Impact of Visual Embellishments on Player Experience in Virtual Reality Exergames

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Abstract

Virtual Reality (VR) has been widely adopted to improve mental and physical well-being through immersive physical exercises. Visual embellishments (VE), such as enhanced graphics, audio elements, and visual effects, are promising methods to increase user engagement in VR activities. This study examines the influence of VE on player experience and performance in gesture-based VR exergames. 28 adults (aged 18–35 years) participated, playing the VR exergame under two experimental conditions: with and without VE. Results revealed that VE significantly enhanced performance, perceived physical exertion, and overall game experience. These findings highlight VE's potential to design engaging VR interventions that combine physical exercise with emotional well-being.

CCS Concepts

• **Human-centered computing → Virtual reality**; **Graphical user interfaces**.

Keywords

Visual Embellishment, Player Experience, Exergames, Virtual Reality

ACM Reference Format:
Suki Yuanxin Zhang, R. Achintha M. Abayasiri, Yanzhuo Yang, Hai-Ning Liang, Wenge Xu, and Nilufar Baghaei. 2025. Impact of Visual Embellishments on Player Experience in Virtual Reality Exergames. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems (CHI EA '25), April 26-May 1, 2025, Yokohama, Japan.* ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/3706599.3721252

ACM ISBN 978-1-4503-XXXX-X/2018/06
https://doi.org/10.1145/3706599.3721252

1 Introduction

Exergames have long been recognised as an effective method to engage players in physical activities [12]. Virtual reality (VR) exergames, in particular, offer a unique opportunity to immerse players in physical activities within virtual environments [22]. Studies have demonstrated that playing VR exergames not only provides entertainment but also motivates players to adopt active lifestyles, breaking the cycle of sedentary behaviour [21]. Furthermore, research has reported the positive effects of VR exergames on physical and motor skills—including balance, strength, cognition, flexibility, and overall physical functioning—as well as on mental well-being, encompassing mental health, social support, enjoyment, balance confidence, reaction time, and processing speed [5–9, 16, 24, 25].

While prior studies have explored various aspects of VR exergames, such as the role of non-player characters [26], avatar customization [1], and self-competition mechanics [20], the impact of visual embellishments (VEs) on gameplay performance and player experience remains under-explored. VEs involve the integration of sensory and visual elements within the game environment to create a more immersive and enjoyable player experience [4]. Previous research has suggested that highly embellished graphics contribute to a more positive player experience across various game genres with enhanced intrinsic motivation, perceived competence, relatedness, and immersion [11]. However, recent studies indicate that the effects of VEs may vary significantly depending on the game genre and platform [10, 18], with findings in VR exergames[3], showing increased engagement but inconclusive effects on enjoyment and perceived exertion . This highlights the need for further investigation into how VEs specifically influence motivation and performance in VR exergame contexts.

This study aims to address this gap by investigating the impact of visual embellishments (present vs absent) on player experience and performance in a gesture-based VR exergame. By examining how VEs influence key aspects of gameplay, this research contributes to understanding the design elements that optimise player engagement and enjoyment in VR-based physical activity interventions.

2 Methodology

This study utilised a gesture-based monster hunting VR exergame, where participants engaged in physical activity to control their character and perform body gestures to trigger in-game actions aimed at defeating opponents from a first-person perspective. The study protocol was approved by the Human Research Ethics Committee (HREC) of the University.

2.1 Gameplay Design Overview

The VR exergame was designed within a visually engaging stadium-like environment, featuring lush grass, a vibrant blue sky, and a friendly, cartoonish monster as the primary opponent. The intention behind this design was to create an approachable and aesthetically pleasing setting, encouraging participants to engage in physical activity in a relaxed, immersive virtual world (see Fig. 1). Players interacted with the game by performing various physical gestures, including raising both arms (detected as the PSI gesture by the Kinect sensor), hand pushing, leg kicking, and squatting. These movements corresponded directly to in-game actions, with the goal of reducing the monster's health points (HP) to zero. Each gesture executed by the player triggered dynamic visual effects within the game environment, providing real-time feedback and enhancing the immersive experience. A summary of the gestures and their corresponding in-game actions is presented in Table 1.

