Evaluating a VR Game Featuring Optical Illusion Challenges: A Study on Workload, VR Sickness, and User Experience

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***Abstract*—VR gaming is rapidly growing in popularity, with puzzle-based games featuring optical illusions attracting gamers attention. Optical illusions are an emerging gameplay mechanic, challenging players' perceptual and cognitive abilities. While widely used in 2D/3D games, their integration into VR remains underexplored. This study investigates the use of optical illusion challenges in a VR game, focusing on players' workload demands, possible onset of VR sickness, and overall experience. A not-so-serious educational game featuring optical illusion challenges as core tasks for progression was developed for VR and PC, and a comparative evaluation was conducted. Results revealed that these challenges provided an enjoyable and immersive experience, with generally low workload demands. However, the complexity and disorienting nature of some illusions occasionally increased physical and mental effort, triggering VR sickness in some players. These findings offer valuable insights for designing VR games, highlighting the importance of balancing challenge and comfort when implementing such mechanics.**

***Index Terms*—Virtual reality, optical illusions, workload, VR sickness.**

THE video game industry holds a significant position in the entertainment market for many years. A rapidly growing segment within the gaming industry is Virtual Reality (VR) hardware and VR games, due to the recent advancements and innovations in hardware and software capabilities, reduction in ownership costs, and maturity of gameplay mechanics [1]. VR games are different from traditional video games due to the immersive sense of presence they provide to players, and their virtual embodiment as the interface within the game environment [2]. A wide range of VR game genres are available, each appealing to different player preferences. Among these, puzzle games stand out as a genre that engages players, and a recent type that is attracting interest is optical illusion based puzzle games [3]. These puzzles present players with visually deceptive tasks that challenge their skills and perceptions, offering an engaging and entertaining experience. However, while numerous optical illusion games are available for desktop Personal Computers (PCs) and handheld devices, the effectiveness and applicability of this type of gameplay challenges in VR is understudied. This paper aims to evaluate a VR game featuring optical illusions as the core gameplay challenges, by assessing players' perceived workload, possible onset of VR sickness and the overall gaming experience after playing the game to develop an understanding of the effectiveness of these gameplay mechanics.

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I. Background and Context

A. Optical Illusions in Videogames

An optical illusion is defined as a phenomenon where our perception deviates from reality, tricking our visual system into seeing something that isn't accurate [4]. Historical roots of the study of illusions trace back to Aristotle, who described the 'waterfall illusion', where prolonged observation of a waterfall causes surrounding elements to appear as though they are moving in the opposite direction [4]. The human visual system is highly sensitive and more prone to optical illusions compared to other senses like touch. While combining vision with touch can help unravel the trick behind an illusion [5], when presented in 2D images that lack depth and motion, various ambiguities occur [6]. In addition to the physical world, optical illusions can exist in digital environments, such as in Augmented, Virtual, and Mixed Reality, introducing new contexts for understanding these phenomena [6], [7]. In VR for example, users can experience illusions such as the sensation of being transported to a new location (place illusion), the perception that virtual events are real (plausibility illusion) [8], and the feeling of inhabiting a virtual body (embodiment illusion) [9]. In fact, illusions form the foundation of VR, as it fundamentally relies on these illusory experiences to create immersive environments [7].

In the field of gaming, the use of optical illusions as a method to create challenges in video games engages the players' perceptual and cognitive abilities in unique ways during the game. Using such challenges, game developers and designers can create puzzles and gameplay mechanics that are intriguing and difficult to solve, employing methods such as altering perceptions, forced perspective manipulations, manipulation of depth and object complexity among others. Optical illusions such as the Munker illusion, which affects color perception, and the Zöllner illusion, where parallel lines appear to be askew, have been creatively and successfully implemented into video games to enhance gameplay and challenge players in creative problem solving [3]. One of the most notable video game that feature optical illusions as its core gameplay mechanic is 'Superliminal' (www.pillowcastlegames.com). This game allows players to interact with in-game objects in unconventional ways, for instance playing with forced perspectives and how objects appear from different angles, requiring the player to resolve challenges that are beyond the conventional constraints of physical spaces [10]. Similarly, games like 'Monument Valley' (www.monumentvalleygame.com) and 'Manifold Garden' (manifold.garden) allow players to manipulate impossible architectures and spatial arrangements, achieving significant commercial success by leveraging optical illusions to create unconventional gaming experiences to engage players [11].

To support implementing optical illusions in video games development, Wang et al. [3] proposes a detailed workflow that includes a comprehensive database of optical illusions, intended to guide designers in 'illusionizing' their games. However, the applicability and effectiveness of optical illusions in VR games has not yet been thoroughly investigated. VR offers unique possibilities for game design by enabling spatial interaction and immersive sensory experiences, and its immersive nature provide opportunities to present optical illusions in dynamic interactive ways. Exploring the added value of these perceptual challenges in leveraging the strengths of VR has the potentials to develop more engaging and cognitively stimulating game experiences. While optical illusions can offer enjoyable gameplay elements, it is important to explore the extent to which their integration into VR presents challenges that could potentially disrupt the player experience. For instance, it may be possible that due to the nature of some optical illusions, in conjunction with VR, to trigger disorientating and visual strain effects that could potentially lead to increased onset of VR sickness to some players. Furthermore, some optical illusions might over complicate the game and confuse players rather than enhancing their experience. This may lead to cognitive overload where players would struggle processing too much information which could potentially cause frustration and fatigue, hindering the enjoyment of the game. These examples highlight the importance of further research to understand the impact of optical illusion challenges to the player experience, and explore ways to successfully integrating them in gameplay mechanics for an immersive, interactive, and stimulating VR gaming experience.

