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Exploring the Impact of Narrative and Sensory Information on User Engagement in VR: The Case of the”'Horizon of Khufu Experience”

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Résumé

Cette thèse explore comment des éléments sensoriels et narratifs spécifiques influencent la réponse émotionnelle, l'engagement de l'utilisateur et la satisfaction dans les expériences immersives en réalité virtuelle (RV). À mesure que la RV devient de plus en plus courante dans les contextes culturels et éducatifs, il devient essentiel de comprendre le rôle des caractéristiques de conception pour créer des expériences percutantes et significatives. Malgré l'intérêt croissant pour la conception immersive, peu d'études ont examiné de manière empirique comment ces éléments individuels contribuent à l'expérience utilisateur lors d'interactions culturelles en RV centrées sur la narration.

Pour combler cette lacune, une étude à méthodes mixtes a été menée à l'aide d'une expérience muséale en RV, guidant les participants à travers une reconstruction virtuelle de la pyramide de Gizeh. Quarante-trois participants ont complété l'expérience pendant laquelle des données physiologiques (activité électrodermale et variabilité de la fréquence cardiaque) ont été collectées. Cette phase a été suivie par des questionnaires post-expérience mesurant l'excitation émotionnelle, la valence, l'engagement, la satisfaction et l'intention de recommandation, ainsi que par des entretiens qualitatifs.

Les résultats ont montré qu'une luminosité plus élevée augmentait significativement l'excitation émotionnelle. Bien que le mouvement vertical ait été perçu comme novateur et stimulant, il n'a pas conduit à une augmentation significative de l'excitation physiologique. Cela suggère que la nouveauté perceptive, sans impact émotionnel fort, ne suffit pas à elle seule à élever les niveaux d'excitation. En revanche, la richesse narrative a significativement renforcé l'engagement des utilisateurs. De plus, l'excitation émotionnelle et la valence se sont révélées être des prédicteurs importants de l'engagement et de la satisfaction lorsqu'elles sont mesurées après l'ensemble de l'expérience, plutôt qu'instant par instant, ce qui indique que les émotions se construisent au fil du récit.

En combinant mesures physiologiques et auto-déclarées, cette étude contribue à la littérature croissante sur l'expérience utilisateur dans les environnements immersifs. Elle

apporte une compréhension plus claire de la manière dont les éléments de conception peuvent favoriser l'absorption émotionnelle et cognitive en RV.

D'un point de vue managérial, l'étude suggère deux implications principales. Premièrement, la conception sensorielle doit équilibrer nouveauté et confort, notamment en ce qui concerne l'éclairage et le mouvement. Deuxièmement, les éléments narratifs doivent être structurés avec un rythme clair et une cohérence émotionnelle afin de maintenir l'attention et l'implication de l'utilisateur. Des stimuli sensoriels mal chronométrés ou trop complexes peuvent nuire à la clarté et interrompre l'engagement.

Mots clés : Luminosité, Mouvement, Richesse narrative, Réponse émotionnelle, Engagement utilisateur, Réalité virtuelle, Expérience utilisateur, Expérience immersive, Méthodes mixtes

Méthodes de recherche : Expérimentation, méthode d'observation, recherche quantitative

Abstract

This thesis explores how specific sensory and narrative elements influence emotional response, user engagement, and satisfaction in immersive virtual reality (VR) experiences. As VR becomes increasingly common in cultural and educational contexts, understanding the role of design features is essential for creating impactful and meaningful experiences. Despite growing interest in immersive design, few studies have empirically examined how these individual elements contribute to user experience during narrative-driven cultural VR interactions.

To address this gap, a mixed-methods study was conducted using a VR museum experience that guided participants through a virtual reconstruction of the Pyramid of Giza. Forty-three participants completed the experience while physiological data (electrodermal activity and heart rate variability) and self-report data were collected. This was followed by post-experience questionnaires measuring emotional arousal, valence, engagement, satisfaction, and recommendation intent, along with qualitative interviews.

The results showed that higher brightness of the immersive experience scene significantly increased user's emotional arousal. Although vertical movement was perceived as novel and exciting, it did not lead to significantly higher physiological arousal. This suggests that perceptual novelty alone, without creating a strong emotional impact, may not be enough to elevate arousal levels. Narrative richness, on the other hand, significantly enhanced user engagement. Additionally, emotional arousal and valence were found to be significant predictors of engagement and satisfaction when measured after the whole experience, rather than moment-by-moment, indicating that emotions build over time during the narrative experience.

By focusing on both physiological and self-reported measures of experience, this study contributes to the growing literature on user experience in immersive environments. It provides a clearer understanding of how design features can support emotional and cognitive absorption in VR.

Managerially, the study suggests two main implications. First, sensory design should balance novelty and avoid overstimulation, particularly in lighting and movement. Second, narrative elements should be structured with clear speech pace and volume of the information being optimised for comprehension, which in turn sustains user attention and involvement. Overly fast delivery and content of the narration may reduce clarity and disrupt engagement.

Keywords : Luminosity, Movement, Narrative Richness, Emotional Response, User Engagement, Virtual Reality, User Experience, Immersive Experience, Mixed Methods

Research methods : Experimentation, observation method, quantitative research

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List of abbreviations and acronyms

CPM	Component Process Model
ECG	Electrocardiogram
EDA	Electrodermal Activity
HMD	Head-Mounted Display
HR	Heart Rate
HRV	Heart Rate Variability
REB	Research Ethics Board
UX	User Experience
VE	Virtual Environment
VR	Virtual Reality

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Above all, this thesis represents a journey of growth, not only as a researcher but as an individual. It is a testament to the power of hard work, persistence, and the belief that dreams can become reality. My sincere thanks to everyone who supported me along the way—your presence and your guidance have been invaluable.

Chapter 1
Introduction

1.1 Introduction

Virtual reality (VR) is a computer-generated, three-dimensional environment designed to simulate real or imagined worlds through user interaction (Hamad & Jia, 2022). Typically accessed via head-mounted displays (HMDs) and motion-tracking sensors, VR transports users to immersive environments and conveys information through sensorial cues like image and sound stimuli. This allows even non-expert users to isolate from the outside world and engage in the virtual world as if they were there physically present (Carrozzino & Bergamasco, 2010; Melo et al., 2022).

Virtual Reality (VR) is experiencing rapid adoption across multiple sectors, evolving beyond its roots in gaming to become an influential tool in education, healthcare, and professional training. As of 2024, the number of active VR users worldwide is projected to reach 171 million, a substantial increase from 58.9 million in 2021 (HQSoftware, 2025). This growth reflects advancements in both hardware affordability and software sophistication, including the integration of photorealistic rendering, intuitive interfaces, and multisensory feedback systems. Institutions are increasingly leveraging VR for its potential to improve engagement and performance—30% of universities now offer VR-based courses, and 40% of healthcare providers incorporate VR into patient care and staff training (HQSoftware, 2025).

Beyond the above mentioned fields, VR is transforming museums in a way that enhances how cultural and historical narratives used to be presented and experienced (Shehade & Stylianou-Lambert, 2020). For example, the Guggenheim Museums in New York City are now partners of the Google Cultural Institute in a project to push things further by creating a virtual reality experience whereby users will be able to explore a museum digitally, get into its exhibitions, and place themselves at the center of the rotunda using their computer or VR viewer (Mir, 2016). This enables the public to do things with exhibitions that could not have done before, hence giving them a better experience.

Through VR technologies, museums would extend access not only to cultural education but also to further interaction between visitors and exhibits (Chang et al., .

The level of user engagement with virtual reality is likely influenced by their sense of presence or the feeling of being physically immersed in the virtual environment (Wagler & Hanus, 2018). The sense of presence is supported by two main elements: context and immersion (Slater & Wilbur, 1997). Context refers to how convincing the virtual environment's setting and storytelling are for the user (Lorenz et al., 2018). This is related to the level of detail and depth in the story content (Dow et al., 2007; Slater, 2009). A well-crafted narrative with rich details provides context and relevance, encouraging users to become emotionally and intellectually involved in the story (Green & Brock, 2000). Narrating a story opens possibilities for engagement in interpretative processes and relational interaction. Immersion refers to both the cognitive state and the technological attributes of the system. It is defined by an individual's experience of deep mental involvement in which their cognitive process causes a shift in their attentional state. There are two major aspects on immersion, including an individual's psychological state and an objective property of technology (Agrewal et al., 2020). Sensory immersion in VR refers to the extent to which the virtual environment can engage all the user's senses, effectively replicating the real world through visual, auditory, and tactile stimuli (Slater & Wilbur, 1997). This has been related to the objective measure of how the Virtual Environment (VE) qualifies, while presence has been related to the subjective, psychological experience of being there (Cummings & Bailenson, 2016; Slater, 2009; Wirth et al., 2007).

When users are immersed in a VR story living experience, the emphasis is not only on the narrative but on the psychological process through which the participant engages with and within the narrative (Vallance & Towndrow, 2022). Engagement in this context is defined as the user's active involvement and emotional investment in the VR experience. It encompasses not just the attention or time spent but also the quality of interaction, characterized by enjoyment, interest, and the value derived from the experience. This engagement is critical, as it makes VR experiences not only immersive but also meaningful as it provides users with memorable and resonant journeys (Dow et al., 2007).

Despite extensive research on factors enhancing presence in VR, such as rendering latency and interaction design, there is a gap in understanding how these elements integrate with narrative richness to affect user engagement in educational settings like museums (Dow et al., 2007). Although a strong presence can make the VR experience more compelling, it doesn't automatically guarantee deeper engagement (Dow et al., 2007).

Dumlu & Demir (2020) examined user experiences within VR storytelling environments by analyzing user behavior, reactions, and memory. The findings were that visual and auditory stimuli significantly influenced user engagement within the narrative space created by the story. Users tended to react to motion, sound, and spatial elements within the narrative. The prediction of how users interact with the story is crucial for effective storytelling and facilitating the directing of user attention to the appropriate immersive experience element. For instance, if users disengage by exploring the environment on their own, rather than following the narrative, the stimulations don’t have the anticipated impact on them.