2.2 Evaluated Conditions

The study followed a within-subjects design with one independent variable—Visual Embellishments (VE)—which had two levels: Visual Embellishments-Present (VE-P) and Visual Embellishments-Absent (VE-A). The primary distinction between the two conditions lies in the presence or absence of VEs, allowing the study to assess their impact on gameplay and player experience.

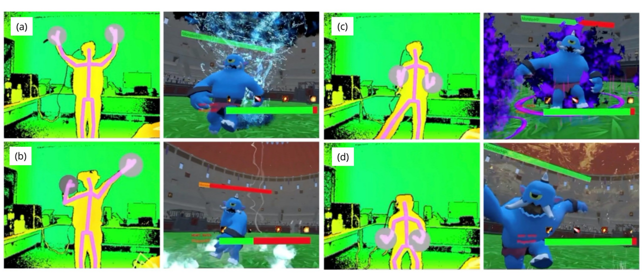

Figure 1: Gesture moves and corresponding in-game skills: (a) PSI (b) Push (c) Kick (d) Squat

Table 1: Gesture Descriptions

Gesture	Description	Cool-down Time
PSI	Raising two arms up	3 seconds
Push	Pushing either left or right hand	3 seconds
Kick	Kicking either left or right leg	3 seconds
Squat	Leaning and performing a squat	3 seconds

2.2.1 VE-P. In the VE-P condition, participants engaged in the game with enriched visual and auditory feedback, including background music, cheering sounds for successful gestures, sound effects for performing attacks, and skill-specific visual effects. As participants performed body gestures to execute attacks, each movement triggered corresponding dynamic visual effects in the VR environment, such as visual flourishes or animated effects that accompanied successful actions (see Fig. 1). This condition aimed to evaluate how these enriched VEs influence gameplay experience, player engagement, and participants' perception of the game's effectiveness, particularly in terms of enjoyment, immersion, and motivation.

2.2.2 VE-A. In contrast, the VE-A condition removed all VE elements, offering a minimalist gameplay experience. Background music, sound effects, cheering, and skill animations were omitted, leaving only the core gameplay mechanics, including the body gestures required to perform attacks. This condition was designed to serve as a baseline for understanding the effects of VEs by comparing the gameplay experience in the absence of sensory embellishments.

By comparing these two conditions, the study comprehensively evaluated the influence of VEs on player performance, subjective player experience, and physiological responses. A counterbalanced design was employed to ensure that participants alternated between VE-P and VE-A as their first and second conditions, minimising potential order effects and ensuring that each participant experienced both levels of the independent variable.

2.3 Participants

A total of twenty-eight participants (M = 27.1 years, SD = 3.5 years, range = 22-35 years; 17 male, 11 female) were recruited to take part in this study. Prior to the session, participants were required to complete the Physical Activity Readiness Questionnaire (PARQ) [14] to evaluate their eligibility for participation. The PARQ acted as a crucial safety measure to assess the participants' physical readiness for the physical activities involved. Only those who passed the PARQ were deemed eligible to participate. Once eligibility was confirmed, participants were provided with an information sheet and were required to sign a consent form before proceeding.

2.4 Experiment Setup and Software Implementation

The experimental setup comprised the following key components: an Oculus Quest 2 head-mounted display (HMD) (Meta, formerly Oculus, Menlo Park, CA, USA), a COOSPO Heart Rate Monitor (HRM) Armband (Shenzhen, Guangdong, China) for heart rate measurements, a Microsoft Kinect 2 sensor (Microsoft Corporation, Redmond, WA, USA) for tracking body movements and gestures to trigger in-game actions within the VR exergame, and a personal computer (PC). The VR exergame was developed using Unity 3D, with integration of the Microsoft Kinect 2 Software Development Kit (SDK) for real-time gesture recognition. The HRM armband communicated with Unity via Bluetooth, enabling the real-time visualization of heart rate data within the VR environment, providing an immersive and interactive experience for participants.