B. Player Experience

Player Experience (PX) is widely acknowledged as a central factor in the success of video games. A positive PX drives engagement and retention, influencing the commercial performance of the game and player satisfaction. Game designers aim to trigger a range of emotional responses such as enjoyment, fear, sadness, and excitement while ensuring that gameplay elements resonate meaningfully with players [12], [13]. The industry and academic communities increasingly emphasize PX research to understand how players interact with and perceive virtual environments [14].

Evaluating PX is a multidimensional process involving assessments of design quality, technical performance, player behavior, emotional response, cognitive effort, and enjoyment [15] among other aspects. A range of data collection tools and heuristics are designed to measure key aspects of PX from various perspectives (see example list in [16]). Factors such as the game's usability, enjoyment, immersion, creativity, satisfaction, social interaction, and visual appeal, are key to understand the target audience, address their gaming needs, and attract new players [17]. Common methods for evaluating video games include usability testing, heuristic evaluation, and play-testing, helping to understand players' behaviors, attitudes, and preferences [16]. Despite its importance however, the impact of optical illusion-driven gameplay on PX and especially in VR remains underexplored. While such illusions may enhance challenge and engagement on 2D screens, their integration in immersive VR environments introduces new complexities. These may include increased cognitive load, fatigue, or symptoms of VR sickness. Conversely, VR also presents unique opportunities to design unique perceptual gameplay, leveraging embodiment and spatial interaction to enrich puzzle design and narrative immersion. Investigating these dynamics is essential for establishing design guidelines that optimize the integration of optical illusions in VR games and enhance player comfort, engagement, and satisfaction.

C. VR Sickness

One of the main challenges affecting the adoption and usability of VR technology is VR Sickness (VRS), a form of motion sickness that occurs during or after VR exposure and can significantly impact user experience. Symptoms commonly include headaches, vertigo, nausea, disorientation, eye strain, and fatigue among others [18], [19]. Unlike traditional motion sickness, which results from physical movement, VRS is typically caused by sensory conflicts particularly between visual and vestibular inputs and is often referred to as Simulator Sickness (SS) or Visually Induced Motion Sickness (VIMS) [18]. While the term 'Cyber Sickness' was initially coined to describe discomfort in virtual environments, it now encompasses a broader range of issues related to digital technology use [19], and to describe the discomfort specific to VR experiences, the term VRS is commonly used. Its causes remain under investigation, but contributing factors span across three main domains: hardware setup, software and content design, and individual user susceptibility [20]. Key influencing elements include exposure duration, activity type, movement acceleration, field of view, and even color schemes used in the environment [21], [22]. Various mitigation strategies have been proposed such as dynamic field-of-view reduction, rest frames, visual blurring, and time manipulation, but these must be carefully balanced against potential impacts on visual clarity and overall immersion [13], [23], [24]. Given that the individual susceptibility to VRS varies among users and cannot be controlled, the development emphasis is placed on effective design of VR content, game mechanics, and user interactions for a more comfortable and engaging experiences, while maintaining the quality of the VR experience [13]. However, there is very little research and evaluation of VR games featuring optical illusions, and the extent to which such illusion based type games could trigger VRS symptoms due to their disorientating nature (for example perspective, motion, depth perception illusions etc).

D. Workload

The nature of video games inherently involves tasks that challenge various player skills and require differing levels of workload. Workload refers to the effort needed to complete tasks and meet their requirements. Psychological literature offers diverse definitions of workload, reflecting its complexity as a construct [25]. It arises from the interaction between task demands, the conditions in which the task is performed, and the individual's behavior, skills, and perceptions. These demands can include both physical actions and cognitive tasks [26]. Cognitive load is a key aspect of workload, involving the interplay of task demands and mental processes such as alertness and fatigue. and is a dynamic variable influenced by task progression [27]. Research identifies three key assumptions about cognitive load: i) human cognitive and attentional resources are limited, ii) tasks vary in their cognitive resource demands, and iii) individuals may experience different levels of cognitive load even when task performance is similar [27].

To assess workload or effort, several methods exist and are mostly categorised in performance, behavioral, physiological, and subjective measures [28]. *Performance-based methods* evaluate task performance changes, often declining under cognitive overload, but isolating cognitive load from other factors (e.g., motivation, arousal) remains challenging [27], [29]. *Behavioral methods* monitor variations in interaction behaviors (e.g., speech, input device usage), offering cost-effective and unobtrusive monitoring. However, these can be influenced by factors like stress or emotions, complicating interpretation [28]. *Physiological measures* (e.g., heart rate, EEG) assess real-time effort but require specialized equipment and may be affected by physiological demands [30]. *Subjective measurements*, which are the most commonly used approach, rely on self-reported questionnaires to evaluate workload after task completion [31], [32]. They are cost-effective and consistent but may interrupt workflow, fail to capture real-time fluctuations, and are prone to memory decay and task outcome biases [28]. The NASA Task Load Index (NASA-TLX) is the most widely used tool for subjective workload assessment [33]. It evaluates workload across six key dimensions: mental demand, physical demand, temporal demand, effort, performance perception, and frustration. Participants rate each subscale on a scale from 1 to 20 after completing a task. The final global workload score is calculated using a weighted approach based on 15 paired comparisons of the subscales [33], [34]. However, although the NASA-TLX is one of the most widely used tools for measuring workload over the past 25 years, it lacks guidelines on how to interpret its scores [25], and benchmark for determining if a specific workload score is considered high or low [34]. In video games, players are often required to exert mental effort to overcome challenges and achieve in-game goals. A key aspect of game design is establishing the right balance of challenge to maintain player engagement and enjoyment. However, there is a notable gap in research concerning standardized methods for measuring cognitive workload during gameplay [35]. In particular, the demands imposed by optical illusion-based challenges and especially when implemented in immersive environments like VR have not been thoroughly examined. This study seeks to address this gap by investigating the impact of a VR game incorporating optical illusion challenges on players' perceived workload, providing insights into the suitability of such mechanics within VR contexts. Given the close link between cognitive demand and user comfort, this research also explores the relationship between workload and VRS which are importnat factors in player experience. Although prior studies suggest that increased cognitive load may influence VRS, findings remain inconclusive [36], [37]. Therefore, a deeper understanding of how workload interacts with VRS is essential for designing effective and comfortable VR experiences [37].