Dow et al. (2007) compared three different versions of the facade to see the impact of different immersion factors on the user’s sense of presence. The results of this quantitative study suggested that while the more immersive interface increases the sense of presence, a heightened sense of presence did not always lead to higher engagement.

While VR has been adopted across industries, designing experiences that go beyond technical immersion to foster meaningful engagement remains a common challenge. To achieve effective engagement in VR, presence must be combined with well-designed interactive experiences that align with user expectations and preferences. This emphasizes the critical role of thoughtful, user-centric design in VR applications.

This study aims to bridge the existing research gap by exploring how variations in narrative richness and sensory immersion levels within museum VR experiences influence user engagement. Understanding these dynamics will provide valuable insights into optimizing VR applications by selecting appropriate extrinsic and intrinsic elements for cultural settings, ensuring that VR continues to be a powerful tool for enhancing user experience (Cummings & Bailenson, 2016).

1.2 Personal Research Contributions

This thesis was conducted as part of the student's master's thesis project, with invaluable supervision provided by the research directors and significant support from the Tech3Lab research team. The student's contributions throughout the various stages of this research are summarized in Table 1, which outlines her responsibilities and involvement in each phase leading to the completion and submission of the thesis.

Table 1. *Individual Contributions to Research Activities*

Research Process	Student Contribution
Literature review	**100% Literature Review:** Conducted an extensive review of existing literature on immersive virtual to assess current methodologies, identify gaps, and inform the development of the research framework. Contributed to selecting relevant psychometric scales and optimal tools for measuring the impact of sensory and narrative cues on user experience.
Research question	**60% Research Question Formulation:** Developed a research question focused on the impact of narrative and sensory cues on user experience in immersive VR environments. Aligned the question with the VR exhibition format and contributions to the field, with input from research directors.
Experimental design	**80% Ethics approval:** Drafted the REB application and all required documentation. Finalized submission with supervisory feedback. **60% Experimental protocol:** Wrote the initial version of the experimental protocol for data collection, which was refined through iteration with the supervisors. **80% Questionnaires & interview questions:** Develop online Qualtrics questionnaires and formulate interview questions. **70% Partner relationship management:** Coordinated with PHI regarding experimental logistics, including ensuring tools compatibility, ticket reservations, and setup for the field study, with guidance from my supervisors.
Recruitment	**30% Participants recruitment:** Contributed to setting eligibility criteria and developed consent materials. Research assistants were

Research Process	Student Contribution
	responsible for executing most recruitment logistics and participant coordination.
Data collection	**70% Experimental Pretests:** Led the coordination and execution of pretests to evaluate the chosen VR stimuli and experimental flow. Worked collaboratively with research assistants and technical staff. **70% Data Collection**: Managed data collection, including welcoming participants on site, assisting in tools installations, and user interviews. Help was provided by a research assistant for tools synchronization and troubleshooting.
Statistical analysis	**50% Psychometric and Psychophysiological Data Analysis:** Data analysis was conducted by statistician, while the interpretation of the data was carried out by the contributor. Also reviewed GoPro camera videos to analyze participants' reported engagement through hand signals. **50% Qualitative Data Analysis:** Transcribed user interviews and identified emerging patterns through a detailed analysis of the qualitative data.
Results	**80% Results Presentation:** Developed content for reports and presentations. Assisted in preparing visual elements and slide decks for presenting findings at conferences.
Thesis	**75% Thesis Writing:** Wrote the thesis, integrating the research findings and discussing their implications. Worked closely with the supervisors for feedback and refinement of the final document.

1.3 Thesis Structure

This thesis is structured into four chapters, each addressing a specific aspect of the research on sensory elements, narrative richness, and their role in shaping user experience in virtual reality.

The first chapter introduces the research topic by framing it within the context of virtual reality and its application in cultural and educational settings. It provides an overview of the research problem, objectives, and significance of exploring how sensory elements

(such as luminosity and movement) and narrative richness affect emotional responses, engagement, and user satisfaction in VR.

Chapter 2 presents the theoretical framework, reviewing key concepts such as emotional arousal and engagement in immersive environments. The research question is outlined, and the methodology used to investigate the role of sensory and narrative elements in VR user experiences is introduced. It describes the experimental design, data collection methods, and analysis strategies employed to test the hypotheses regarding the effects of luminosity, movement type, and narrative richness on emotional arousal, engagement, and satisfaction. The results of the study are detailed, providing both quantitative and qualitative insights into the impact of these factors on user experience. The findings contribute to understanding how sensory and narrative cues shape VR interactions, with a focus on educational and cultural contexts.

The third chapter explores the practical implications of the study's findings for VR designers and developers, particularly in cultural and educational contexts. It discusses how designers can leverage sensory information and narrative richness to create more engaging and immersive user experiences in VR. The chapter bridges theory and practice by translating research findings into design guidelines that can be used to optimize user experiences in immersive environments.

The final chapter synthesizes the key findings of the thesis, summarizing the contributions to the field of VR user experience design. It discusses the implications of the results for both theory and practice, emphasizing how sensory and narrative elements impact emotional engagement and user satisfaction in VR. The chapter also reflects on the limitations of the study and suggests avenues for future research.

The in-progress preliminary version of this study was submitted to the AMCIS (Americas Conference on Information Systems); see Appendix E.

Chapter 2
Narrative and Sensory Cues Impact on User Experience in VR

Abstract

Virtual Reality (VR) enhances user engagement by providing immersive and interactive experiences, but the effects of sensory cues and narrative richness on engagement remain unclear. This study explores how sensory cues—specifically luminosity and movement—and narrative richness affect emotional response and perceived engagement in a narrative-driven VR exhibition. Using a mixed-method approach combining physiological measures (EDA, ECG), self-reported engagement metrics, and interview data, the study finds that brighter environments increase enjoyment and arousal, while vertical movement induces higher engagement than horizontal navigation. Furthermore, higher narrative richness significantly enhances emotional involvement and overall user satisfaction. These findings contribute to VR research and design by demonstrating how sensory and narrative integration enhances user engagement, offering guidance for creating more immersive, emotionally engaging cultural and educational applications.

2.1 Introduction

Immersive exhibitions have emerged as a turning point in the cultural and creative industries, reshaping how audiences engage with art, heritage, and education. The global Traveling Immersive Exhibitions market reached USD 4.27 billion in 2024 and is projected to grow to USD 12.35 billion by 2033 (Dataintelo, 2024). The integration of digital and immersive technologies has redefined how stories are told and experienced within exhibition contexts. These multisensory and interactive environments not only enhance visitor engagement but also transport them to different times and places, while encouraging curiosity and active exploration (Li et al., 2023).

Beyond its market growth, immersive technologies have two main areas of importance. First, they play a crucial role in preserving and sharing cultural heritage. Many artworks, monuments, and historical sites are at risk of deterioration or loss over time, while others

are located in places that are difficult to access. Virtual reality provides a valuable opportunity to digitally reconstruct and experience these cultural assets, allowing audiences to explore and interact with them beyond geographical and physical limitations. In this way, VR helps protect cultural heritage while also making it accessible to a wider public (Carrozzino & Bergamasco, 2010).

Second, immersive technologies improve learning and understanding by enabling intuitive and sensory forms of interaction. Instead of relying only on symbolic or text-based information, VR allows users to engage directly with objects and environments through sight, sound, and movement. This type of active participation supports deeper learning, emotional connection, and memory retention, creating an experience that is both educational and personally meaningful (Carrozzino & Bergamasco, 2010; Parong & Mayer, 2018). As museums and cultural institutions increasingly adopt these technologies, understanding how specific design elements shape users' emotional and cognitive experiences becomes essential for creating effective and meaningful immersive environments.

Virtual Reality is no longer just a futuristic concept—it is becoming part of everyday life. With the release of Apple's Vision Pro and Meta's Oculus Go, VR has once again captured public attention as a powerful and emerging technology. While gaming has played a major role in VR's rise, its impact reaches far beyond entertainment. Today, VR is used by surgeons to prepare for complex procedures, by educators to take students on virtual field trips, and by architects to walk through buildings before they are built (Hamad & Jia, 2022). In this context, VR delivers simulated content to the senses, creating experiences where visual perception, auditory input, and tactile sensations closely replicate real-world conditions (Ariya et al., 2025). These features allow VR to go beyond traditional media by engaging users on both sensory and emotional levels, enabling experiences that can alter mental states or simulate a sense of physical presence (Mathew, 2014).

VR's power lies in its ability to generate immersion in which users feel transported into an alternative reality. Immersion is a multidimensional construct that involves both perceptual and psychological aspects. This can be organized in three dimensions including

the property of the system, the response to an unfolding narrative, and the response to challenges demanding the users' intellect or sensorimotor skills of the system (Nilsson et al., 2016). Immersive systems provide a stronger sense of being there, where users feel that they are physically present in the virtual world (Lee, 2020). The sensory stimulation provided by VR systems, such as visual, auditory, or haptic feedback, contributes significantly to perceptual immersion, allowing users to feel surrounded by the environment (Eaton, 2020).

On the other hand, subjective immersion refers to the emotional and cognitive engagement users feel when they are absorbed in the virtual world in which with or without sensory simulation, their cognitive process causes the dissociation from the awareness of the physical world (Agrewal et al., 2020). The cognitive aspect of immersion helps the users to be deeply transported to a completely other reality that emerges and grows through the development of storytelling (Green & Brock, 2000; Zhan et al., 2020).

Diemer et al. (2015) determined immersion as "the fundamental concept of the facilitation of emotion in a VE". The research found that emotional responses in VR systems mediate the effect of immersive technology. Users' emotional reactions are induced in immersive environments as VR relies on the selection of specific perceptual cues to activate emotions.

Exhibitions and museum environments are shifting from passive displays to multisensory, interactive encounters that rely on narrative and sensory cues to sustain engagement and emotional connection. The integration of VR into these contexts allows for the simulation of rich, realistic environments that foster presence and curiosity. However, while technological sophistication has made such experiences possible, it does not guarantee their effectiveness.

