Comparing Flow, Enjoyment, and Stress Responses in Desktop and Immersive Virtual Reality Gaming Environments

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ABSTRACT

Although immersive video games have been extensively developed, gamers often prefer traditional desktop setups. The aim of this study is to compare user enjoyment and the possibility of entering flow states (defined as states of enhanced focused attention and absorption) while playing a narrative-style video game in two different environments: a regular desktop computer and an immersive virtual reality (VR) environment.

Twenty-five participants played the game for 30 minutes in each environment across two consecutive days, with the order of environments randomized. Electrocardiography was employed to measure heart rate variability (HRV), a physiological indicator of autonomic nervous system activity and stress. Cognitive engagement was assessed using attentional tests administered before and after each gaming session. Post-session questionnaires evaluated motion sickness and the effect of presence.

Attentional test performance improved significantly in both conditions, suggesting equivalent cognitive engagement across the two gaming environments. However, reported enjoyment and the frequency of entering flow states were significantly lower in the VR condition. Although the VR condition elicited significantly higher presence ratings, indicating a stronger sense of immersion, it also resulted in higher levels of motion sickness. Importantly, motion sickness was correlated with increased physiological stress, as evidenced by changes in HRV during the VR condition.

These findings demonstrate that while VR gaming enhances immersion and may support flow experiences, motion sickness induces stress, which in turn reduces enjoyment and impairs the ability to achieve a state of flow. Addressing motion sickness is essential for improving user experience in immersive VR gaming environments.

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INTRODUCTION

In today's competitive gaming industry, companies strive to distinguish themselves by creating emotionally resonant experiences. One effective approach is the integration of narratives, which have long shaped how people engage with media. Narratives influence perception, interaction, and emotional investment, and research by Naul and Liu (2020) shows that their inclusion in serious games enhances engagement, immersion, and motivation—key factors for player retention. While these benefits are well-documented in serious games, this study explores whether similar effects occur in first-person shooter (FPS) games, a genre traditionally driven by action rather than story. Despite the popularity of narrative-driven games, there is limited empirical evidence on the role of narration in FPS contexts. This study aims to address that gap by examining whether narrative elements increase player engagement and contribute to enhanced cognitive states. These states, often described as "flow state" (Csikszentmihalyi, 1975) or "peak experiences" (Maslow, 1962), are marked by deep focus, altered time perception, and intrinsic satisfaction (Csikszentmihalyi, 1990, 1997). In gaming, flow typically occurs when challenges are well-matched to a player's skill level, maintaining optimal engagement (Csikszentmihalyi, 1990).

Kozhevnikov et al. (2018) found that 30 minutes of FPS gameplay can induce flow, characterized by improved temporal and visuospatial attention and associated with decreased high-frequency (HF) components of heart-rate variability (HRV). Their later work (Kozhevnikov et al., 2022) identified two key conditions for eliciting flow in FPS games: an egocentric (first-person) perspective and adrenaline-fueled gameplay. These elements, when combined, create optimal conditions for flow, with the parasympathetic nervous system (PSNS) playing a central psychophysiological role. This study investigates whether narrative elements and immersive technologies like virtual reality (VR) can enhance flow in FPS games.

While FPS games are known to induce flow, the role of narrative in this process remains underexplored. Schneider (2004) found that narrative elements can deepen emotional engagement and immersion in FPS games. Factors such as character identification, presence in the game world, and emotional resonance significantly influence engagement. Designers aim to create narratives that make players feel like active participants, either through decision-making agency or relatable characters and storylines. Character identification enhances emotional investment, which may facilitate flow. Schneider also emphasized the importance of emotional valence (tone) and dominance (sense of control) in narrative design. These elements shape how players interact with the story and influence their emotional responses. In FPS games, the egocentric perspective may amplify this involvement, making players feel directly embedded in the narrative. However, narrative-driven games may lack the adrenaline-pumping intensity typical of traditional FPS titles, potentially limiting flow induction. Still, the emotional engagement fostered by narrative and egocentric perspective may compensate for this, a hypothesis this study aims to test.

