to traditional mindfulness methods. As mental health challenges continue to rise globally, particularly in high-stress environments such as healthcare, aviation, and business, finding effective and scalable stress-reduction interventions is crucial. Traditional 2D applications lack sensory depth and are prone to external distractions, limiting user immersion. VR's immersive qualities are believed to improve mindfulness by boosting concentration and

involvement. Because VR creates a more excellent sensation of presence, Navarro-Haro et al. (2017) discovered that mindfulness exercises based on virtual reality helped with emotional regulation. The specific processes, such as the functions of flow states, neuroplasticity, or attention modulation, are yet unclear.

The effectiveness of directed versus unguided VR sessions is another topic that needs investigation. While unguided sessions let users explore VR settings independently, directed sessions incorporate spoken instructions. Both approaches have potential. However, Chandrasiri et al. (2020) underlined the need for more studies to ascertain their success in objectives like stress reduction or emotional well-being. By reducing distractions and creating peaceful virtual environments, VR may enable deeper engagement that is difficult to achieve in conventional settings. However, with the rapid advancements in virtual reality (VR), a new question emerges: Can VR's immersive environments enhance the mindfulness experience, providing deeper engagement and more significant benefits?

This study examines whether VR-based mindfulness is more effective than traditional methods in reducing stress and enhancing well-being. Two hypotheses were tested: (1) VR-based mindfulness will lead to greater stress reduction and engagement than traditional techniques, and (2) Longer mindfulness sessions will produce greater benefits than shorter sessions. Studies on VR-based mindfulness may have broad implications for human factors, particularly in high-stress fields like healthcare, aviation, and business environments where mental health and performance are essential. Finding out if virtual reality (VR) can promote mindfulness more effectively than conventional techniques may pave the way for stress-reduction strategies suited to users' requirements and surroundings, promoting enhanced performance, safety, and health.

## **METHOD**

### **Design and Participants**

A 2 × 2 between-subjects design with Method (VR vs. Traditional) and Duration (8 vs. 16 minutes) as independent variables was designed. 40 participants (19 males, 21 females; ages 18–45) from the university community participated in this study. Inclusion criteria required fluent English, everyday or corrected-to-normal vision, and mild to moderate stress levels. Individuals with acute mental health concerns, epilepsy, severe cybersickness susceptibility, or regular meditation practice were excluded.

### **Materials and Procedure**

VR participants used a Meta Quest 2 headset with a custom Unity-designed underwater environment featuring a jellyfish whose expansion/contraction cued inhalation/exhalation, as shown in Figure 1. Additional aquatic elements, such as schools of fish and a whale, were incorporated to deepen immersion and sustain visual engagement. The VR mindfulness environment was intentionally designed to support clarity, comfort, and cognitive ease

during breathing exercises. To ensure an intuitive experience, several user interface (UI) and visual design principles were applied, guided by human factors considerations and mindfulness research such as User Viewpoint and Visual Framing, Textual Support and Instructional Clarity, and Clear Differentiation Between Inhale and Exhale Animations.

Traditional participants listened to identical audio instructions on a laptop. Both conditions included left-nostril and ocean breathing techniques (5-second inhale, 5-second hold, 5-second exhale). Physiological responses using GSR devices (electrodermal activity) and Zephyr BioHarness 3.0 (heart rate, HRV, breathing rate) were collected during the session.

Before the study session, participants were randomized to one of the four experimental conditions. Post informed consent, the sensors were placed on the participants, and baseline measures (Perceived Stress Scale (PSS), Mindful Attention Awareness Scale (MAAS)) were collected. Participants completed their assigned 8 or 16-minute session with continuous physiological monitoring, then completed post-session questionnaires. VR participants additionally completed the System Usability Scale (SUS). The collected data was processed using Excel and change scores were computed. Statistical analysis was conducted using a  $2 \times 2$  between-subjects ANOVAs in SPSS to examine effects on  $\Delta$ HR,  $\Delta$ HRV,  $\Delta$ BR, and  $\Delta$ SI.



**Figure 1:** VR breathing interface featuring an animated jellyfish within a custom underwater environment, designed to guide paced inhalation and exhalation.

## RESULTS

### Physiological Outcomes

Descriptive statistics for all physiological outcome variables across Method and Duration are summarized in Table 1. The physiological analyses were conducted on data from 40 participants assigned to VR or Traditional mindfulness conditions and to either 8 or 16-minute session durations. A series of  $2 \times 2$  between-subjects ANOVAs examined the effects of Method and Duration on physiological and self-report outcomes using a significance level of 0.05. Given the modest sample size ( $N = 40$ ) and the resulting limited statistical power, interpretation emphasizes effect directionality, convergence across measures, and theoretical plausibility rather than sole reliance on p-values.