The effectiveness of immersive experiences does not depend solely on technological sophistication. While higher levels of immersion are often associated with enhanced presence—a key factor linked to engagement and enjoyment (Cummings & Bailenson, 2016)— research has produced mixed results regarding their actual impact on learning and satisfaction (Parong et al., 2020). These inconsistencies indicate that psychological

mediators such as presence, cognitive load, and emotional involvement play a crucial role in determining when and how immersion contributes to positive user outcomes.

Previous studies have shown that even simple stimuli can elicit an emotional reaction. It can be assumed that all media formats can evoke a change in the emotional state of the user. The media types that engage a greater number of senses and immerse users are likely to evoke a higher emotional response (Bujić et al., 2023). However, there is a significant gap that remains in our understanding of how sensory and narrative cues influence emotional response and engagement in VR. While such cues—like lighting, motion, and unfolding storylines—are widely used in immersive design, empirical research has not sufficiently explored how these elements affect users' engagement. Without clear insights into how users respond to sensory intensity or narrative complexity, designers risk creating experiences that overwhelm or disengage visitors. Therefore, examining how specific sensory variables, such as luminosity and movement, interact with narrative richness is essential for advancing both theoretical understanding and practical design strategies for immersive storytelling environments. This knowledge contributes not only to the refinement of VR design principles but also to the broader effort of enhancing emotional resonance and learning effectiveness in cultural applications.

From a theoretical standpoint, VR in cultural and educational settings presents an opportunity to explore the mechanisms linking sensory design and user experience. Most existing studies focus on general immersion or presence, often overlooking the distinct contributions of specific design variables, particularly in narrative-rich VR experiences. Furthermore, few studies adopt multimodal approaches that combine physiological tracking with self-report measures to gain deeper insights into the user experience. From a practical perspective, understanding how these factors interact can help designers and curators balance sensory intensity and narrative flow to create emotionally meaningful and cognitively effective experiences.

This study contributes to addressing these gaps by examining how sensory and narrative cues in combination influence emotional and cognitive responses in immersive virtual environments. Specifically, it explores how variations in luminosity and movement orientation—as sensory elements—interact with narrative richness to shape user

engagement, enjoyment, and satisfaction. By integrating self-reported measures with physiological indicators such as electrodermal activity, this research offers a multimodal understanding of user experience, advancing the methodological and theoretical foundations of VR studies:

RQ: What is the effect of narrative and sensory cues on user experience in immersive virtual environments?

We hypothesized that variations in sensory and narrative cues would influence users' emotional and cognitive responses in virtual environments. Specifically, luminosity, movement type, and narrative richness were expected to shape users' emotional arousal, engagement, and enjoyment, which together contribute to their overall satisfaction and intention to recommend the experience. In particular, we anticipated that higher luminosity, more dynamic movement, and richer narratives would elicit stronger emotional reactions and foster deeper engagement, resulting in a more positive user experience.

The next section introduces the theoretical concepts that underpin this study. Section 2.3 details the methodology. Section 2.4 presents the results, followed by a discussion in Section 2.5. The chapter concludes with key insights and future works for immersive media design and research.

2.2 Theoretical Background and Hypothesis Development

2.2.1 Stimulus–Organism–Response (S–O–R)

A stimulus–organism–response (S–O–R) perspective offers a coherent way to explain how design features in immersive VR shape user experience. In this view, stimuli are environmental cues presented to users, organismic states are the cognitive and affective processes these cues evoke, and responses are the downstream attitudinal or behavioral outcomes. The framework has been widely applied across service and technology contexts to link environmental inputs to emotions, cognitions, and behaviors, and is therefore well suited to VR, where controlled sensory and narrative features can be systematically manipulated (Kim et al., 2020).

In the present study, stimuli are operationalized as luminosity (bright vs. dark scenes), movement type (vertical vs. horizontal), and narrative richness (high vs. low). These are theorized to influence organismic states (emotional arousal and valence, engagement, and enjoyment) which in turn shape responses (user satisfaction and intention to recommend). Adopting S–O–R provides a unifying rationale for the hypothesis development that follows environmental design choices in VR (S) are expected to alter users' internal states (O), which subsequently guide evaluative and behavioral tendencies (R).

2.2.2 Luminosity and emotional responses in immersive environments

Metaphor representation theory suggests that individuals understand abstract concepts, like emotions, by relating them to physical experiences (Lakoff & Johnson, 1999). Emotions such as happiness and positivity have long been associated with bright environments, while darker settings are often linked to depressive or subdued states (Meier & Robinson, 2004). Humans metaphorically map brightness to positive emotions and darkness to negative emotions in the pleased/depressed dimension (Zhang, 2014). The connection between brightness and emotions is further supported by embodiment theories, which propose that emotional processing relies on perceptual and motor systems. Studies have shown that brightness plays a significant role in emotional regulation (Tussyadiah et al., 2018). Zhang (2014) explored this relationship by examining how the brightness of visual stimuli impacts emotional states. The study found that viewing a white screen elicited feelings of happiness, while a black screen was associated with depressive feelings. A later study by Zhang et al. (2016) extended this research and uncovered that not only does brightness influence emotions, but emotions themselves can alter how brightness is perceived.

Russell's Circumplex Model of Affect (1980) categorizes emotions based on two dimensions: arousal, or the intensity of emotional activation, and valence, the degree of positivity or negativity in an emotional state. Brightness has been shown to enhance arousal and positive valence, leading to feelings of energy and happiness, while darker settings are often associated with lower arousal and subdued emotions (Zhang et al., 2016). However, darker environments do not necessarily trigger fear or heightened arousal. Lighting conditions have been shown to influence perceived pleasantness

consistently, regardless of the specific type of simulated environment (Rohrmann, 1995). Nighttime virtual environments are perceived as less pleasant than daytime ones, but they did not elicit significantly higher arousal (Toet, 2009).

Within the stimulus–organism–response (S–O–R) framework, luminosity can be conceptualized as a stimulus that shapes users' organismic states. Specifically, their emotional arousal, valence, engagement, and enjoyment, which then influence consequent responses such satisfaction. Brightness has been shown to enhance arousal and positive affect (Zhang, 2014; Zhang et al., 2016), but darker environments may also heighten certain emotions such as fear, mystery, or absorption, which can in turn influence engagement (Meier & Robinson, 2004). This suggests that luminosity does not act in a uniformly positive manner but rather shows varied impacts depending on context and content. By presenting both sides of the evidence, the current study positions luminosity as a critical stimulus in VR environments, hypothesizing that higher luminosity will foster positive emotional responses, while acknowledging the potential for darker scenes to elicit alternative affective states.

H1a: Luminosity will positively influence the user's emotional arousal in the immersive environment.

Variations in brightness provide the contrast needed for visual processing, which is essential for vision and influences the actions of humans. Eroğlu et al. (2020) explored the impact of brightness on neural activity during visual processing, emphasizing its role as a key perceptual feature influencing emotional and cognitive responses. The study demonstrated that brightness has strong and consistent effects on emotions, alongside its influence on behavioral and visual processes. The research revealed how brightness affects brain activity across different frequency bands and cortical regions, particularly for visual stimuli with varying emotional content (pleasant, unpleasant, and neutral).

Chamilothori et al. (2019) compared real daylit spaces with their virtual representations created using photometrically accurate lighting simulations. Their study revealed no significant differences in subjective evaluations of attributes such as pleasantness, complexity, and interest between the two settings. These findings validate the capability

of virtual reality (VR) to replicate real-world lighting conditions and elicit similar emotional and perceptual responses.

Similarly, Xia et al. (2021) highlighted the emotional and behavioral impacts of lighting in VR, demonstrating that immersive environments designed with high visual fidelity can consistently evoke emotional responses comparable to those in real-world environments. They emphasized the role of brightness and color in fostering positive emotions, enhancing presence, and increasing arousal in VR, reinforcing the notion that virtual environments can serve as effective surrogates for real-world contexts in lighting studies.

H1b: Luminosity will positively influence the user engagement in the immersive environment

H1c: Luminosity will positively influence the user enjoyment in the immersive environment

Based on these findings we expect that luminosity in immersive environments will evoke positive emotional responses similar to those observed in real-world settings. Bright environments are likely to enhance arousal (the intensity of emotional activation) and valence (the positivity of the emotional state). In this study, luminosity refers to the perceived brightness or intensity of light within a visual scene. By comparing these two conditions, we can see how changes in luminosity affect users emotionally.

2.2.3 Movement type and emotional responses in immersive environments

The way users navigate and interact in virtual environments (VEs) profoundly influences their emotional and cognitive experiences. Movement, as a fundamental aspect of interaction, shapes users' sense of presence, engagement, and emotional responses.

Embodiment theory provides a framework to understand how technological mediation integrates users' perceptual and motor systems, creating a sense of being within a virtual body or environment (Tussyadiah et al., 2018). This concept, referred to as technological embodiment, allows users to feel as though their virtual body is an extension of their real body in the virtual space (Kilteni et al., 2012). According to the theory of technological mediation (Ihde, 1990), human-technology interactions shape perception and behavior

that foster a sense of immersion. Embodied technologies, such as VR headsets, can improve emotional experiences by enhancing sensory integration and user interaction (Kim et al., 2020). For example, Flavián et al. (2021) in a study of guest engagement in hotels' pre-experience demonstrated that embodied technologies amplify positive emotional states by seamlessly blending movement and user perception, which is particularly relevant for different types of movement in VEs.

Research has shown that virtual embodiment affects emotional responses to stimuli. Gall et al. (2021) found that higher levels of virtual embodiment led to increased emotional arousal, valence, and dominance. This suggests that movement in VR, which is closely tied to having a body in an environment, plays a critical role in shaping emotional experiences. This aligns with the theory of depersonalization that embodiment increases the relevance of the virtual environment, thereby intensifying emotional reactions (Dewe et al., 2018).