As immersive technologies become increasingly integrated into everyday life, virtual reality (VR) has emerged as a transformative medium, reshaping how people engage with entertainment and media. Its applications span from leisure to professional domains, offering experiences that transcend the limitations of traditional formats. VR has also been adopted in contemporary theatre to enhance audience immersion. According to Iudova-Romanova et al. (2023), VR enables more interactive and engaging performances while expanding the theater's reach beyond physical venues. This ability to foster visceral, interactive narrative experiences suggests that VR could have a similar effect in FPS games. If VR can heighten emotional involvement in theater, it is reasonable to expect that it could also amplify narrative impact in FPS games, thereby increasing player engagement and enjoyment.

Pallavicini et al. (2019) explored emotional responses and the sense of presence in games played in immersive (VR) versus non-immersive (desktop) formats. Using a game that featured both an egocentric perspective and adrenaline-inducing gameplay, they employed self-report questionnaires and psychophysiological measures. Their findings showed that VR significantly enhanced emotional responses and the sense of presence, suggesting that VR's immersive nature can intensify flow by deepening emotional engagement and spatial immersion. Similarly, Shelstad et al. (2017) examined the effect of VR on overall user satisfaction in a non-egocentric, adrenaline-driven game. They found that VR significantly increased enjoyment and the intensity of the gaming experience. These results highlight VR's potential to elevate player satisfaction and contribute to the induction of flow in FPS games.

However, despite its benefits, VR also presents challenges, most notably motion sickness, which can undermine immersion and hinder flow induction. Chang et al. (2020) identified that motion sickness arises from a mismatch between the visual and vestibular systems. In VR, users perceive motion visually, but the vestibular system does not detect corresponding physical movement, leading to sensory conflict. Factors such as motion speed, field of view, and head movement can exacerbate this mismatch, increasing discomfort. Ohyama et al. (2007) investigated the physiological effects of VR-induced motion sickness on heart rate variability (HRV). Participants exposed to visual-vestibular conflicting imagery for 14 minutes showed a significant increase in the low-frequency (LF) to total power (TP) ratio, with no significant change in the high-frequency (HF) to TP ratio. These results suggest that while motion sickness may not affect parasympathetic nervous system (PSNS) activity, it could influence cognitive engagement by increasing cognitive load, potentially impairing performance on tasks like the attentional blink task (ABT). Based on these findings, this study hypothesizes that VR will enhance flow due to its immersive qualities, even when accounting for the effects of motion sickness. While motion sickness may impact ABT performance, it is not expected to significantly alter HF-HRV, allowing for a clearer assessment of flow induction.

Building on existing research on enhanced cognitive states (flow states) and player enjoyment, this study aims to investigate the role of narrative and immersive technologies in inducing flow within the context of first-person shooter (FPS) games. Specifically, it addresses two central research questions: (1) Does the incorporation of narrative elements in FPS games lead to enhanced flow? and (2) Can the integration of virtual reality (VR) amplify the effects of narrative on flow and increase overall enjoyment? To explore these questions, the study will assess flow through two primary indicators: improvements in attentional blink task (ABT) performance and reductions in high-frequency heart rate variability (HF-HRV) before and after gameplay. It is hypothesized that these effects will be more pronounced in the VR condition. Additionally, the VR modality is expected to enhance enjoyment, as reflected in stronger character identification, a heightened sense of presence, and more positive emotional responses. The study also considers the potential impact of motion sickness, anticipating that while it may impair ABT performance in the VR condition, it will not affect HF-HRV in either modality. In contrast, motion sickness is not expected to influence either variable in the non-immersive condition. Through this investigation, the study seeks to clarify the combined effects of narrative and VR on cognitive and emotional engagement in FPS games, contributing to a deeper understanding of how immersive storytelling can shape player experience.

DESIGN AND METHODOLOGY

Design

This study employed a within-subjects design, where participants engaged in gameplay under two conditions: VR and NonVR. The order of condition exposure was randomized to control for order effects. The dependent variable for this study included electrocardiogram (ECG) data and results from cognitive tests and questionnaires. The quantification method for these variables will be elaborated upon in subsequent sections.