II. Research Methodology

To explore the effectiveness of optical illusion challenges in VR games and its impact to player experience, a not-so-serious educational game prototype was developed for both VR and PC platforms to experiment with. A comparative study was conducted evaluating the players' level of workload involved in resolving these challenges, their overall gaming experience, and the potential onset of VRS symptoms after playing the game. In particular, this study aims at exploring:

1) The level of workload required to complete an optical illusion game and how it differs between PC and VR platforms, assessing the perceived levels of players' workload of completing the game through solving a combination of challenges.

2) The possible VRS symptoms developed after playing the VR version of the game, since some of the optical illusions require manipulation of perception, perspective and spatial orientation of players.

3) Evaluate the player experience across both PC and VR platforms in terms of usability, level of engrossment, enjoyment, and visual aesthetics.

A. VR Game Prototype Development

'PerceptaVR' is a not-so-serious game prototype with educational emphasis developed by a team of researchers and students at the University of Central Lancashire, Cyprus (UCLan Cyprus). The term 'not-so-serious' describes game design efforts different to traditional educational games, which are often perceived as lacking interactivity, or enjoyment, and draw best practices in entertainment game design through playful mechanics, storylines, and aesthetics (even humour [38]), to develop entertaining educational experiences [39]. *'PerceptaVR'* incorporates educational elements such as perceptual reasoning, spatial awareness, and problem-solving, through interactive challenges rather than through formal instruction or explicit learning goals for a rich experience within a fun and informal context. This game aims to increase awareness of Cyprus's cultural heritage by engaging players in a puzzle-based learning experience where they can visualize and learn important historical information during interactive gameplay in entertaining ways. The game features several historically significant sites and exhibits including digital reconstructions of key landmarks such as: the curch of Panayia Aggeloktisti, its renowned 6th-century mosaic, econostasi and specific religious artwork, the exterior of Ayios Mamas in the deserted village of Ayios Sozomenos, the UNESCO listed Panayia Asinou church and Profitis Elias chapel. The game incorporates riddles and environmental cues that guide players through the puzzle-solving activities and are directly related to these heritage sites,

encouraging players to explore, manipulate, and learn about the cultural significance of Cyprus's religious and historical heritage in an immersive and engaging way. 'PerceptaVR' is developed using Unreal Engine 4 and targets the Meta Quest 2 VR headset, and PCs with Microsoft Windows operating system. More details about the environment design can be found in [40]. The game is an escape room type, where advancing through different rooms depends on solving several optical illusion puzzles. It features various optical illusion challenges that encourage players to actively explore the VR environment and interact with immersive exhibits and educational materials. Players read riddles, identify clues and hints, and interact with in-world objects, resizing, moving, and manipulating their placement and gravity, among other tasks.

The puzzle mechanics employ 'misleading' and 'swapping realities' optical illusions as characterized by Wang et al. [3]. 'Misleading' illusions appear to be simple but are intriguingly complex, enhancing the level of game challenge. 'Swapping realities' illusions alternate the game environment between a standard setting and one that deviates from reality. For example, the game incorporates challenges where key objects required to solve the task are cleverly hidden or obscured within the environment, requiring players to solve riddles, observe closely, and interact with their environment, relying on visual cues and their perceptions to uncover and solve these puzzles. The game features 4 specific types of optical illusion challenges: i) Forced perspective challenges requiring players to manipulate the size of 3D objects in real time to match their visual perspective (Fig. 1); ii) View perspective challenges encouraging players to explore rooms, identify specific textures projected onto the environment (Fig. 2, a) where when viewed from certain angles (Fig. 2, b) are then transformed into objects (Fig. 2, c) that can be used to solve further challenges; iii) Gravity-based illusions challenging players to interact with a series of rooms where gravity needs to be manipulated to solve challenges and progress (Fig. 3, a); iv) Deception challenges presenting what appears to be a hallway with an object of interest at the end of it, which upon closer inspection, turns out to be a 2D image, adding to the complexity of the game (Fig. 3, b, c). For example, the gravity alteration mechanic is used as a spatial metaphor where players must manipulate gravity to navigate between different layers of the environment. In the Ayios Mamas church level (Fig. 3, a) it is implemented to allow exploration of the exterior structure below, while ascending reveals a text-based historical description and a riddle, which players must interpret to proceed to the next stage. In other levels, the forced perspective mechanic is used to engage players with a digitally reconstructed artifact from the church's interior, and players are required to resize and reposition the object to match a riddle's description, which in turn activates access to the next cultural exhibit. The perspective-alignment challenge currently implemented in prototype form using basic geometric primitives, are designed to reveal hidden historical forms or symbols only when viewed from a specific angle. These types of optical illusions were chosen to create cognitively stimulating gameplay, and provide engaging interactions that are unique to virtual environments. Additionally, these illusions have been proven successful in other video games, such as The Witness (view perspective), Portal (gravity-based manipulation), and Superliminal (forced perspective), showcasing their successful implementation and player appeal. As players advance, the game's difficulty increases through new combinations of challenges, more complex riddles, tasks require multiple actions to complete, and fewer clues.