The type of movement in VEs plays a critical role in shaping emotional responses. Studies comparing real walking, virtual walking, and flying in VEs have demonstrated the importance of movement fidelity significantly impacts presence and emotional arousal. Usoh et al. (1999) showed that real walking elicited the highest levels of presence and natural movement, followed by virtual walking, with flying being the least immersive. Boletsis (2017) reviewed 36 studies and found that physical locomotion techniques, such as walking-in-place and redirected walking, supported continuous movement and closely aligned with natural body motion, enabling more intuitive navigation and a stronger sense of embodiment. Realistic and natural movement types not only enhance presence but also positively influence emotional responses, as they align closely with users' proprioceptive and sensory expectations. In this study, vertical movement is related to the part of VR experience, where elevation changes are designed to intensify novelty and arousal.

H2a: The type of movement significantly influences the user's emotional arousal in the immersive environment, such that the vertical movement leads to higher emotional arousal.

Särkelä et al. (2009) found that users who experienced fluent movement in VEs reported higher presence and evaluated the environment as more pleasant and engaging. Conversely, users with less fluid or stationary movements experienced lower engagement and boredom. These findings align with the flow theory (Csikszentmihalyi, 1997), which suggests that a balance between skill and challenge fosters optimal engagement and emotional responses. In VEs, movement fluency enhances the sense of control and interaction which contribute to a more immersive and emotionally engaging experience (Slater, 2009).

Movement in virtual environments used to translate user from a location to a target position could be controlled virtually or physically, or the action of motion to be active or passive (Bowman et al., 1997). Medeiros et al. (2020) introduced a new approach of a Magic Carpet, which applies real-walking metaphors to flying, improving flexibility and reducing discomfort in vertical locomotion. This approach demonstrated that high interaction fidelity in vertical movement could enhance emotional engagement and immersion. Recent work by Nguyen-Vo et al. (2018) emphasized that incorporating real-world references in vertical movement improves spatial orientation and user confidence. While horizontal movement, such as walking, aligns more naturally with human behavior, vertical movement, when designed thoughtfully, can provide unique advantages for exploring expansive VEs. In this study, vertical elevation is expected to strengthen engagement by directing attention to new perspectives within the environment.

H2b: The type of movement significantly influences the user's engagement in the immersive environment, such that the vertical movement leads to higher engagement.

Interaction fidelity, defined as "the objective degree of exactness with which real-world interactions can be reproduced" by McMahan et al. (2012), is a key determinant of movement effectiveness in VEs. High-interaction fidelity techniques, such as redirected walking, enhance spatial knowledge and presence while reducing cybersickness (Langbehn et al., 2018; Petkova et al., 2011). Soler-Domínguez et al. (2020) studied various movement designs and found that natural movement methods, like walking, yielded higher arousal and presence compared to abstract techniques, such as flying.

These findings suggest that intuitive and natural movement types positively influence emotional responses by fostering immersion and reducing discomfort.

H2c: The type of movement significantly influences the user's enjoyment in the immersive environment, such that the vertical movement leads to higher enjoyment.

Based on the reviewed literature, movement types in immersive environments influence emotional responses through their impact on presence, embodiment, and interaction fidelity. Horizontal movements, such as walking, evoke higher levels of arousal and valence due to their natural alignment with human behavior. Vertical movements, such as flying, while less intuitive, can also enhance emotional engagement when designed with high fidelity and realism.

2.2.4 Narrative richness in immersive environments

Narratives have been an integral part of human culture, providing a powerful means to connect, engage, and evoke emotions. Stories allow individuals to experience and interpret the world from new perspectives, shaping their opinions and values (Wolfe et al., 2022). Immersive storytelling, particularly in Virtual Reality (VR), takes this experience to another level by allowing users to become active participants within the narrative. Unlike traditional storytelling, VR enables users to explore, interact, and become a part of the story world, fostering a deeper emotional connection and engagement for shaping a positive experience (Irshad & Perkis, 2020; Dumlu & Demir, 2020).

Transportation theory suggests that individuals who are deeply absorbed in a narrative, experience a sense of detachment from the real world, becoming fully immersed in the narrative world. Transported individuals may empathize with characters, experience emotions tied to the narrative, and temporarily suspend disbelief that makes the story feel more real. (Green & Brock, 2000).

Flow theory (Csikszentmihalyi, 1997) describes a state of optimal engagement, where individuals become so absorbed in an activity that they lose track of time and external distractions. Narratives with clear goals, engaging challenges, and compelling storylines

can trigger this state, particularly when combined with the immersive qualities of VR (Lee. H, 2020).

Emotional flow theory by Nabi & Green (2015) explains the dynamic nature of emotional responses during narrative experiences. In storytelling, there are two types of emotions involved in experiencing a narrative: the stimulus level emotions to direct audiences' attention and are implied in the story and the emotion that is felt by the characters within the story.

Recent research has highlighted the complex relationship between narrative structure and emotional responses with an emphasis on how varying narrative elements evoke different levels of arousal and valence (Schmidt et al., 2023). The emotional dynamics of stories across various genres have been shown to influence both immediate and retrospective emotional responses. Narrative structures with dynamic variations in valence—such as emotionally intense sections—tend to elicit stronger arousal, particularly for negatively charged emotions. These shifts in emotional intensity were more aligned with arousal metrics for negative emotions than for positive ones. (Schmidt et al., 2023).

However, narrative richness does not always lead to uniformly positive outcomes. In VR contexts, complex stories can increase cognitive workload, making it more difficult for users to process information and sustain attention. Research on VR digital storytelling highlights that while richer narratives enhance immersion and emotional engagement, they also require users to manage workload at a reasonable level (Škola et al., 2023). These findings suggest that narrative richness must strike a balance: it can deepen immersion and emotional arousal, but only when demands do not exceed users' cognitive capacity.

Therefore, while narrative richness can increase cognitive demands, most evidence indicates that richer narratives usually enhance emotional arousal by drawing users more deeply into the story and strengthening their emotional responses.

H3a: Narrative richness (complexity and depth of the story) will positively influence users' emotional arousal in the immersive environment, such that richer narratives will lead to higher levels of arousal.

Furthermore, Schmidt et al. emphasized the critical role of narratives in shaping emotional experiences by acting as a framework for classifying both physiological (e.g., arousal) and subjective (e.g., valence) emotional responses. Their study found that complex or ambiguous narrative sections heightened emotional intensity, particularly for negative emotions, which emphasizes the role of storytelling structures in shaping the depth and quality of emotional engagement.

VR amplifies narrative richness by engaging multiple senses simultaneously, enabling users to see, hear, and interact with the story (Škola et al., 2020). Irshad & Perkis (2020) observed that narratives in VR significantly increase user engagement and evoke stronger emotional responses compared to non-narrative environments.

H3b: Narrative richness will positively influence users' engagement in the immersive environment, such that richer narratives will lead to deeper cognitive and emotional involvement compared to simpler narratives.

VR storytelling transforms users from passive observers to active participants, giving them the agency to explore and influence the story (Xu & Ragan, 2019). This interactivity enhances emotional engagement by allowing users to experience the story from their unique perspective. Wolfe et al., 2022 argue that VR storytelling elicits empathy and emotional reactions more effectively than traditional media by enabling users to feel present within the narrative world. Immersive storytelling in VR relies on dynamic sensory stimuli, including visual and aural elements, to evoke emotional responses (Dumlu & Demir, 2020). Narratives designed with careful consideration of sensory and emotional elements—such as color, sound, and pacing—can amplify arousal and valence, creating a deeply engaging user experience (Wolfe et al., 2022; Schmidt et al., 2023).

Narratives in VR evoke emotional responses through their structure and content. Schultze (2010) found that narrative-rich environments enhance users' ability to empathize, process emotions, and engage with the story, resulting in greater emotional arousal and

valence. Similarly, Škola et al. (2020) observed increased cognitive and emotional engagement in VR storytelling experiences, as indicated by EEG readings and user feedback.

H3c: Narrative richness will positively influence users' enjoyment in the immersive environment, such that richer narratives will result in a more enjoyable experience.

Rich narratives provide opportunities for users to relate to characters and events on a deeper level, fostering empathy and cognitive engagement (Wolfe et al., 2022). This connection intensifies emotional responses, as users process the narrative's complexities and integrate them into their own experiences.

2.2.5 Emotional response and User engagement

Emotions play a fundamental role in shaping cognitive processing, decision-making, and interaction within immersive environments (Schreiner & Riedl, 2019). These affective reactions significantly influence user engagement, as heightened emotions enhance the sense of presence and interaction within a virtual environment (Flavián et al., 2021). The Component Process Model (CPM) of emotion (Delplanque et al., 2009) suggests that emotions arise from synchronized changes in multiple subsystems, including appraisal, motivation, physiology, expression, and subjective feeling (Somarathna et al., 2023).

User engagement in immersive environments is a multidimensional construct, encompassing behavioral, cognitive, and emotional dimensions (Lequerica & Kortte, 2010). O'Brien et al. (2018) describe engagement as the extent of a user's affective, cognitive, and behavioral investment in an experience. Research suggests that higher emotional arousal and pleasure lead to stronger user engagement, as individuals become more absorbed in experiences that elicit intense emotions (Bilro et al., 2019).

In the Process Model of Engagement, user engagement is conceptualized as a stage-based process including point of engagement, sustained engagement, disengagement, and reengagement. Throughout this process, key engagement attributes—focused attention, perceived usability, aesthetic appeal, endurability, novelty, and felt involvement—fluctuate based on the user's evolving interaction with the system (O'Brien et al., 2018).

Focused attention reflects cognitive absorption and the ability to lose track of time, while perceived usability relates to effort, control, and the presence of negative affect during interaction. Aesthetic appeal refers to the visual and sensory attractiveness of the interface, whereas endurability represents a user's willingness to re-engage with and recommend an experience. Novelty sustains engagement by stimulating curiosity and interest, while felt involvement captures the sensation of being drawn into the experience.

Similarly, emotional peaks and shifts within immersive narratives sustain engagement by maintaining user attention and investment (Schmidt et al., 2023). Positive emotions (e.g., joy and excitement) foster sustained engagement, while negative emotions (e.g., fear and tension) capture immediate attention but may reduce long-term engagement (Bilro et al., 2019; Willis, 2007).