**Table 1:** Descriptive statistics (Mean  $\pm$  SD) for physiological outcome variables across mindfulness conditions.

Outcome Variable	Traditional – Short (8 min)	Traditional – Long (16 min)	VR – Short (8 min)	VR – Long (16 min)
$\Delta$ HR (bpm)	-1.20 $\pm$ 10.7	-0.07 $\pm$ 2.28	-4.99 $\pm$ 8.69	-3.24 $\pm$ 5.78
$\Delta$ BR (breaths/min)	-5.89 $\pm$ 3.14	-5.79 $\pm$ 3.79	-2.69 $\pm$ 4.46	-3.11 $\pm$ 2.32
$\Delta$ HRV (RMSSD)	12.07 $\pm$ 24.83	15.70 $\pm$ 15.54	7.17 $\pm$ 21.98	7.69 $\pm$ 16.44
$\Delta$ SI	-0.64 $\pm$ 0.53	-0.65 $\pm$ 0.35	-0.44 $\pm$ 0.45	-0.43 $\pm$ 0.37
z-GSR	0.22 $\pm$ 1.31	-0.43 $\pm$ 0.09	0.19 $\pm$ 0.70	0.02 $\pm$ 1.35

*Note.* Method was coded as Traditional audio-guided mindfulness and VR-based mindfulness. Duration was coded as Short (8 minutes) and Long (16 minutes). Values represent mean change scores ( $\pm$  standard deviation) unless otherwise noted. z-GSR values reflect mean z-normalized skin conductance across the session.

### Breathing Rate ( $\Delta$ BR)

Analysis of breathing rate revealed a significant main effect of Method, where Traditional methods produced significantly larger reductions ( $M = -5.8$  breaths/min) than VR ( $M = -2.9$ ;  $p < .05$ ), indicating more effective respiration slowing. In other words, audio-guided mindfulness may be more effective in directly influencing paced or conscious breathing.

### Heart Rate ( $\Delta$ HR)

No statistically significant main effects or interactions were observed for heart rate change. Descriptive statistics indicated that VR demonstrated greater reductions in heart rate ( $M = -4.1$  bpm) than Traditional ( $M = -0.6$  bpm), indicating more substantial cardiovascular calming effects. This pattern was consistent across both session durations, suggesting that VR-based mindfulness may promote greater cardiovascular downregulation.

### Heart Rate Variability ( $\Delta$ HRV)

Although no significant effects emerged for HRV, descriptive trends showed that traditional participants showed nearly double the improvement in HRV ( $M = 13.88$  ms) compared with VR ( $M = 7.4$  ms), suggesting better autonomic regulation and greater parasympathetic activation.

### Stress Index ( $\Delta$ SI)

No significant main or interaction effects were detected for the Stress Index. Both mindfulness modalities produced small reductions, with the Traditional condition again showing slightly stronger decreases. The inferential implication is that acute, single-session mindfulness interventions may exert only modest effects on composite stress indices, particularly when participants begin with relatively low baseline stress.

### **Skin Conductance (z-GSR)**

No significant main or interaction effects were detected for skin conductance. However, a descriptive pattern was observed wherein for the Traditional methods also showed lower z-GSR values, particularly in the 16-minute condition ( $M = -0.4$ ), indicating greater reduction in sympathetic arousal. This finding suggests that while VR may enhance engagement, it may simultaneously maintain a level of sensory stimulation that limits reductions in sympathetic nervous system activity. Inferentially, the GSR results converge with HRV and Stress Index trends, reinforcing the conclusion that Traditional mindfulness more consistently promotes physiological relaxation, whereas VR may operate through different experiential pathways.

### **Self-Report Survey Outcomes**

Self-report measures revealed modest patterns across conditions. VR participants showed a slight decrease in stress on the PSS ( $M_{\text{change}} = -0.9$ ), while Traditional participants showed minimal change ( $M_{\text{change}} = +0.4$ ), though neither reached statistical significance and the effect sizes were negligible. Inferentially, perceived stress may require repeated practice or longer interventions to change reliably, and self-report measures may be less sensitive to short-term state fluctuations than the physiological measures. Both modalities produced positive shifts on the MAAS: Traditional ( $M_{\text{change}} = +2.0$ ) and VR ( $M_{\text{change}} = +2.8$ ), indicating modest improvements in mindful attention. The results might allude to the notion that brief mindfulness exposure could nudge mindful awareness but is probably insufficient to produce robust or reliable shifts, regardless of delivery modality. Finally, for the SUS scale, it was observed that the VR participants rated the system highly on the SUS ( $M = 77.9$ ,  $SD = 8.4$ ; range 60.0–90.5), indicating “Good” usability and high user acceptance. This might be a good finding since it could rule out poor usability as a confounding factor for the VR condition.