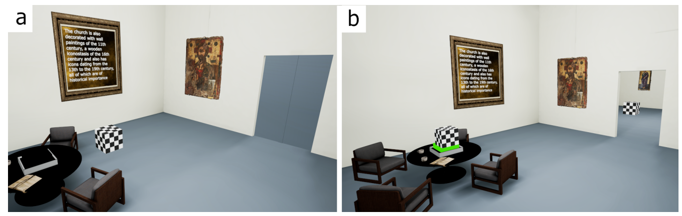

Fig. 1. Example of resizing and placing a cube into a trigger box to unlock the next room door.

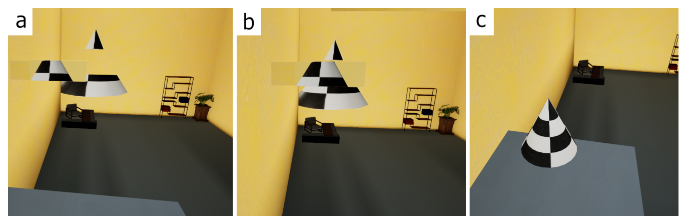

Fig. 2. Perceived visual angle illusion, converting a 2D texture (a, b) into a 3D cone (c)

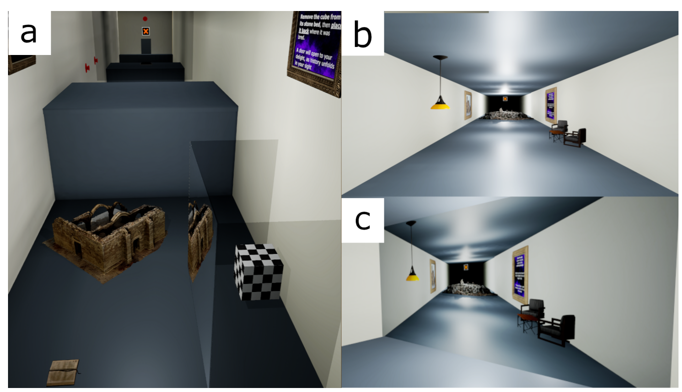

Fig. 3. Gravity (a) illusion where players must manipulate gravity to explore Ayios Mamas church (decent) and its description (ascent); and deception (b, c) optical illusions where players believe they are walking towards Profitis Elias chapel, only to realise that it is a 2D projection.

B. Data Collection Instruments

To collect data for this study, a combination of established, psychometrically validated instruments was employed. To assess players' workload while resolving the optical illusion challenges, the NASA Task Load Index (NASA-TLX) [33] was used. This tool includes six subscales (Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration) each rated on a 20-point scale, with higher scores indicating greater perceived workload. For this study, the Raw TLX (RTLX) scoring method was adopted, which calculates overall workload by summing and averaging subscale scores without using the paired comparison weighting procedure [25]. This approach has been shown to yield highly correlated results with the weighted version while reducing response time and complexity [34].

To evaluate players' overall gaming experience, the Game User Experience Satisfaction Scale (GUESS) developed by Phan et al. [16] was employed. GUESS is a validated instrument for assessing satisfaction across nine user experience subscales/factors. In this study, four subscales were selected: Usability/Playability, Play Engrossment, Enjoyment, and Visual Aesthetics. Each item is rated on a 7-point Likert scale (1 = Strongly Disagree to 7 = Strongly Agree), with aggregate scores for the selected subscales ranging from 27 to 189.

To investigate symptoms of VRS, the Simulator Sickness Questionnaire (SSQ) [41] was administered before and after gameplay for participants in the VR group. The SSQ evaluates 16 symptoms across four categories: Nausea (N) Oculomotor (O), Disorientation (D), and Total Severity TS, using a 4-point scale from 0 (none) to 3 (severe). Weighted scores are calculated using standard multipliers for each subscale (9.54, 7.58, and 13.92, respectively), with Total Severity derived from the cumulative score multiplied by a factor of 3.74. Severity levels are interpreted using common thresholds: negligible (<5), minimal (5–10), significant (10–15), severe (15–20), and very severe (>20).

To complement these instruments and capture real-time data, a dynamic feedback method was used during gameplay, particularly for VR participants. Informal, verbal feedback was collected during and immediately after each challenge to avoid interrupting immersion. Participants were encouraged to self-report any emerging VRS symptoms and reflect on their experience with specific illusion-based tasks. Demographic data including gender, age, prior experience with VR or PC games, and gaming habits were collected using a brief questionnaire administered online before gameplay. Post-experience feedback sessions were also held, focusing on players' perceptions of the illusion-based mechanics, usability of the VR environment, and any discomfort experienced.

C. Experimental Procedure

Participants were randomly assigned to play the game on either a VR (Meta Quest 2) or PC platform. All participants were briefed, provided informed consent, and completed a short demographics questionnaire. Those in the VR group also completed the Simulator Sickness Questionnaire (SSQ) to establish a baseline. All participants reported normal or corrected vision and no relevant health conditions. VR participants played the game seated on 360-degree rotating chairs in a lab setting, while PC participants downloaded the game and played independently. Gameplay lasted 15–25 minutes. Players began with an orientation level to learn mechanics like forced perspective and object resizing. The game then progressed through a series of illusion-based puzzles, such as identifying hidden objects, manipulating gravity, and aligning perspectives to reveal symbols or activate triggers. As the game advanced, environmental cues decreased and challenge complexity increased. All participants completed the game without dropouts. Informal verbal feedback was collected during gameplay, and post-experience questionnaires (including SSQ for VR) were completed after the session.