While emotional responses capture initial attention, maintaining engagement in VR also depends on how users allocate cognitive attention to process narrative and sensory input effectively. Cognitive attention is a critical cognitive function that influences user experience in immersive environments by determining where mental resources are allocated during VR interaction (Barton et al., 2020). Unlike emotional engagement—which reflects subjective enjoyment and affective resonance—attention involves selectively focusing on relevant stimuli while filtering distractions (Chang et al., 2018).

In immersive virtual reality environments, attention operates on both internal and external levels. Internal attention focuses on thoughts or memories, while external attention is directed toward sensory inputs like visual and auditory stimuli. External attention can be guided in a top–down manner, when users consciously focus on task-relevant elements, or it can be captured bottom–up by noticeable features such as brightness or movement. Because VR environments are rich in sensory cues, balancing these attentional processes is essential to avoid overload and maintain engagement (Chiossi et al., 2025).

Poor attention balance or excessive cognitive load—especially in highly interactive or distracting VR environments can reduce the quality of engagement (Wen et al., 2024). Attention also modulates how users perceive and respond to virtual narratives and sensory cues, reinforcing its role as a mediator between design elements and sustained cognitive

engagement. Therefore, attention is not only essential for meaningful interaction in immersive environments, but it also helps strengthen users' emotional connection, supports the feeling of flow, and contributes to overall satisfaction.

Studies have found that VR enhances emotional engagement through sensory integration, allowing users to see, hear, and feel the virtual space, which leads to greater affective and psychological engagement (Qaisar et al., 2024).

Given the reviewed literature, emotional response (arousal and valence) plays a crucial role in shaping user engagement in immersive environments. Users who experience higher arousal and positive valence are more likely to feel psychologically engaged, leading to greater attention, interaction, and extended involvement in VR experiences. We expect that greater emotions will lead to higher user engagement levels:

H4: Greater emotional arousal will lead to higher user engagement during the immersive experience.

H6 (abcd): Greater emotional arousal will positively influence focused attention (H6a), Perceived usability (H6b), Aesthetic appeal (H6c), Endurability, novelty, and felt involvement (H6d)

H7 (abcd): Greater emotional valence will positively influence focused attention (H7a), Perceived usability (H7b), Aesthetic appeal (H7c), Endurability, novelty, and felt involvement (H7d)

User enjoyment is increasingly recognized as a key driver of engagement in immersive experiences. Enjoyment refers to the degree of fun or pleasure users derive from an activity, and it can significantly shape their level of involvement (Nguyen, 2025). Highly enjoyable experiences tend to capture users' interest and motivate them to continue interacting, thereby sustaining engagement over time. For instance, students in a simulation study reported significantly greater engagement when a VR training scenario was highly enjoyable, compared to a less immersive desktop version of the scenario (Walls et al., 2024). This positive correlation between enjoyment and engagement aligns with broader findings that pleasurable, fun experiences increase users' intrinsic

motivation and focused attention, fostering deeper involvement and willingness to re-engage:

H5: Higher user enjoyment will positively correlate with user engagement

2.2.6 Engagement, Satisfaction, Behavioral Intentions

User satisfaction is a key determinant of user behavior in tourism and digital experiences (Walls et al., 2024). Satisfaction arises from fulfilling user expectations and creating enjoyable, meaningful interactions (Talukdar & Yu, n.d.). In immersive environments, satisfaction is closely linked to engagement, as users who find VR experiences compelling are more likely to feel positive about the overall experience (Jessen et al., 2020). Research has shown that engagement fosters satisfaction by increasing confidence in decision-making and enhancing emotional involvement (Abou-Shouk & Soliman, 2021; Wu & Lai, 2021).

Talukdar & Yu, n.d. found that immersive VR experiences generate higher satisfaction levels due to their novelty and ability to provide engaging interactions compared to non-immersive systems. In a recent study by Abou-Shouk et al. (2024) investigated the impact of immersive technology adoption on customer satisfaction and loyalty and found that engagement satisfies users' needs and persuades them that their choice of destination is right.

H8: Greater perceived user engagement will positively correlate with higher overall user satisfaction.

Satisfaction also plays a critical role in user intention to recommend. A satisfied user is more likely to engage in positive word-of-mouth behavior, sharing their experience with others (Han et al., 2021; Jebbouri et al., 2021). Hosany & Prayag (2013) demonstrated that tourists' emotional responses to destinations strongly influence both satisfaction and the likelihood of recommending the experience.

Flavián et al. (2021) found that VR-based pre-experiences significantly enhanced users' emotional engagement, which in turn influenced their behavioral intentions, including the likelihood of recommending the experience to others.

The theoretical frame builds upon extant theory and previous research, leading us to posit the following hypothesis:

H9: Higher user satisfaction will positively correlate with user intention to recommend immersive experiences to others.

The above hypotheses are reflected in the proposed research models presented in Figure 1 and Figure 2. Figure 1 illustrates the low-level model, which captures user responses during the interaction, while Figure 2 represents the high-level model, which captures outcomes after the interaction.

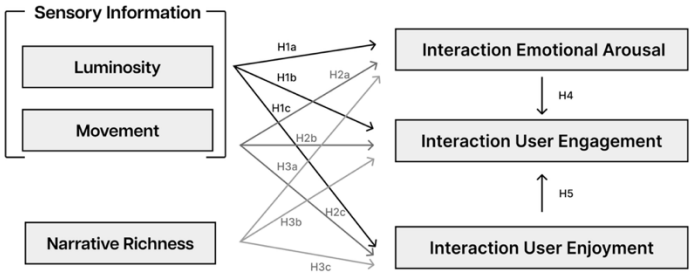


Figure 1. Low level (During interaction) Research model

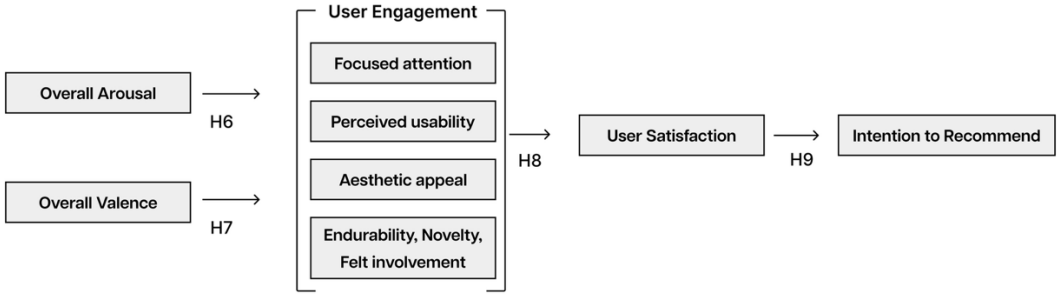


Figure 2. High level (After interaction) Research model

2.3 Method

2.3.1 Sample

A total of 48 participants were recruited for the study, with forty-three participants yielding usable data. All participants reported normal vision (with or without correction), no history of psychiatric or neurological disorders, and no disabilities that prevented

participation. All of the participants had prior experience with VR. They were required to be 18 years old or older and be fluent in English. The sample consisted of twenty-two females and twenty-one males. Participants had an average age of thirty-one and reported a low average VR usage frequency (M = 1.88) on a 7-point Likert scale, indicating that most rarely use VR. Their primary engagement with VR was for gaming and entertainment experiences. Participants expressed a moderate-to-high interest in ancient Egyptian history and culture (M = 5.09), so most of them were interested in the topic. Participants were recruited through emails sent to members of the panel HEC Montréal. These emails provided detailed information about the study, including the inclusion criteria and compensation. The data collection took place 6 weeks in an exhibition space in Old Montréal. The Ethics Research Committee of the authors' institution approved the study with participants' prior written consent and their verbal consent provided at the time of the study (Certificate number 2025-6043). Participants were provided free entry to the VR experience, valued at CA$50, as compensation.

Table 2. Participant Demographic Information (N = 43)

Age	18-24	32.60%
	25-34	37.20%
	>=35	30.20%
Gender	Male	51.20%
	Female	48.80%
VR Usage Frequency	Never	25.60%
	Rarely – 1-2 times a year	62.80%
	Occasionally – 3-6 times a year	9.30%
	Sometimes – About once a month	2.30%
Types of VR Experience	Gaming and Entertainment	88.40%
	Education and Training	25.60%
	Tourism and Travel	25.60%
	Social Interaction and Communication	4.70%
	Architecture and Design	7.00%
	Other	4.70%
Interest in Egypt Culture	Low interest	2.33%
	Slightly interested	11.63%
	Neutral	2.33%
	Moderately interested	41.86%
	Very interested	41.86%

2.3.2 Virtual Environment

VR head-mounted display (HMD), virtual avatar

The VR experience relied on the head-mounted display (HMD) for immersion. There were no controllers; participants interacted with the virtual environment using their bodies. Each user is represented in the virtual environment as a full-body representation. While users could see the full bodies of others, they could only see their own hands from a first-person perspective. Around 10 spectators were present simultaneously in both the physical and virtual spaces. Every user could observe others in the experience as a simple body avatar, with all movements tracked in real time.

VR stimulus

The "Horizon of Khufu[1]" experience is guided by different characters, including Mona, a contemporary avatar guide, and the Bastet, an ancient Egyptian goddess who appears as a large cat. As the second guide, Bastet dives deep into the historical and cultural context of the Pyramid of Khufu. The experience is structured into several sections, each designed to bring ancient Egypt to life through interactive and sensory-enriched VR simulations. The first section starts with meeting Mona, participants are introduced to their guide, who sets the stage for a journey through the pyramid. This is followed by the Horizon of Khufu, where participants experience a virtual elevation within the pyramid. The Bastet guides participants through the internal structure of the pyramid, leading to a panoramic view of the Giza plateau. This offers them a unique perspective by transforming participants into giants, allowing them to view the pyramid and its surroundings from a monumental perspective. This journey continues with traveling in time through a boat to the Funerary Complex of Khufu to explore the detailed aspects of Khufu's funerary complex, including burial practices and architectural designs typical of the time, highlighting the pyramid's role in ancient Egyptian spiritual life. During these segments, participants could explore the virtual environment through different sensory immersions, including visuals and types of movement like walking and going up through flying carpets. The narration of the story

[1] https://horizonkheopsexperience.com/montreal/

also changes according to the quantity of information in the story. So, participants were free to walk according to the guidelines provided. They also experienced a simulated sensation of vertical movement, even though they remained physically stationary. The VR experience lasted around 45 minutes.