2.5 Outcome Measurement

Player performance was assessed based on two primary metrics: (1) the average game completion time, and (2) the success rate of game completion, defined as the ability to defeat the in-game opponent. To evaluate player experience, several questionnaires were employed: the Game Experience Questionnaire (GEQ) [15] measured key emotional and cognitive responses, including positive affect, negative affect, tension, challenge, competence, flow, and immersion, using a 5-point Likert scale (0 for "not at all" and 4 for "extremely"). Additionally, the Virtual Reality Sickness Questionnaire (VRSQ) [19] was used to assess symptoms of VR sickness, again on a 5-point Likert scale (0 for "None" to 4 for "A great deal"). Participants' perceived physical exertion during gameplay was measured using the Borg Rating of Perceived Exertion (Borg RPE) scale [2], where scores of 12 indicated "moderate" exertion and 13 signified "somewhat hard" exertion. As an alternative and more objective measure of physical exertion, players' heart rate was recorded in beats per minute (BPM) during the gameplay, providing real-time data for analysis.

2.6 Procedure

Eligible participants were outfitted with the HRM armband, VR headset, and controllers, with assistance from the experimenter. Each participant first underwent a training phase for both experimental conditions to become familiar with the equipment and practice the required body-based gestures, which triggered in-game actions. Once participants were comfortable with the gestures and controls, they proceeded to the experimental phase. During this phase, they were instructed to defeat the in-game opponent by reducing its HP to zero through physical movements. Following each experimental condition, participants completed the VRSQ, Borg-RPE, and the GEQ to assess their physical and emotional responses to the game. Between conditions, participants were given the opportunity to rest and recover as needed, allowing their heart rate to stabilize before moving on to the next condition. The entire experiment lasted approximately 30 minutes, including around 10 minutes of active gameplay.

3 Results

Paired t-tests were conducted to compare performance data (average game completion time and success rate), as well as player experience metrics (VR sickness, game experience, and perceived exertion), between the two conditions: VE-P and VE-A. Statistical significance was determined with a 95% confidence interval, with a p-value threshold of < 0.05.

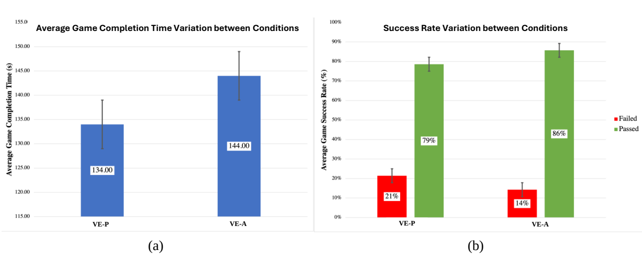

Figure 2: Game Performance: (a) Average Game Completion time and (b) Success Rate.

3.1 Participants' Performance

3.1.1 Game Completion Time. The average game completion time for participants was 134 seconds in the VE-P condition and 144