D. Participants

A total of 40 participants (32 males and 8 females) were recruited through an open call for participation circulated within the computing department of UCLan Cyprus. Participants were undergraduate or postgraduate computing students who volunteered to take part in the study and their participation was entirely voluntary and conducted in accordance with the institution's ethical guidelines. Participants were randomly allocated to play the game in VR or in PC. The VR group comprised of 17 male and 3 female players (Mdn=20 years old, IQR=2). The majority (55%) had minimal experience with VR, with 10% having no previous experience, and 45% having very little. Regarding VR usage for gaming, 20% of the participants had never used VR, 65% had used it very rarely, and only 15% used VR regularly for gaming, 2-3 times per week or more. Participants were mostly PC gamers, with the majority (35%) playing PC games daily and 30% playing between 4-6 times per week.

The PC group consisted of 15 male and 5 female players (Mdn=23 years old, IQR=6). They were mostly experienced PC users (65%). Only 15% described their experience as limited (5%) or somewhat experienced (10%). In terms of gaming frequency, 50% reported playing games more than 2-3 times a week. The majority (50%) are playing PC games very frequently, and (45%) between 1-3 hours each day.

III. Results

Before conducting statistical analyses, the normality of data distribution was assessed using the Shapiro-Wilk test. Most individual RTLX and GUESS subscales were not normally distributed, although their overall scores were approximately normal. Given these findings, we adopted a conservative approach and used non-parametric statistical tests to avoid generalization. SSQ data were also non-normally distributed which is quite common for SSQ [42], and were analyzed using Medians (Mdn) and Interquartile Ranges (IQR). For completeness, Means and Standard Deviations (SD) for SSQ subscales and the Total Severity (TS) score were also reported, following recommendations by Bimberg et al. [43]. Visual data inspection techniques were also used. All scales used in this study have established validity and reliability in prior research, and we have also explored reliability using the Cronbach's α coefficient, revealing high internal consistency among all items comprising the used scales.

A. Workload

The workload results as measured by the RTLX (Cronbach's α: VR version =.797, PC version =.873, no of items: 6), for both conditions were analysed first, and are outlined in Table I, and can be visualised in Fig. 4. The overall RTLX workload for the VR group was 39 (IQR=34.25) compared to

32 (IQR=28.25) for the PC group. The workload results for both groups are lower than the average NASA TLX scores (M=45.29) reported by Grier's review of 33 studies [34], indicating that in general, neither version of the game was requiring very high workload.

The factor that contributed the most to the overall workload in the VR version of the game was Effort (Mdn=10, IQR=13) which was notably higher than of the PC version (Mdn=3.35, IQR=9), highlighting that the physical and mental effort devoted to complete the challenges were higher in VR. This could be suggesting that the nature of VR and the interactions within the VR game may demand more from players for the challenges to be resolved. Performance was lower in PC (Mdn=5, IQR=5) compared to VR (Mdn=6.5, IQR=8), indicating more successful perceptions towards the completion of the challenges from the players in the PC group, suggesting that some aspects of the VR gaming experience may not felt as successful as playing on a PC. Interestingly, the Physical Demand on the PC group, while low (Mdn=4.5, IQR=4), it was higher than in VR (Mdn=3, IQR=4), indicating more physical load perceived while playing the game using the mouse and keyboard than using the VR controllers and wearing the headset. Similarly, the Frustration levels in VR were lower (Mdn=3, IQR=7) than the PC condition (Mdn=4.5, IQR=7), indicating that the players in the PC group were more irritated and annoyed during the game in comparison. Mental Demand and Temporal Demand for both conditions were low and similarly rated, indicating low mental workload and pressure of completing challenges to progress in the game.

The cumulative frequency distributions of the Overall Workload for both groups was also explored, using percentile based comparisons. For the PC group, the 25th percentile reported a workload score of 17.25, indicating that 25% of players experienced relatively low workload. The median (50th percentile) was 32, suggesting that half of the PC players rated the workload as moderate, and the 75th percentile was 45.50, indicating that 75% of the PC players reported a workload below this level, which is the average NASA TLX workload score (M=45.29) [34]. On the other hand, the 25th percentile was 16.75 on VR group, which is is slightly lower than the PC group. However, the median for the VR group was 39, higher than the PC group. Additionally, the 75th percentile was 51, also higher than the PC group, indicating that the upper quartile of VR players reported higher levels of workload in comparison. These findings suggest that while the lower quartile of players in both versions of the games experienced similar levels of low workload, the players on VR game on average and particularly in the upper quartile, reported higher workload compared to PC. Although the workload results for the VR group were higher compared to the PC group, the levels were not excessively high. This suggests that resolving the challenges and experiencing the game in VR did not require significant amount of workload. The results were further explored for potential differences between the two groups using a Mann-Whitney test, revealing no significant statistical differences.

The players' gaming habits, along with their familiarity and use of PCs and VR (for the VR group) were also explored to identify potential correlations with the Overall Workload results. A Spearman's rank-order correlation test showed no significant correlations within the VR group, suggesting that that these variables did not influence the perceived workload for VR users. However, moderately negative correlations were found between the time spent playing games each day (r(18) = -.545, p = .013) and frequency of gaming during the week (r(18) = -.565, p = .009) with the Overall Workload for the PC group, suggesting that more experienced gamers reported lower workload scores.