Figure 3. Participant setup with HMD, chest-mounted GoPro, ECG and EDA sensors, and Fitbit (left), navigating the Horizon of Khufu VR environment during the experience (right). *Credits:* Photos by David Brieugne, Tech3Lab.

2.3.3 Experimental design

This research was conducted on the immersive VR exhibition, the Horizon of Khufu, shown in Old Montréal, Canada. It employed a correlational 2x2x2 within-subject design. All participants experienced the full narrative of the "Horizon of Khufu". We divided the experience into eight segments based on specific attributes: varying sensory characteristics (luminosity, movement) and narrative content. These attributes were objectively defined, and the segments were selected in a way to corresponded to these elements. Three factors varied across the eight segments of the experience: luminosity (low/high brightness), movement type (horizontal/vertical), and narrative richness (low/high narrative content). These variations are illustrated in Figure 4, which depicts the distribution of narrative and sensory cues across the selected segments of the immersive experience.

A manipulation check was conducted to confirm whether the objective classifications of experience segments were perceived consistently by participants. The results are presented below:

Luminosity levels were checked through participants' self-reported ratings to confirm that their perceptions aligned with the predetermined brightness levels across the eight scenes, where four scenes had high brightness and four had low brightness. During the pretest, participants were asked to rate the brightness of each scene on a 5-point scale (1 indicating low brightness and 5 indicating high brightness). Responses from three participants were analyzed, confirming that at the significance level of 0.05, there is a significant difference in the brightness level, calculated using the UX Calc[2]. (p-value=0.0005) (Appendix B)

Movement type was a binary variable measured ojectively, with participants encountering two types of virtual motion. The Horizon of Khufu experience included three types of movement, including horizontal walking, vertical elevation, and boat travel. In the horizontal walking segments, participants moved forward along a predefined path, experiencing the environment from a ground-level perspective. Vertical elevation simulated an upward motion, similar to a flying carpet, lifting participants to higher vantage points for an aerial view of the surroundings. Boat travel provided a forward-moving experience, where participants were moving along the water while having the freedom to explore the environment by walking within the boat. For this study, movement was categorized into horizontal movement (walking and boat travel) and vertical movement (elevation) to analyze how different movement types influenced user experience.

Narrative richness also varied by adjusting the amount of information provided in each scene; some scenes offered richer, more complex narrative content, while others contained less information. Narrative richness was checked based on subjective data from a reference provided by the producers of the exhibition, specifically included an average measure of the quantity of information delivered in each scene. The average quantity of information for each segment was determined and used in the analysis. A manipulation

[2] https://uxcalc.web.app/

check using UX Calc, at the 0.05 significance level, shows a statistically significant difference in narrative richness across segments. (p-value=0.0005) (Appendix C)



Figure 4. Narrative and sensory cues variations in selected immersive experience

2.3.4 Procedure

When each participant arrived on site of the experience, they were welcomed and directed to a preparation room. There, participants were given information about the tools to be used and the general format of the experiment. First, the participant signed the study consent form, followed by the specific consent required by the center to experience the "Horizon of Khufu" exhibition. They then completed a brief pre-experiment questionnaire measuring demographic variables, frequency of VR usage, type of prior VR experience, and interest in ancient Egypt. Next, the participant was instructed on how to install the required tools. They were guided in placing the EDA sensors on the palm of their non-dominant hand and the ECG sensors on their lower left rib and under the clavicle. Additionally, the participant was fitted with a GoPro camera mounted on a chest harness to record hand signals used for engagement ratings. A Fitbit smartwatch was also provided, along with an iPhone placed in a fanny pack, to deliver vibrations signaling the end of each segment. The participant received a vibration notification, which prompted them to rate their engagement level on a scale from 1 (low engagement) to 5 (high

engagement) for the segment that just ended by showing the appropriate number of fingers to the GoPro camera. Once all tools were set up, the participant was ready to begin the VR experience and was guided to the exhibition area (Figure 5).

Before entering, the participant added their name to a monitor and received name tags, which were used to identify their avatars within the VR. They were briefed on the experience guidelines and assisted by a VR exhibition employee as the participant put on their VR head-mounted displays (HMDs). The VR experience then started, with audio instructions delivered through the HMD speakers. The participant followed the virtual wayfinding guidelines displayed on the ground and interacted with avatars of the experience (but not necessarily those of other visitors) throughout the story.

After completing the VR experience, the participant was instructed to remove their headset and were guided back to the preparation room, where they filled out a post-experience questionnaire. Following the questionnaire, they participated in a 10-minute semi-structured interview to gather more in-depth insights into their experience. The interview focused on the segments they most and least enjoyed, the effect of luminosity, movement type, level of the narration richness, and their experience with the moment requiring interaction. Additionally, they were asked one question aimed at providing insights for the industry research partner on how to improve the overall VR experience.

To minimize error and improve internal validity, experimental procedures were outlined in a standardized laboratory protocol; procedural steps and verbatim were closely followed by the moderator during the experiment. Each test session lasted for approximately 90 minutes.

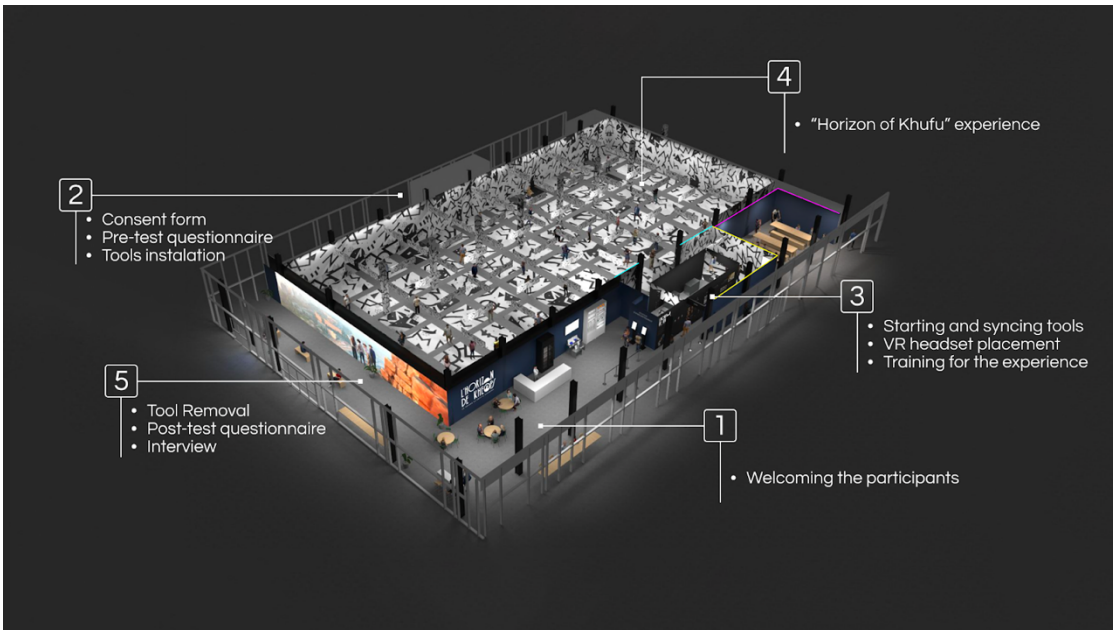


Figure 5. The experimental procedure is detailed along the exhibition room plan

2.3.5 Materials and measures

This study employed a mixed methods approach, integrating psychometric and psychophysiological measures to assess user experience in an immersive virtual environment. Psychometric measures included self-report questionnaires. The briefing and instructions, immersive experience, questionnaires, and interviews were conducted in English. Physiological measures involved Electrodermal Activity (EDA) and Electrocardiography (ECG) sensors to track real-time arousal, and a Fitbit with GoPro Camera to notify and record participants' hand signals indicating engagement levels during the experience. The following sections describe the measures used to assess participants' experiences, including perceived experience, self-reported responses, and physiological data collected during and after the immersive experience.

2.3.5.1 Perceived experience

All surveys were administered using the software Qualtrics and were presented on an iPad for participants to complete before and after the VR experience. The study included three different surveys. First, participants completed a pre-experiment survey to access their prior VR experience (i.e., frequency of use, familiarity, level of interest in Egypt history) and basic demographic information (i.e., age, gender). Then, during the experience, after each segment participants were asked to rate their level of engagement using hand signals in front of a GoPro camera. Finally, participants completed a post-experience questionnaire that assessed their enjoyment, emotional response, engagement, overall satisfaction, and intention to recommend the VR experience. Based on Cronbach's alpha, the internal consistency of all chosen scales ranged from marginally acceptable to excellent with values between 0.652 and 0.897. Focused Attention (α = .652) and Perceived Usability (α = .681) demonstrated marginally acceptable internal consistency, as removing any item did not improve reliability. The remaining constructs showed acceptable to excellent reliability (α > .75).

Table 3. Cronbach's Alpha

Construct	Number of items	Cronbach's alpha
Focused attention	3	0.652
Perceived usability	3	0.681
Aesthetic appeal	3	0.804
Edurability, novelty, involvement	3	0.765
User satisfaction	3	0.812
Intention to recommend	2	0.897

Reliability coefficients for self-report scales

2.3.5.2 Self-report Questionnaires

During the Interaction

To measure participants' engagement levels of the VR experience's segments in real-time, participants were notified by vibration on the Fitbit and phone at the end of each of the eight segments. This vibration signaled them to rate their level of engagement for the segment that finished. Participants were instructed to use a hand signal in front of a GoPro camera to indicate their engagement level on a 5-point scale, with ratings ranging from 1 (low engagement) to 5 (high engagement). Engagement was defined as "the extent to which participants felt immersed in the experience and consciously processed their environment and interactions within it" (Chang et al., 2018). To ensure accuracy, participants were guided to maintain their hand at hip height, showing clear and distinct numbers with their fingers.