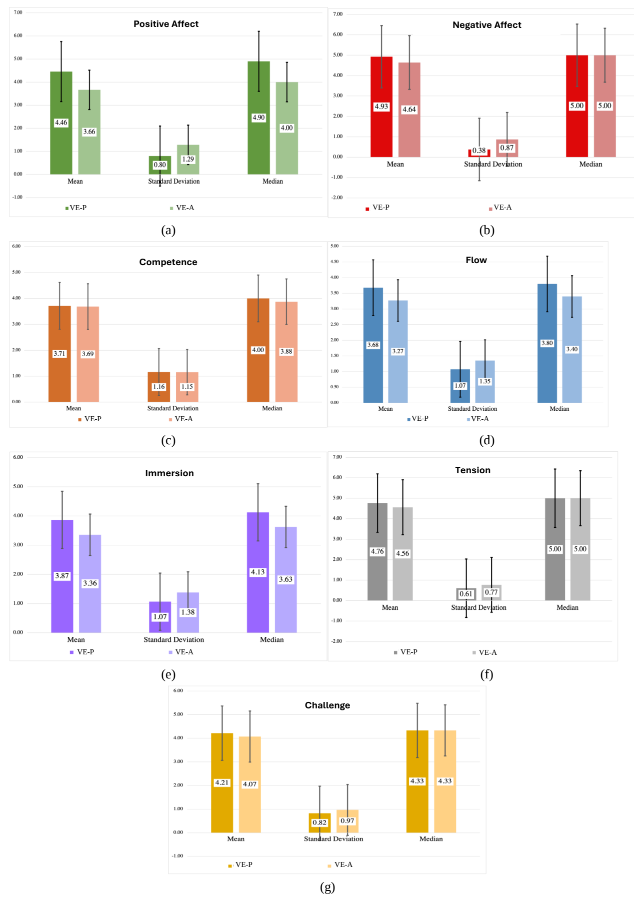

Figure 3: Game Experience Questionnaire Responses variations between conditions: (a) Positive Affect, (b) Negative Affect, (c) Competence, (d) Flow, (e) Immersion, (f) Tension, and (g) Challenge.

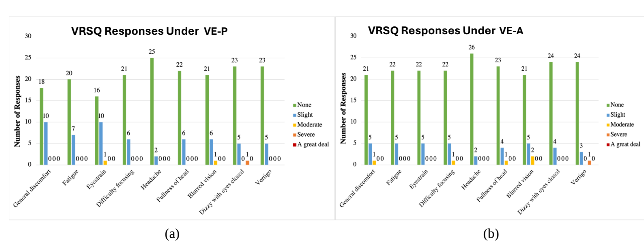

Figure 4: Virtual Reality Sickness Questionnaire Responses between Conditions: (a) VE-P (b) VE-A

Table 2: Descriptive statistics of GEQ results under VE-P and VE-A conditions.

Measure	Dimension	VE-P			VE-A			p
		M	Md	SD	M	Md	SD	
GEQ	Positive Affect	4.46	4.90	0.80	3.66	4.00	1.29	$< 0.001^{***}$
	Negative Affect	4.93	5.00	0.38	4.64	5.00	0.87	0.119
	Competence	3.71	4.00	1.16	3.69	3.88	1.15	0.378
	Flow	3.68	3.80	1.07	3.27	3.40	1.35	0.865
	Immersion	3.87	4.13	1.07	3.36	3.63	1.38	0.003^{*}
	Tension	4.76	5.00	0.61	4.56	5.00	0.77	0.061
	Challenge	4.21	4.33	0.82	4.07	4.33	0.97	0.378

seconds in the VE-A condition, as shown in Fig. 2(a). A paired t-test revealed no statistically significant difference between the two conditions (p = 0.34), suggesting that the presence of VEs did not notably affect the time required to complete the game.

3.1.2 Success Rate of Game Completion. Participants achieved a success rate of 86% in the VE-A condition and 79% in the VE-P condition, as depicted in Fig. 2(b). However, the difference in success rate was not statistically significant (p = 0.33), indicating that VEs did not have a substantial impact on the likelihood of successfully completing the game.

3.2 Player Experience

3.2.1 Game Experience. Table 2 presents the descriptive statistics and p-values for the GEQ dimensions under the VE-P and VE-A conditions in the VR exergame. The results reveal that the inclusion of VEs significantly enhanced both positive affect (p < 0.001) and immersion (p = 0.003), suggesting that these design elements substantially improve players' emotional engagement and deepen their sense of presence within the game environment.