Participants

Twenty-nine undergraduate students (20 female, 9 male) aged between 19 and 24 (M=21.00, SD=1.36) were recruited for this study. The sequence of conditions was randomly assigned, although the assignment became unequal due to participants dropping out midway through the experiment. This resulted in 13 participants completing the VR condition first, followed by the NonVR condition, and 16 participants completing the NonVR condition first, followed by the VR condition.

Materials

Electrocardiogram (ECG) Monitoring

Participants' ECG data were continuously recorded throughout the experiment using the Biopac MP160 System (Biopac Systems, Inc., USA), coupled with the BioNomadix RSP with ECG Amplifier (Biopac Systems, Inc., USA). The system was configured to capture physiological signals at a sampling rate of 2000 Hz, with a bandwidth ranging from 0.05 Hz to 150 Hz. ECG signals were transmitted wirelessly via the BioNomadix transmitter, ensuring minimal disruption to participants' movements. AcqKnowledge software (Version 5.0, Biopac Systems, Inc., USA) was used to record and process the data in real time.

Cognitive Tasks

Attentional Blink (AB) refers to a phenomenon resulting from the "temporal limits of the deployment of selective attention" (Dux & Marois, 2009, p. 1683). In the ABT, a sequence of black letters was rapidly presented, one by one, on a grey background at the center of the screen (see Figure 1). Participants were then asked to identify a single white letter (Target 1, T1) and determine whether the letter "X" (Target 2, T2) appeared after it. T2 was only present in 50% of the trials. Each letter was presented for 16.7 ms, followed by an 83.3 ms inter-stimulus interval (ISI). The number of letters in the sequence ranged from 16 to 24, with the white letter appearing unpredictably between the 8th and 16th positions in the sequence. The test included four ABT lags (2,3,4, and 7), where T2 appeared at specific lag times after T1 (lag-2, 200ms; lag-3, 300ms; lag-4, 400 ms; and lag-7, 700ms). Previous research has identified the AB window as approximately 500 ms (Shapiro et al., 1997). Therefore, lag-2 to lag-4 were within this window, while lag-7 fell outside of it. The ABT consisted of 56 trials with 7 trials per lag. It was scored for the accuracy of T2 detection, given that T1 had been correctly identified, denoted as T2|T1 accuracy.

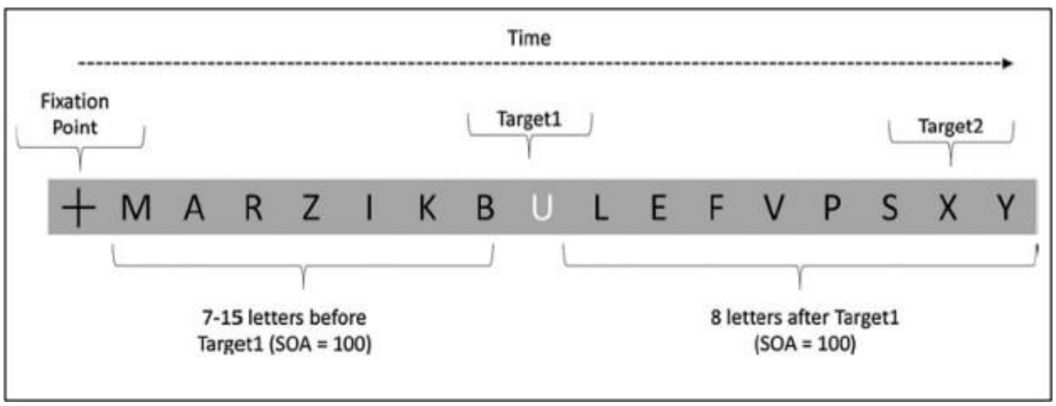

Figure 1. ABT Paradigm

Game Stimuli

The game, Half-Life: Alyx, was chosen as the gaming stimuli for this experiment (see Figure 2). In the segment of the game where the participants play, the main character, Alyx, is on a mission to save her father, who has been captured by evil forces. Participants played the game on two different modalities: VR and the computer (NonVR). In the VR condition, participants played the game using the Meta Quest 2 VR headset. In the NonVR condition, participants play the game on a standard computer setup. A NonVR mode was downloaded to allow gameplay without the VR headset.