Post Interaction

One item of the *User Enjoyment Questionnaire* designed by Delignières & Pérez (1998) was used to measure user enjoyment for each scene of the VR experience. Participants rated their agreement with the statement, "I really enjoyed this scene of the experience" for each of the eight scenes presented. The item was recorded on a 7-point Likert scale, ranging from (1) strongly disagree to (7) strongly agree.

The emotional response of participants was measured using *The Affective Slider*, a digital self-assessment tool developed by Betella & Verschure (2016) for the measurement of human emotions. This scale captures two primary dimensions of emotional response: *arousal* and *valence*.

The short format of the *User Engagement Questionnaire* by Heather O'Brien (O'Brien et al., 2018) was used to measure user engagement through 12 items covering 4 dimensions including:

- Focused attention: the feeling absorbed in the interaction, losing track of time

- perceived usability: Negative effect experienced as a result of the interaction and the degree of control and effort expended
- Aesthetic appeal: The attractiveness and visual appeal of the interface
- Endurability and novelty: the overall success of the interaction and users' willingness to recommend an application to others or engage with it in the future, curiosity, and interest in the interactive task

Each item was recorded on a 7-point Likert Scale ranging from (1) strongly disagree to (7) strongly agree.

User satisfaction was measured using the scale developed by Lee et al. (2011), consisting of 3 items designed to assess participants' overall satisfaction with the VR experience. Each item was rated on a 7-point Likert scale, ranging from (1) strongly disagree to (7) strongly agree.

The intention to recommend the VR experience was measured using a two-item adapted from Hosany & Prayag (2013). Participants were asked to rate their agreement with two statements: *"I would say positive things about the immersive experience"* and *"I would recommend this experience to others"*. Each item was rated on a 7-point Likert scale, ranging from (1) strongly disagree to (7) strongly agree.

2.3.5.3 Lived experience: Psychophysiological sensors

To assess users, lived experiences through physiological data, non-invasive tools were used. *Emotional arousal* was measured by measuring the participants' heart rate over time by an electrocardiogram (ECG). Additionally, electrodermal activity (EDA) was tracked by placing disposable Ag/AgCl sensors from the portable Cobalt system on the palm of the participants' non-dominant hand. The Cobalt system is a portable device developed in-house at the Tech3Lab for collecting physiological activity remotely (Cobalt, Tech3Lab, Montreal, Quebec).

2.3.6 Data preprocessing

Psychophysiological data were processed to align with the different segments of the Horizon of Khufu experience. Specifically, timestamps for each of the eight predefined segments were identified to ensure accurate alignment of physiological responses (EDA, ECG) with the corresponding narrative and sensory variations.

Video recordings from the GoPro camera were visually inspected to identify the engagement level reported for each segment by participants' hand signals. Any irregularities, such as technical malfunctions, external interruptions, or inconsistent data recordings, were identified and excluded from analysis.

2.3.7 Statistical analyses

Given the relatively small sample size (n=43) and the non-normal distribution of the psychophysiological and self-reported data, non-parametric Wilcoxon signed-rank tests were conducted to examine differences across VR experience segments (luminosity, movement type, and narrative richness) in relation to emotional arousal, user engagement, and enjoyment.

Additionally, linear regression analyses were performed to assess the relationships between emotional arousal, emotional valence, user engagement, satisfaction, and intention to recommend, as well as to evaluate the influence of luminosity, movement type, and narrative richness on dependent variables. Statistical analyses were conducted using SAS, with a significance threshold set at $p < 0.05$.

2.4 Results

2.4.1 During Interaction Results

To examine the effects of sensory and narrative variables on user experience during the immersive VR experience, non-parametric Wilcoxon signed-rank tests were conducted. The results, presented below, assess the impact of luminosity, movement type, and narrative richness on emotional arousal, user engagement, and user enjoyment.

Luminosity, movement, and narrative richness effect on emotional arousal

The results show a significant effect of luminosity on emotional arousal ($Z = 17.91$, $p < .0001$), with high luminosity ($M = 0.646$, $SD = 0.208$) leading to higher arousal compared to low luminosity ($M = 0.625$, $SD = 0.226$). This supports H1a, indicating that increased brightness enhances physiological arousal.

However, no significant differences were found for movement type ($Z = 2.41$, $p = 0.122$) or narrative richness ($Z = 2.29$, $p = 0.1315$) on emotional arousal. This suggests that variations in movement direction (horizontal vs. vertical) and the amount of narrative information did not strongly influence physiological arousal. Thus, H2a and H3a are not supported.

Table 4. Sensory and Narrative Cues Effects on Emotional Arousal

	Emotional Arousal				
	M	**Median**	**SD**	**Z**	**P**
Low Luminosity	0.625	0.604	0.226	17,91	<.0001
High Luminosity	0.646	0.634	0.208		
Horizontal Movement	0.634	0.630	0.190	2.410	0.122
Vertical Movement	0.636	0.615	0.241		
Low Narrative	0.640	0.632	0.225	2,29	0,1315
High Narrative	0.631	0.615	0.211		

Results from Wilcoxon signed-rank tests examining differences in emotional arousal across sensory and narrative conditions (luminosity, movement type, and narrative richness) during the immersive experience.

Luminosity, movement, and narrative richness effect on user engagement

Movement type significantly influenced user engagement ($Z = 23.81$, $p < .0001$), with vertical movement ($M = 4.319$, $SD = 0.832$) leading to higher engagement than horizontal

movement (M = 3.876, SD = 1.061). This supports H2b, indicating that experiencing elevation enhances engagement.

Narrative richness also showed a significant effect on user engagement (Z = 5.99, p = 0.0149), with high-narrative segments (M = 4.217, SD = 0.876) leading to greater engagement than low-narrative segments (M = 3.984, SD = 1.057), supporting H3b.

However, luminosity did not significantly impact engagement (Z = 0.22, p = 0.6427), meaning H1b is not supported.

Table 5. Sensory and Narrative Cues Effects on User Engagement

	User Engagement				
	M	**Median**	**SD**	**Z**	**P**
Low Luminosity	4.073	4.000	1.003	0,22	0,6427
High Luminosity	4.129	4.000	0.950		
Horizontal Movement	3.876	4.000	1.061	23,81	<.0001
Vertical Movement	4.319	5.000	0.832		
Low Narrative	3.984	4.000	1.057	5,99	0,0149
High Narrative	4.217	4.000	0.876		

Results from Wilcoxon signed-rank tests examining differences in user engagement across sensory and narrative conditions (luminosity, movement type, and narrative richness) during the immersive experience.

Luminosity, movement, and narrative richness effect on user enjoyment

The results show a significant effect of luminosity on user enjoyment (Z = 8.54, p = 0.0037), with high luminosity (M = 6.129, SD = 1.078) leading to higher enjoyment than low luminosity (M = 5.766, SD = 1.233). This supports H1c, indicating that increased brightness enhances enjoyment.

Similarly, movement type significantly influenced user enjoyment (Z = 8.73, p = 0.0033), with vertical movement (M = 6.214, SD = 0.910) leading to greater enjoyment compared to horizontal movement (M = 5.667, SD = 1.338). This supports H2c, suggesting that vertical motion enhances the enjoyment of the experience.

However, narrative richness did not have a significant effect on user enjoyment (Z = 0.38, p = 0.5406). Thus, H3c is not supported.

Table 6. Sensory and Narrative Cues Effects on User Enjoyment

	User Enjoyment				
	M	**Median**	**SD**	**Z**	**P**
Low Luminosity	5.766	6.000	1.233	8,54	0,0037
High Luminosity	6.129	6.000	1.078		
Horizontal Movement	5.667	6.000	1.338	8,73	0,0033
Vertical Movement	6.214	6.000	0.910		
Low Narrative	5.851	6.000	1.328	0,38	0,5406
High Narrative	6.037	6.000	0.989		

Results from Wilcoxon signed-rank tests examining differences in user enjoyment across sensory and narrative conditions (luminosity, movement type, and narrative richness) during the immersive experience.

2.4.2 Post Interaction Results

Emotional response (arousal and valence) effect on user engagement (focused attention, Perceived usability, Aesthetic appeal, Durability, novelty, and felt involvement)

Both emotional arousal and emotional valence significantly influenced various dimensions of user engagement. Higher emotional arousal was associated with increased focused attention (M = 5.653, SD = 1.091, Z = 5.61, p = 0.0221), aesthetic appeal (M = 6.111, SD = 0.794, Z = 11.23, p = 0.0016), and endurability, novelty, and felt involvement

(M = 6.132, SD = 0.759, Z = 10.32, p = 0.0024), supporting H6a, H6c, and H6d. However, emotional arousal did not significantly impact perceived usability (Z = 0.53, p = 0.4685), meaning H6b was not supported.

Similarly, emotional valence had a significant positive effect across all engagement dimensions except for perceived usability (Z = 2.48, p = 0.1218), which was not significant. More positive valence increased focused attention (Z = 35.07, p < 0.0001), aesthetic appeal (Z = 47.24, p < 0.0001), and endurability, novelty, and felt involvement (Z = 63.86, p < 0.0001). These findings support H7a, H7c, and H7d, confirming that positive emotions enhance engagement across multiple dimensions, except for perceived usability.

Table 7. Emotional Response Effects on User Engagement

	Focused Attention					Perceived Usability				
	M	**Median**	**SD**	**Z**	**P**	**M**	**Median**	**SD**	**Z**	**P**
Emotional Arousal	5.653	6	1.091	5,61	0,0221	2.764	2.667	1.258	0,53	0,4685
Emotional Valence				35,07	<.0001				2,48	0,1218

	Aesthetic appeal					Endurability, novelty, involvement				
	M	**Median**	**SD**	**Z**	**P**	**M**	**Median**	**SD**	**Z**	**P**
Emotional Arousal	6.111	6.333	0.794	11,23	0,0016	6.132	6.333	0.759	10,32	0,0024
Emotional Valence				47,24	<.0001				63,86	<.0001

Results from Wilcoxon signed-rank tests examining the effects of emotional arousal and valence on different user engagement dimensions (focused attention, perceived usability, aesthetic appeal, and endurability, novelty, and felt involvement) after the immersive experience.