While dimensions such as competence, flow, tension, and challenge exhibited minor variations between conditions, these differences were not statistically significant (p > 0.05), indicating that

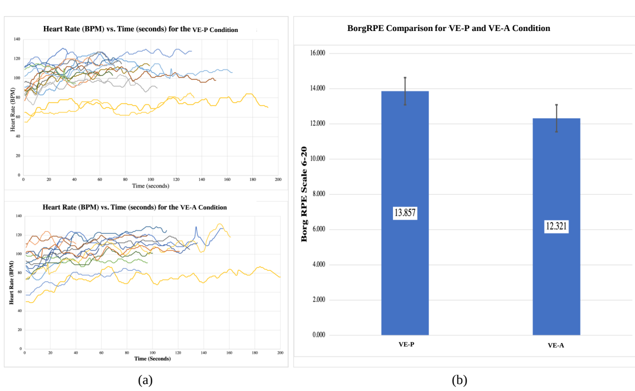

Figure 5: Exertion Measurements between conditions: (a) Heart Rate and (b) Borg RPE ratings.

VEs primarily impact experiential aspects, rather than altering perceived performance or difficulty. Notably, negative affect remained comparable across both conditions (p = 0.119), signifying that the presence of VEs did not have an adverse effect on the emotional balance of gameplay.

3.2.2 Virtual Reality Sickness. Reported symptoms of simulator sickness were minimal in both conditions. In the VE-P condition, 82% of participants reported experiencing "None" of the symptoms, while 23% reported "Slight" symptoms. In comparison, in the VE-A condition, 76% of participants reported "None," and 15% reported "Slight" symptoms (see Fig. 4(a) and (b)). In both conditions, less than 2% of participants reported "Moderate" symptoms, and no participants reported experiencing "Severe" symptoms.

3.2.3 Perceived Exertion: Borg. Participants reported a higher perceived exertion in the VE-P condition (M = 13.86) compared to the VE-A condition (M = 12.32) on the Borg-RPE scale (see Fig. 5(b)). A statistically significant difference was observed (p = 0.015), indicating that the inclusion of VEs in the exergame led to an increased sense of physical effort by the participants.

3.2.4 Physical Exertion: Heart Rate. Heart rate (BPM) patterns over time, measured in seconds, revealed notable increases during gameplay in both conditions, compared to the resting heart rate recorded at the start of the experiment (see Fig. 5(a)). Outliers were excluded from the analysis to ensure data integrity. These results suggest that both conditions induced physical exertion, though further analysis is needed to explore any potential differences in heart rate responses between the two conditions.

4 Discussion

Our findings indicate that the inclusion of VE did not significantly affect players' performance, specifically in terms of average game completion time and success rate, aligning with prior studies conducted outside the context of VR games [13, 17]. Despite the lack of impact on performance, VE significantly enhanced the player experience, particularly in terms of positive affect and immersion. These findings are consistent with existing research on VE in games [13, 17] and the positive effects of vibrotactile embellishments in gaming environments [23], where enhanced visual and sensory experiences foster greater emotional engagement.

Moreover, our results also revealed a novel impact of VE on perceived exertion, as measured by the Borg RPE scale. Players in the VE-present condition reported significantly higher perceived physical effort, suggesting that VEs may increase the subjective feeling of physical engagement. This finding extends the existing literature by highlighting not only the emotional and immersive benefits of VE but also its potential to intensify the physical experience in VR exergames. Previous research has shown that gameplay immersion can influence physical effort in VR settings [13]; however, our study specifically demonstrates that VE can make the exergame feel more physically demanding.

Focusing on VE in VR exergames is particularly important because these games rely on sustained physical engagement, which can be influenced by psychological factors like motivation and immersion. Unlike other (more passive) VR experiences, exergames require users to perform continuous physical movements, making it crucial to maintain both mental and physical engagement over time. VE can enhance the sensory richness of the virtual environment, making exercise feel more rewarding and less monotonous, which may increase users' willingness to participate and persist in physical activity. Additionally, VE provides immediate feedback, creates immersive narratives, and amplifies the sense of achievement—factors that are particularly valuable in exergames to sustain long-term motivation and physical engagement.