## **DISCUSSION**

This study compared VR and traditional audio-guided mindfulness in brief, single-session contexts. With respect to Hypothesis 1, which predicted greater stress reduction and engagement for VR-based mindfulness, the hypothesis was not supported overall. Descriptive statistics indicated that the traditional audio-guided condition exhibited stronger relaxation-related trends across breathing rate, heart-rate variability, stress index, and electrodermal activity. In contrast, VR-based mindfulness demonstrated slightly greater reductions in heart rate and higher perceived usability. Secondary analyses indicated a significant Method effect for the stress index ( $\Delta SI$ ) as well as trend-level Method effects for  $\Delta HR$  and  $\Delta BR$ , suggesting that physiological responses may differ by modality depending on the metric examined. Regarding Hypothesis 2, which predicted greater benefits for longer sessions, the hypothesis was not supported in the primary statistical analyses. The session duration did not yield consistent main effects across physiological and

self-report measures. However, descriptive trends indicated greater reductions in breathing rate during the 16-minute sessions compared with the 8-minute sessions, although this difference did not reach statistical significance. Although secondary analyses using percentage change scores indicated significant Duration effects for percent heart-rate change, these findings were not consistent across raw change metrics and should be interpreted cautiously. While the primary  $2 \times 2$  between-subjects ANOVAs conducted on change-score measures did not reveal consistent main effects of Method or Duration across all outcomes, the results indicate measure-specific and trend-level differences in physiological responses between mindfulness delivery modalities. Traditional audio-guided mindfulness demonstrated more stable relaxation-related patterns across several autonomic indicators, including breathing rate, heart-rate variability, electrodermal activity, and stress index, suggesting that familiar, non-immersive contexts may reduce cognitive load and support sustained physiological regulation. In contrast, VR-based mindfulness produced slightly greater reductions in heart rate and showed evidence of method-dependent effects for certain measures, including a significant Method effect for stress index and marginal effects for heart rate and breathing-rate changes. These findings suggest that immersive environments may facilitate initial calming responses, even if broader autonomic regulation is less consistent during short exposure periods.

Self-report outcomes further contextualize these physiological patterns. Perceived stress levels remained largely unchanged, and mindful awareness increased only modestly across both conditions, reinforcing the idea that brief, single-session mindfulness interventions may be insufficient to alter stable psychological constructs. Notably, the VR condition received high usability ratings, indicating that participants found the immersive experience intuitive and engaging despite its limited short-term physiological advantages. Collectively, these findings suggest that VR is a feasible and acceptable platform for mindfulness delivery, with potential modality-specific benefits that depend on the outcome measure examined. The results highlight the importance of considering sensory load, user familiarity, and design elements when implementing immersive mindfulness systems and suggest that combining immersive visuals with features that enhance emotional comfort and attentional stability may be necessary to achieve stronger regulatory effects. These implications are further addressed in the following sections.

## LIMITATIONS

The small sample size constrained statistical power, however, the predominance of non-significant findings should not be interpreted as evidence of no effect. Single, brief sessions (8–16 minutes) might not yield quantifiable psychological changes that require consistent practice. External factors, such as sleep, coffee intake, and individual variability, may affect physiological markers. Some participants reported discomfort with the VR headset, which may have affected relaxation.

## FUTURE DIRECTIONS

Future studies should increase sample sizes, investigate multiple sessions spread over several weeks, incorporate customized audio guidance (e.g., familiar voices), use adaptive virtual reality environments that respond to real-time physiological feedback, provide customizable settings, and assess efficacy across a range of populations experiencing chronic stress or anxiety.

## CONCLUSION

In summary, while statistical power was limited by sample size ( $N = 40$ ), meaningful patterns emerged. Traditional methods demonstrated more stable relaxation across multiple autonomic indicators (breathing rate, HRV, stress index, GSR), suggesting that familiar, non-immersive contexts may reduce cognitive load and support sustained physiological regulation. VR produced slightly greater heart rate reductions and received high usability ratings, indicating strong engagement despite limited physiological advantages in brief sessions. The lack of significant changes in perceived stress and mindfulness awareness reinforces that single, brief sessions may be insufficient to alter stable psychological constructs. However, VR's high usability (77.88 SUS) demonstrates its feasibility and acceptability as a mindfulness platform.

The results of this study seem to indicate that VR-based mindfulness offers an immersive, engaging platform with high usability that performs comparably to traditional methods in brief sessions. Traditional methods produced stronger physiological relaxation across most measures, while VR showed advantages in heart rate reduction and user engagement. With enhancements such as personalized audio, adaptive environments, and extended practice, VR has the potential to be a powerful tool for stress reduction and mental wellbeing.

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