Questionnaires

All questionnaires were administered through Qualtrics, an online survey platform.

<u>Pre-Gaming Questionnaire</u>: This questionnaire collected demographic information, including gender, age, and gaming experience.

Post-Gaming Questionnaire: This questionnaire assessed several factors related to the gaming experience. The same questionnaire used in Schneider (2004) was employed to assess identification with the character and presence in the game world. The Self-Assessment Manikin (SAM) (Lang et al., 1993) was used to capture participants' emotional experience. The SAM measures key emotional factors, including valence, arousal, and dominance, which were discussed in the introduction as essential for understanding the emotional experience. To supplement the SAM, the Positive and Negative Affect Schedule (PANAS) (Watson et al., 1988) was added to assess positive and negative emotional states of participants after gameplay. The Simulator Sickness Questionnaire (SSQ), developed by Kennedy et al. (1993) was used to assess the presence and severity of any induced motion sickness from the gameplay.

Debrief Questionnaire: Lastly, this questionnaire utilized qualitative questions to gather participants' reflections regarding their gameplay experience during the past two sessions.

Figure 2. A screenshot of the Half-Life: Alyx game.

Procedure

First session

When participants first arrived, they were outfitted with an electrocardiogram (ECG) monitor. Three small electrodes, placed on the collarbones and lower left rib, collected heart rate data throughout the experiment. They then completed ABT. Next, they watched a 10-minute gameplay of the first chapter of the game, sourced from YouTube (GamerMax Channel, 2021). The video has been edited to include relevant storyline elements to prevent participant boredom. Afterward, participants completed a trial to familiarize themselves with the game controls on their assigned modality for that session. Once familiarized with the controls, the participants will play the game on their assigned modality for 30 minutes. After gameplay, all participants retook the ABT and completed the post-game questionnaire, in this specific order.

Second Session

Participants then returned on a separate day, within two weeks of the first session. They watched the last 10 minutes of what they had played in the previous session, sourced from the same gameplay video on YouTube (GamerMax Channel, 2021). Afterwards, they completed another trial again to reacquaint themselves with the game controls for the session's modality. Participants then resumed gameplay for 30 minutes, starting from where they had left off in the previous session. After gameplay, all participants retook the ABT and completed the post-game questionnaire. Finally, participants completed the debrief questionnaire.

RESULTS

Three participants were excluded from the ABT results but still have their HRV data kept as these participants did not show the expected AB effect (nonblinker) based on the definition provided by Martens et al. (2006). Three additional individuals were excluded from the analysis because they exhibited unusually high changes in either LF or HF-HRV, which were identified as outliers. Twenty-three people were therefore left in the ABT performance analysis, while twenty-six people were left in the HF-HRV analysis.

Analysis for Flow States

HRV analysis

In this analysis, HF-HRV was used as an indicator of PSNS activity, as discussed in the introduction. For this analysis, HF-HRV normalized was used, where it refers to adjusting the frequency bands, LF and HF, relative to the total power of the HRV spectrum. This standardization allows for consistent comparisons across subjects and conditions. Less noisy segments, 5 minutes for the NonVR condition, and 3 minutes for the VR condition, were selected for this analysis. The pre-game segment falls before, while the post-game segment falls after the 30-minute gaming session. A repeated measures ANOVA was conducted to assess the effects of modality and time on HF-HRV (see Figure 3). A significant main effect for modality was found, $F(1,25) = 25.34$, $p < .001$, suggesting a significant difference in HF between the VR and NonVR conditions. Furthermore, there was a significant main effect of time on HF, $F(1,25)=6.03$, $p=.021$, indicating a significant change in HF-HRV from pre-game to post-game. However, no significant interaction effect was found between modality and time, $F(1,25)=0.08$, $p=.780$, suggesting that the change in HF-HRV was consistent across both VR and NonVR conditions.