TABLE I
RTLX RESULTS FOR VR AND PC GROUPS

	Median	IQR	Min	Max
VR Group				
Mental Demand	5	8	1	15
Physical Demand	3	4	1	10
Temporal Demand	5	7	1	15
Effort	10	13	1	19
Performance	6.5	8	1	20
Frustration Level	3	7	1	20
Overall Workload	39	34.25	7	79
PC Group				
Mental Demand	5.5	5	2	13
Physical Demand	4.5	4	1	14
Temporal Demand	4.5	6	1	10
Effort	3.5	9	1	16
Performance	5	5	2	14
Frustration Level	4.5	7	1	16
Overall Workload	32	28.25	9	73

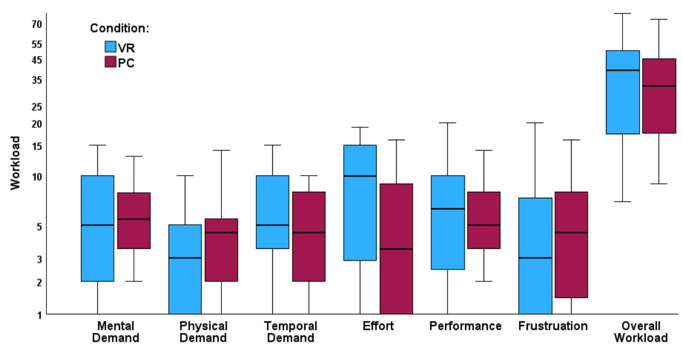

Fig. 4. Workload Results

B. User Experience

The results of the player experience for both VR and PC groups as measured by the GUESS questionnaire (Cronbach's α: see Table II) are shown in Table III. The Usability/Playability of both the VR (Mdn=5.04, IQR=.91) and PC (Mdn=5.41, IQR=.8) groups were perceived very positively, and rated similarly. This indicates that the game was easy to play for both groups, with clear goals and objectives, and minimal cognitive disruptions or confusions caused by the controls or the game environment. Play Engrossment was moderately positively rated for both VR (Mdn=4.44, IQR=1.22) and PC (Mdn=4.5, IQR=.1.1), suggesting that the game was capable of maintaining the players' attention and interest during the experience. Players had very positive response to the Enjoyment factor, with the PC version of the game (Mdn=5.6, IQR=.1.1) rated slightly more favorably than the VR version (Mdn=5.1, IQR=2), suggesting that players on both groups were pleased and satisfied from playing the game. For the Visual Aesthetics factor, which assesses the game's graphics and their appeal to players, the PC version (Mdn=6, IQR=1.5) was perceived higher than the VR version (Mdn=4.83, IQR=2.25). This could be attributed to the higher graphical fidelity that can be achieved on PCs, the lower rendering capabilities of the VR devices, and/or from the VR's capability to allow players to view objects more closely, potentially exposing graphical limitations which may not as noticeable on PC screens.

The overall scores for both groups were quite high, indicating a very positive overall experience, considering the maximum achievable score of 189, with the PC version (Mdn=139.5, IQR=19.25) rated slightly higher than the VR version of the game (Mdn=135, IQR=32.5). A Mann-Whitney test was employed to explore differences between the two groups, revealing no statistically significant differences. The results were further explored to identify potential correlations between the GUESS and Workload scores. A Spearman's rank-order correlation test was conducted, without revealing any correlations between the factors comprising the two scales. The Spearman's test was also conducted to explore potential relationships between the players' gaming habits and their PC usage experience, also without revealing any correlations.

TABLE II
CRONBACH'S α RELIABILITY INDEX OF EACH SCALE FOR VR AND PC GROUPS

Scale	VR Group	PC Group	Items
Playability/Usability	.823	.900	11
Player Engrossment	.876	.811	8
Enjoyment	.875	.924	5
Visual Aesthetics	.918	.906	3

TABLE III
PLAYER EXPERIENCE GUESS RESULTS FOR VR AND PC GROUPS

Parameter	Median	IQR	Min	Max
VR Group				
Usability/Playability	5.04	.91	3	6.18
Engrossment	4.44	1.22	2.5	6.25
Enjoyment	5.1	2	3.4	6.4
Visual Aesthetics	4.83	2.25	2	7
Overall Score	135	32.5	76	169
PC Group				
Usability/Playability	5.41	.8	2.36	6.45
Engrossment	4.5	1.1	2.38	6.38
Enjoyment	5.6	1.1	2	7
Visual Aesthetics	6	1.5	2.33	7
Overall Score	139.5	19.25	94	168

C. VR Sickness

The results of the VRS as measured by the SSQ (Cronbach's α = .727, no of items: 16), are outlined in Table IV and depicted in Fig 5. The analysis used a relative score approach by comparing the differences between the SSQ scores before and after the intervention to evaluate the impact on users. In cases where relative scoring resulted in negative outcomes suggesting that post VR exposure scores were lower than pre exposure, the results were interpreted as having no negative effects on participants, rather than being beneficial, following the interpretation advise by Bimberg et al. [43].

The SSQ results revealed a range of symptom severity among participants after their exposure with the VR game. Out of 20 participants, 8 participants (40%) reported no symptoms of VRS. 3 participants (15%) experienced mild symptoms with scores ranging from 3 to 10, another 3 (15%) had moderate symptoms with scores between 10 and 20, and 6 participants (30%) reported severe symptoms, scoring higher than 20. Numerical (Table IV) and visual (Fig. 5) inspection of data indicate that the majority of the VRS symptoms' median scores are categorized as low to mild, ranging from 0-10 for Nausea, Oculomotor, Disorientation, and for Total Severity. However, a closer look on the visual data, the IQR scores, and taking into consideration the reported Mean and SD scores, there is some considerable variation in the spread of scores, highlighting a diverse range of symptom levels reported among some of the participants. While Total Severity, Nausea, and Oculomotor symptoms have been rated mild to moderate in general, most notably, Disorientation has a particularly wide spread in its IQR range, varying from 0 to 27.8. This variability is visible in the Disorientation boxplot depicted in Fig 5, and is also confirmed by the higher Mean and SD in comparison with the Median value. This could be due to the nature of the illusions implemented in the game, and in particular, to the strain these can potentially put to the user's visual and cognitive system.