In practice, these findings suggest that incorporating VE into VR exergames, particularly those designed to promote physical activity, can enhance player engagement and enjoyment, even though it does not directly improve performance outcomes. The visual effects in our game included dynamic animations such as sparks, explosions, and glowing effects triggered by player actions (e.g., hitting or punching), as well as immersive background elements like a monster opponent and environmental effects like lighting changes. These embellishments not only boosted immersion but also enhanced players' emotional reactions during the gameplay, making the experience more enjoyable and compelling.

While VE may not impact performance, its influence on the emotional and physical aspects of gameplay underscores the importance of visually rich and interactive environments in VR exergames. This aligns with recent studies that highlight the role of sensory feedback in sustaining player motivation and increasing physical engagement in virtual environments [23].

5 Limitations and Future Work

This study had several limitations that should be addressed in future research. First, while wearing glasses did not significantly interfere with the experiment, some participants noted that the VR headset could be more inclusive for individuals who wear glasses. Future studies could explore the development of more inclusive VR headsets that cater to users with glasses, potentially broadening the accessibility of VR-based exergames. Another limitation is that this study focused solely on healthy young adults. While these participants provided valuable insights, the generalizability of these findings to other populations, particularly older adults, remains unclear. Older adults are at higher risk of physical inactivity and declining health-related quality of life (HRQOL), making them an important target population for VR exergames. Future work could investigate how VEs and VR-based exergames could be adapted to meet the needs of older adults, enhancing usability and promoting physical activity in this demographic.

Moreover, incorporating real-time health indicators such as heart rate, blood pressure, and oxygen saturation could further enrich the VR exergame experience. Integrating these metrics into the game, and displaying them to players, would allow users to monitor their health status during gameplay, providing an additional layer of motivation and control over their physical activity levels. Real-time health feedback could help users make informed decisions about their exercise intensity, contributing to better health outcomes. Future research could also examine how VE design can be adapted for specific exercise types, such as strength, balance, or aerobic training. Customizing visual feedback based on the physical demands of each exercise could improve user engagement and optimize the balance between visual stimulation and exercise intensity.

Furthermore, while our study focused on the impact of VEs, it did not isolate their effects from auditory feedback, making it difficult to determine their independent contributions. Future research will examine these elements separately to better understand their distinct roles in player experience. Additionally, their combined effects with other sensory modalities, such as haptic sensations, should be explored, as these elements may work synergistically to further enhance immersion, emotional engagement, and perceived exertion, potentially offering a more comprehensive and effective VR exergame experience.

6 Conclusion

This investigation into the role of VE in VR exergames has provided valuable insights into their potential to enhance player experience. Results from 28 participants demonstrated that VE had a significant positive impact on immersion and positive affect, as measured by the GEQ. This underscores the crucial role that visual elements—such as dynamic graphics, sound effects, and animations—play in making VR exergames not only engaging but also emotionally resonant. These findings align with existing literature that supports the idea that immersive and interactive elements are key to fostering enjoyment in VR environments [13, 17].

While VE did not affect performance outcomes (game completion time or success rate), it did influence players' emotional and physical experiences, as evidenced by higher ratings of perceived exertion. This suggests that VE can enhance the physical engagement aspect of VR exergames, increasing both the perceived intensity of the game and the overall level of effort expended by players.

The practical implication of this study is clear: incorporating VE in VR exergames is valuable for improving player enjoyment, immersion, and physical engagement. For game designers, including dynamic visual effects (e.g., particle systems, lighting effects, and animated interactions) can significantly boost the emotional and physical experience of the game, particularly in fitness-based applications. By enhancing both the emotional and physical aspects of VR exergames, VE can help maintain player motivation and contribute to longer-term engagement, which is critical for the success of exergames aimed at improving physical fitness and health. In conclusion, VR exergames that integrate VE not only provide a more immersive and emotionally rewarding experience but also increase perceived physical effort, making them a promising tool for encouraging physical activity, especially in settings where motivation and sustained engagement are key factors.

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Received 23 January 2025; revised 26 February 2025; accepted February 2025