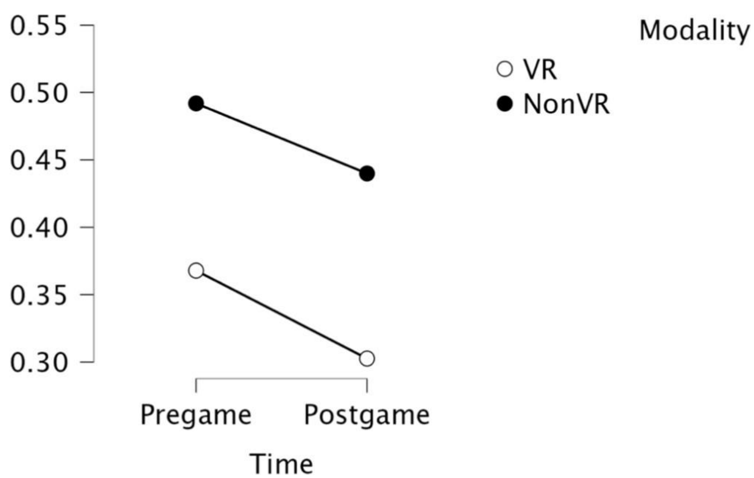

Figure 3. Normalized HF-HRV across two time points (Pregame and Postgame) for VR and NonVR Conditions.

A separate repeated measures ANOVA analysis was also conducted for VR and NonVR conditions, using motion sickness scores for the respective conditions as a covariate, to control for the effects of motion sickness. This approach ensures that any observed changes in HF-HRV can be attributed to the gaming modality, rather than the motion sickness. The independent variable in this analysis is time, pre-game and post-game, and the dependent variable is HF-HRV normalized. For the VR condition, the main effect of time was not significant, $F(1,24)=0.20$, $p=.659$, indicating no significant increase in HF-HRV from pre-game to post-game in the VR condition. The interaction between time and motion sickness in VR was not significant, $F(1,24)=0.82$, $p=.376$, suggesting that motion sickness did not have an effect on HF-HRV. For the NonVR condition, the main effect of time was also non-significant, $F(1,24)=1.51$, $p=.232$. Likewise, the interaction between time and motion sickness in the NonVR condition was not significant, $F(1,24)=0.71$, $p=.409$.

ABT performance

The ABT score was calculated as the average of T2|T1 accuracy across three lags, lag 2, lag 3, and lag 4. A repeated measures ANOVA (see Figure 4) revealed that the main effect of modality on the ABT scores was not significant, $F(1, 22)=0.02$, $p=.893$. This suggests that the type of modality did not significantly affect the ABT performance. The main effect of time on the ABT scores was also not significant, $F(1, 22)=0.20$, $p=.665$. This indicates that the game did not significantly influence the participants' performance in the ABT. There was no significant interaction between modality and time, $F(1,22)=2.08$, $p=.164$. This suggests that the effect of modality did not change significantly over time, and the two factors acted independently in influencing the ABT scores.

A repeated measures ANOVA was also conducted for the VR and NonVR conditions separately, with motion sickness scores as a covariate. In the VR condition, the results revealed a significant main effect of time on the ABT performance, $F(1,21)=7.31$, $p=.013$, indicating that performance was significantly better post-game (M=0.44, SD =0.16) compared to pre-game (M=0.48, SD=0.19). Additionally, there was a significant interaction between time and motion sickness in the VR condition, $F(1,21)=9.61$, $p=.005$, suggesting that motion sickness significantly influenced the change in ABT performance across time. For the NonVR condition, the main effect of time was not significant, $F(1,21) = 0.05$, $p=.830$, indicating that there was no difference in ABT performance between pre and post gaming. Furthermore, the interaction between time and motion sickness was not significant, $F(1,21)=6.29 \times 10^{-4}$, $p=.980$, suggesting that motion sickness did not impact performance over time in the NonVR condition.