The Total Severity results were further explored for potential correlations with Overall Workload and GUESS using a Spearman's rank-order correlation test. The VRS results did not reveal any significant correlations with the GUESS results ($r(18) = -.093$, $p = .698$), but revealed moderately positive correlation with the Overall Workload results, which was statistically significant ($r(18) = .593$, $p = .006$). This may suggest that higher levels of Workload required to complete challenges in the game may lead to increased VRS. This finding is in line with results from the existing literature, which indicate that changes in workload can impact VRS [37], with higher workload levels being associated with more severe VRS symptoms [44]. The players' gaming habits, and their familiarity and use of PCs and VR for gaming were also investigated revealing no significant correlations.

D. Observations

Collecting participants feedback and observations during gameplay revealed some interesting insights of the player experience and the effectiveness of the optical illusion challenges used in the game. Participants reported that the forced perspective resizing challenges were straightforward and enjoyable, indicating that these tasks effectively engaged players without causing significant difficulty. The deception illusion

TABLE IV
VR SICKNESS DESCRIPTIVE RESULTS

	N	O	D	TS
Median	0.0	7.58	0.0	7.48
IQR	19.8	20.85	27.84	28.05
Mean	9.5	10.6	13.22	12.52
SD	12	11.63	18.9	13.85

Legend: N = Nausea; O = Oculomotor; D = Disorientation; TS = Total Severity

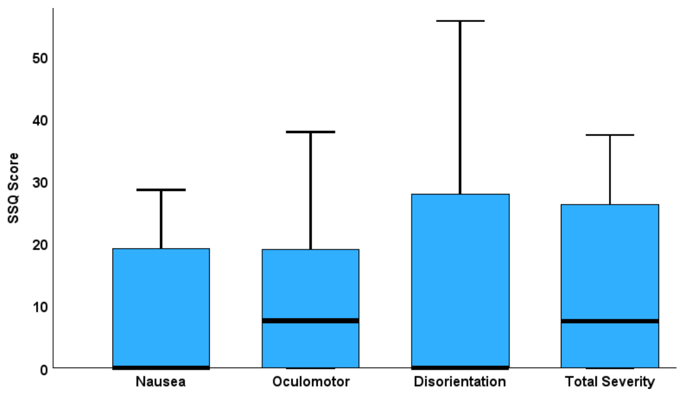

Fig. 5. SSQ Results.

was perceived fun as well, and after some navigation and problem solving they all managed to proceed to the next level.

Player feedback highlighted specific optical illusion mechanics that affected comfort and gameplay experience. The gravity manipulation challenge in particular, initially caused disorientation due to unexpected involuntary movement, which is an effect consistent with literature linking unanticipated motion to VR sickness [45]. However, as players progressed and recognized that specific buttons triggered gravity shifts, they adapted and reported improved comfort. Another noted mechanic involved aligning the camera perspective to transform a flat wall texture into a 3D object. While conceptually engaging, this task required extensive physical head movement, leading to neck fatigue. Similarly, challenges involving object resizing and virtual jumping were perceived as physically demanding, especially when players needed to climb onto objects to reach the next stage. Despite these difficulties, no persistent VR sickness symptoms were reported beyond the gravity level. Players also emphasized that simplified spatial layouts and reduced visual clutter improved their ability to focus on tasks, confirming that minimal distractions support more comfortable and efficient problem-solving in VR.

IV. DISCUSSION

This study evaluated a VR game with optical illusions as the core gameplay challenges, focusing on how players' perceived workload, possible onset of VR sickness after playing the game, and their overall gaming experience through a comparative evaluation study. The game prototype was developed to explore different types of optical illusion challenges embedded across progressively difficult levels and designed to encourage exploration and spatial reasoning. The results of this evaluation revealed that players engrossed in an enjoyable immersive gaming experience, and positively evaluated the usability/playability, and graphical aesthetic aspects of the game. The overall workload results showed that players were able to complete the game without experiencing high levels of workload in general, suggesting that the workload required to resolve the puzzles was manageable and balanced. The workload findings can serve as a positive indications of the applicability of this type of challenges in VR to support an interactive, challenging and stimulating gaming experience. The VRS results revealed a range of symptoms severity. Most notably, the majority of players did not report any symptoms after their experience with the VR game, and some indicated mild to moderate symptoms. However, some players reported severe symptoms, mainly in the Disorientation domain, which could be attributed to the nature of the illusion challenges, and their potential strain on their visual and cognitive systems.

The unique affordances of embodiment, spatial interaction, and the ability to physically manipulate objects dynamically in VR introduces a level of interactivity that extends beyond traditional desktop computer games. The finding that VR did not result in significantly higher perceived workload validates and supports the viability of VR for such applications, demonstrating its potential for delivering engaging perception-driven gaming experiences.

Player feedback and behaviour observation during the study provided important insights into how users engaged with the illusion-based challenges. While most participants completed the tasks without reporting high workload or severe VR sickness, several common points emerged, for instance, challenges involving frequent or complex physical movements particularly in gravity manipulated tasks were associated with increased disorientation. Similarly, moments where players were unable to anticipate the effect of an illusion (for example hidden objects or abrupt perspective shifts) often resulted in confusion, momentary disorientation, or breaks in immersion.

Based on the combination of players' feedback, post-experience questionnaire data and observations during gameplay, several adjustments can be implemented in the design of optical illusion challenge mechanics to improve the VR experience, grounded in specific usability and comfort issues identified during the study to enhance the player experience while minimizing cognitive, physical strain and comfort:

- ***Reduce the physical efforts needed to complete challenges.*** Workload effort should be taken into consideration in the design of the mechanics of the optical illusions, to ensure that while the tasks are mentally stimulating and challenging, they should be balanced and requiring relatively low physical efforts to resolve them. Simplifying and minimising physical movements needed to complete the challenges in VR, can help to reduce physical strain and accumulated fatigue especially in prolonged exposure. Avoiding the need of unnatural locomotion actions such as jumping or sprinting to resolve optical illusion challenges can also help to minimise VRS triggers.

- ***Provide indications of how optical illusion challenges will manipulate the environment.*** Such design consideration can help to avoid involuntary and unanticipated player movement in the VR space, which are known to be triggering VRS, and were also reported by the study participants. Also, configuring the core gameplay mechanics to allow players predict and anticipate actions within the game, may reduce possible disorientation associated with the optical illusions tasks.

- ***Use simplified spatial layout, and simplified visual and informational elements.*** This can help to reduce cognitive workload and enable players to identify and focus on the optical illusion task at hand, without being overwhelmed by excessive details or distractions that could increase the workload efforts required to resolve the challenge.
- ***Design rest points between intensive tasks.*** Include moments of reduced activity or calming environments between challenging sections to mitigate the onset of VR sickness and provide players a chance to physically and mentally recover.
- ***Minimize overlapping challenges.*** Avoid combining too many complex elements (e.g., gravity manipulation, perspective shifts) within a single task, as this can overload players and increase cognitive and physical strain.
- ***Use gradual introduction of complex mechanics.*** Gradually introduce complex optical illusion mechanics, starting with simpler tasks and progressively increasing complexity. This helps players build confidence and gameplay familiarity.

The alignment of these recommendations with our study results offers actionable suggestions for VR designers aiming to integrate optical illusions within gameplay in ways that balances cognitive challenge with physical comfort. The proposed guidelines are grounded in the empirical findings of our evaluation and directly reflect the interaction patterns, feedback, and challenges observed during gameplay to support the design of VR experiences that effectively incorporate optical illusions while preserving user immersion, minimizing discomfort and take mental and physical workload into consideration. The proposed design guidelines are also grounded and align with well-established principles in VR interaction, cognitive load management, and educational game design. These recommendations reflect widely acknowledged best practices aimed at enhancing user comfort, reducing disorientation, and supporting cognitive engagement in immersive environments [46], [47]. These principles are also consistent with educational game frameworks that emphasize progressive complexity and scaffolding to maintain engagement and facilitate learning [48], [49], [50], and game design reviews to support enjoyment and effective player interaction [51], [52], [53].

This study demonstrated that optical illusions, when used as core gameplay elements in a VR environment, can create an immersive, enjoyable, and mentally engaging experiences without excessive workload or discomfort for most users. The findings highlight the added value of incorporating optical illusions in VR games, as they leverage its unique affordances to present challenges in ways not possible in traditional 2D/3D formats, opening new directions for game design, for the development of video games combining cognitive stimulation and immersive interaction to enrich the user experience.

V. Conclusions, Limitations and Future Work

Based on the findings of this study, it can be concluded that optical illusion challenges offer opportunities for developing and designing immersive and interactive gaming experiences in VR. The results indicated that use of optical illusions can offer unconventional and stimulating gameplay elements that challenge players' perceptions and cognitive abilities, making the gaming experience enjoyable and mentally challenging. The key to successful implementation is based on a balanced approach in complexity and effort needed to complete challenges, without overwhelming the player mentally and physically. The findings suggest that optical illusion challenges seem to be applicable within a VR gaming environment, but their successful integration requires careful design and development to ensure they enhance the user experience without causing discomfort or increased workload levels.

This study contributes to the growing literature on VR game design by evaluating a prototype focussing on optical illusion-based gameplay and examining its impact on user experience and VR sickness. It offers preliminary guidance on how specific illusion mechanics such as gravity manipulation, forced perspective, and deception may influence player comfort, workload, and engagement. The findings provide actionable suggestions for designing perceptually rich VR experiences while highlighting areas where attention should be devoted. However, the applicability of these results is constrained by the study's limited sample size, the early development stage of the game prototype, and the specificity of the illusion types used. Technical limitations, gameplay bugs, and the aggregation of multiple illusion mechanics within a single evaluation further restrict the generalisability of the results. It also remains unclear which design elements contributed to VR sickness symptoms the most. In future studies, we aim to isolate and evaluate each illusion mechanic separately to better understand their individual contributions to workload, immersion, and comfort. Another limitation concerns the informal verbal feedback collected during gameplay. While it provided useful player experience insights, and especially to understand potential onset of VR during specific tasks, it was gathered through open-ended prompts without a standardized script. Although care was taken to avoid leading questions, the lack of structured protocol may have introduced variability or unintended bias, and qualitative responses are therefore be interpreted with caution. Future work is underway to evaluate the implemented optical illusions more comprehensively by refining the game prototype, isolating the evaluation of each type of illusion, and testing with a larger and more diverse sample to further explore and validate the current findings, while addressing the limitations identified in this study.

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