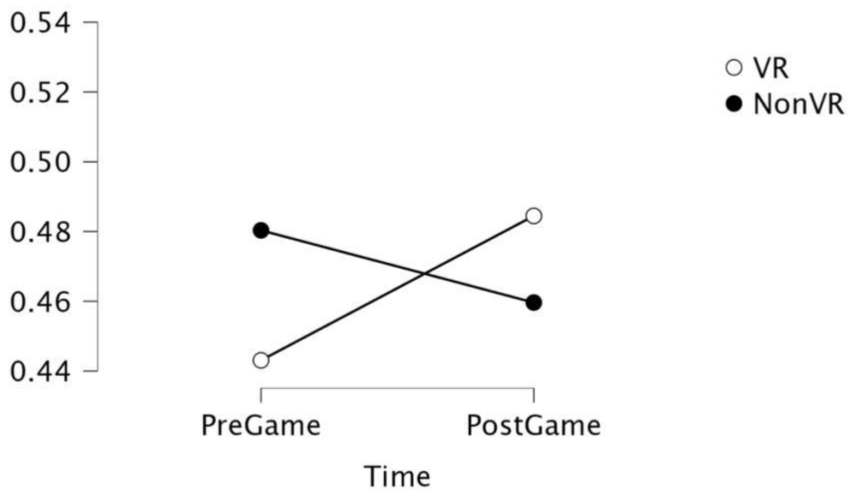

Figure 4. ABT score across two time points (Pregame and Postgame) for VR and NonVR Conditions.

Participants in flow

From the pool of participants, those who did not experience flow in either VR or NonVR conditions were identified. These participants exhibited a decrease in ABT performance, an increase in raw LF-HRV, and a decrease in raw HF-HRV across both conditions. A total of 7 participants met these criteria, meaning that 18 participants, 72.0% of participants, were able to enter flow in either VR or NonVR conditions.

Post-Gaming Questionnaire

A paired sample t-test revealed significant differences observed in some of the measures between the VR and NonVR conditions. For presence, participants reported significantly greater presence in the VR (M=15.54, SD=4.15) condition than in the NonVR (M=10.27, SD=3.95) condition, $t(25)=4.86$, $p<.001$. Additionally, there was a significant difference in motion sickness scores, where participants experienced more motion sickness in the VR condition (M=28.27, SD=7.18) than in the NonVR condition (M=22.69, SD=5.72), $t(25)=4.56$, $p<.001$. However, identification, $t(25)=1.05$, $p=.304$, valence, $t(25)=-0.62$, $p=.542$, arousal, $t(25)=1.48$, $p=.152$, and dominance, $t(25)=-2.04$, $p=.052$ did not show significant differences.

For the PANAS scales, negative affect was significantly higher in the VR condition ($M=30.39$, $p=9.93$) than in the NonVR condition ($M=25.96$, $SD=8.17$), $t(25)=2.11$, $p=.045$, indicating that participants experienced more negative feelings in the VR condition. No significant differences were found in positive affect between the conditions, $t(25)=1.50$, $p=.147$.

Qualitative Data

According to the debrief survey, participants' responses regarding their interest in continuing to play the game were divided equally. A total of 15 participants indicated that they would like to continue playing, while the other 14 participants expressed that they would not. Some were enticed by the game's plot, while others expressed disinterest in gaming or a preference for more competitive, fast-paced games. When asked about their preferred modality, 15 participants preferred to play the game on the computer (NonVR), while 14 expressed a preference for the VR modality. Notably, participants who preferred the VR modality mentioned that the game's immersive experience contributed to their enjoyment, while those who preferred the NonVR modality noted that the discomfort from the motion sickness arose from the headset.

DISCUSSION

This study examined the impact of gaming modality and narrative on players' cognitive and emotional experiences, particularly focusing on the induction of enhanced cognitive states (flow states) in FPS games. The results revealed a significant improvement in attentional blink task (ABT) performance following gameplay in the VR condition, after controlling for the effects of motion sickness. No such improvement was observed in the NonVR condition. Additionally, there were no significant changes in high-frequency heart rate variability (HF-HRV) in either condition, suggesting that neither modality elicited substantial parasympathetic nervous system (PSNS) activation. Taken together, these findings indicate that neither the VR nor the NonVR condition successfully induced flow, contrary to the initial hypotheses. However, motion sickness was found to significantly affect ABT performance in the VR condition, highlighting its potential to interfere with cognitive outcomes.

Post-game questionnaire data further revealed that participants in the VR condition reported significantly higher levels of presence, negative effect (as measured by PANAS), and motion sickness compared to those in the NonVR condition. However, no significant differences were found in character identification or positive effect. Similarly, no significant differences emerged in emotional arousal, as measured by the Self-Assessment Manikin (SAM), which assessed valence, arousal, and dominance. These results suggest that while VR enhances the sense of presence, it does not necessarily translate into greater emotional engagement or enjoyment.

One of the key findings of this study is that narrative-driven FPS games may not induce flow or enjoyment to the same extent as traditional FPS games, as previously observed by Kozhevnikov et al. (2018, 2022). A potential explanation lies in the level of emotional engagement that the narrative elicits. Busselle and Bilandzic (2009) identified emotional engagement as a critical factor in making compelling narratives. However, qualitative feedback from participants indicated that some struggled to relate to the characters, storyline, or game objectives, which likely limited their emotional involvement and, consequently, their ability to enter flow. Future studies should consider comparing identification levels between traditional and narrative-driven FPS games to better understand this dynamic.

Elsaesser (2014) offers an alternative perspective on narrative in video games, noting that while narratives are typically structured with clear progression, the interactive nature of games introduces branching paths and nonlinear experiences. This can create tension between narrative coherence and player agency. Although games offer the illusion of freedom, they still operate within predetermined structures, which may limit true interactivity. As a result, narrative and gameplay mechanics may sometimes work against each other, reducing player engagement and the likelihood of achieving flow.

Another important observation is that the immersive quality of VR did not increase the occurrences of flow states as initially expected. Although participants in the VR condition reported a significantly higher sense of presence, this did not correspond with improved ABT performance or reduced HF-HRV. This suggests that presence alone may not be sufficient to induce flow. One possible explanation is the disruptive effect of motion sickness, which may have prevented participants from fully engaging in the game. Qualitative responses indicated that while some participants appreciated the immersive nature of VR, others experienced increased stress, potentially due to overstimulation or the fear-inducing elements of the game. This is supported by the significantly higher negative effect scores in VR condition. However, the literature on how VR immersion contributes to both positive and negative emotional responses remains limited, and future research should explore this dual impact more thoroughly.

It is also essential to consider individual differences in gameplay experiences, as these can significantly influence cognitive and emotional engagement. Factors such as reaction time, familiarity with game mechanics, and personal preferences may affect the likelihood of entering flow. This highlights the need for future studies to account for individual variability when examining the effects of narrative and immersion on player experience.

Our findings highlight the need for thoughtful design of virtual learning environments, particularly in STEM education, where immersive technologies are becoming increasingly common. Motion sickness emerged as a key factor that can undermine both learning effectiveness and student enjoyment in VR settings, emphasizing the importance of limiting the duration of VR activities, designing them carefully, and considering individual differences in motion sickness susceptibility, which should ideally be assessed early in the process. Beyond these practical recommendations, our use of physiological measures, such as HRV, to monitor student involvement in learning processes in terms of arousal offers a broadly applicable tool for understanding student engagement in various educational settings. Since decreases in HF HRV reflect greater involvement and enjoyment, this approach could be valuable for evaluating how different instructional environments affect learning. Together, these results suggest that combining careful technological design with physiological monitoring can help maximize the benefits of immersive learning while minimizing drawbacks such as motion sickness.

To summarize, this study contributes to the growing body of literature by investigating how narrative and VR, individually and in combination, affect flow and enjoyment in FPS games. The findings offer valuable insights for game developers seeking to design more immersive and engaging experiences. As immersive technologies continue to evolve, developers should prioritize reducing motion sickness to lower barriers to VR adoption. Additionally, understanding the target audience's motivations, preferences, and emotional drivers is crucial for crafting narratives that resonate and sustain player engagement over time.

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