Emotional response and user engagement effect on user satisfaction

Both emotional arousal and emotional valence significantly influenced user satisfaction. Higher emotional arousal was associated with greater user satisfaction ($Z = 14.21$, $p = 0.0005$), while emotional valence showed a strong positive effect ($Z = 115.84$, $p < 0.0001$).

Additionally, all dimensions of user engagement positively affected user satisfaction. Focused attention ($Z = 32.59$, $p < 0.0001$), perceived usability ($M = 6.354$, $SD = 0.794$, $Z = 4.88$, $p = 0.0323$), aesthetic appeal ($Z = 36.19$, $p < 0.0001$), and endurability, novelty, and felt involvement ($Z = 81.58$, $p < 0.0001$) were all significant predictors of satisfaction. These results support H8(abcd), confirming that both emotional responses and engagement factors contribute to an enhanced overall user experience.

Table 8. Emotional Response and User Engagement Effects on User Satisfaction

	User Satisfaction				
	M	**Median**	**SD**	**Z**	**P**
Emotional Arousal				14,21	0,0005
Emotional Valence				115,84	<.0001
Focused Attention				32,59	<.0001
Perceived Usability	6.354	6.667	0.794	4,88	0,0323
Aesthetic appeal				36,19	<.0001
Endurability, novelty, involvement				81,58	<.0001

Results from Wilcoxon signed-rank tests examining the effects of emotional arousal and valence, and user engagement dimensions (focused attention, perceived usability, aesthetic appeal, and endurability, novelty, and felt involvement) on user satisfaction after the immersive experience.

Emotional response and user satisfaction effect on user intention to recommend

Both emotional arousal and emotional valence significantly influenced the intention to recommend. Higher emotional arousal was associated with a greater likelihood of recommendation ($Z = 11.81$, $p = 0.0013$), while emotional valence had a strong positive effect ($M = 6.385$, $SD = 0.814$, $Z = 77.25$, $p < 0.0001$).

Additionally, user satisfaction was a strong predictor of intention to recommend ($Z = 78.43$, $p < 0.0001$), supporting H9. These findings suggest that users who experienced higher emotional engagement and satisfaction were more likely to recommend the immersive experience to others.

Table 9. Emotional Response and User Satisfaction Effects on Intention to Recommend

	Intention to recommend				
	M	**Median**	**SD**	**Z**	**P**
Emotional Arousal				11,81	0,0013
Emotional Valence	6.385	7	0.814	77,25	<.0001
User Satisfaction				78,43	<.0001

Results from Wilcoxon signed-rank tests examining the effects of emotional arousal and valence, and user on user intention to recommend after the immersive experience.

Table 10. Results of Hypothesis Testing

H	From	Directionality	To	Z	P-value	Status
H1a	Luminosity	↑	Emotional Arousal	4.230	<.0001	Supported
H1b	Luminosity	↑	Engagement	-0.460	0.643	Not supported
H1c	Luminosity	↑	Enjoyment	2.920	0.004	Supported
H2a	Movement type	↑	Emotional Arousal	2.410	0.122	Not supported
H2b	Movement type	↑	Engagement	4.880	<.0001	Supported

H2c	Movement type	↑	Enjoyment	-2.960	0.003	Supported
H3a	Narrative richness	↑	Emotional Arousal	2.290	0.132	Not supported
H3b	Narrative richness	↑	Engagement	-2.450	0.015	Supported
H3c	Narrative richness	↑	Enjoyment	-0.610	0.541	Not Supported
H4	Emotional Arousal	↑	Engagement	0.140	0.890	Not Supported
H5	Enjoyment	↑	Engagement	7.760	<.0001	Supported
H6a	Emotional Arousal	↑	Focused Attention	2.37	0.0221	Supported
H6b	Emotional Arousal	↑	Perceived Usability	-0.73	0.4685	Not Supported
H6c	Emotional Arousal	↑	Aesthetic appeal	3.35	0.0016	Supported
H6d	Emotional Arousal	↑	Endurability, novelty, involvement	3.21	0.0024	Supported
H7a	Emotional Valence	↑	Focused Attention	5.92	<.0001	Supported
H7b	Emotional Valence	↑	Perceived Usability	-1.58	0.1218	Not Supported
H7c	Emotional Valence	↑	Aesthetic appeal	6.87	<.0001	Supported
H7d	Emotional Valence	↑	Endurability, novelty, involvement	7.99	<.0001	Supported
H8a	Focused Attention	↑	User Satisfaction	5.71	<.0001	Supported
H8b	Perceived Usability	↑	User Satisfaction	-2.21	0.0323	Supported
H8c	Aesthetic appeal	↑	User Satisfaction	6.02	<.0001	Supported
H8d	Endurability, novelty, involvement	↑	User Satisfaction	9.03	<.0001	Supported
H9	User Satisfaction	↑	Intention to Recommend	8.86	<.0001	Supported

↑ enhancing effect

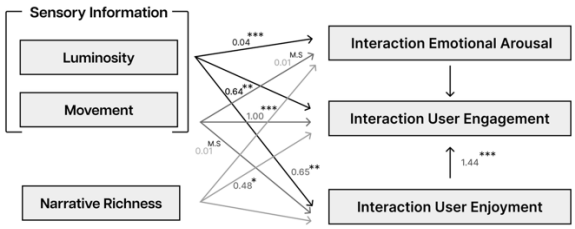


Figure 5. Low level (During interaction) model

Note: * significant at 0.05 level; ** significant at 0.01 level; *** significant at 0.001 level; M.S marginally significant

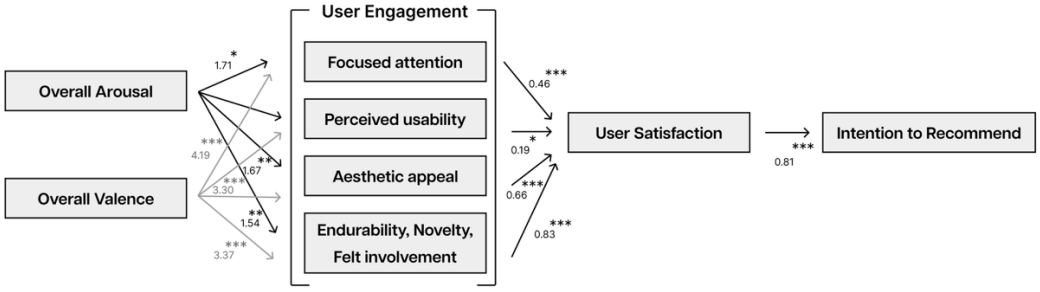


Figure 6. High level (After interaction) model

Note: * significant at 0.05 level; ** significant at 0.01 level; *** significant at 0.001 level

2.4.3 Qualitative results

4.3.1 Balanced Luminosity Enhances Realism and Engagement

The majority of participants (thirty-six out of forty-three) reported that the balance between bright and dark environments contributed positively to their experience. Rather than preferring only one type of lighting, they emphasized that both bright and dimly lit moments were necessary to create a sense of realism and immersion in the VR environment. Many participants expressed that this contrast helped structure their perception of space, making outdoor areas feel open and expansive while interior spaces felt enclosed and mysterious, closely aligning with their real-world expectations.

Participants noted that brighter environments enhanced visual clarity, making them feel freer and alert, while darker scenes evoked a sense of exploration and mystery, increasing their engagement with the environment:

"When it was dark, I was not as interested in looking around. It felt like a way to guide me—where I should go. In brighter scenes, I could see everything and felt freer." (P2)

"The transition between bright and dark made it feel more realistic. When I was outdoors, it felt open and sunny. Indoors, the walls were closer, the space tighter, making it feel like I was really inside a pyramid." (P13)

Many participants highlighted that the lighting transitions also influenced their emotional state, with brighter environments making them feel more awake and alert, while dimly lit spaces induced a calmer emotional state:

"I felt more engaged when the light was higher. When it got darker, I became a little sleepier, less alert. The bright scenes outside or at the top of the pyramid kept me more focused, while the tunnels felt more reflective." (P19)

Other participants appreciated the contrast between brightness levels, stating that it helped structure their journey through the experience:

"It felt more like an exploration in the darker areas, like I was truly inside the pyramids. When it was brighter, it felt like I was emerging, transitioning into a different phase of the experience." (P28)

"The contrast made me appreciate the scenery more. If everything had been bright from the start, I wouldn't have valued the grand views as much." (P33)

Overall, participants emphasized that the interplay between light and dark added depth to their experience, making the environment feel more natural, engaging, and emotionally dynamic.

4.3.2 Vertical Movement Enhances User Engagement

A majority of participants (thirty-six out of forty-three) reported that vertical movement was the most engaging and immersive of the three types of motion in the experience. While participants appreciated the variety of movement styles—including walking, boat travel, and vertical elevation—many described the feeling of elevation as the most intense and memorable part of the experience. The sense of height, motion, and loss of control contributed to a heightened emotional and physical response, making this movement mode stand out.

Several participants highlighted the thrill and excitement associated with the vertical elevation, describing it as a magical sensation that evoked feelings of wonder and experiencing something impossible in real life:

"I liked all three types of movement, but the one that felt like a flying carpet was the coolest for me." (P3)

"The elevation part was really interesting. I had a lot of feelings when it started to go up, and I was like 'whoa'—I could really feel the height." (P26)

Others described a strong physical reaction to the vertical ascent, with some participants experiencing a sense of vertigo or imbalance, reinforcing the realism of the movement:

"When I was high up in the air, I felt insecure, like I needed to crawl or hold onto something. It was really strong, and I wasn't prepared for that feeling." (P12)

"As the platform moved up, I actually felt my body reacting, like it was confused about what was happening. It was super immersive." (P36)

Comparatively, horizontal movement—including both walking and boat travel—was perceived as more predictable and less intense. Some participants appreciated walking for its realism and interactivity, while others found it less engaging compared to the vertical movement:

"Walking was the most immersive because I actually had to do something physically, like watch out for walls and other people." (P17)

"The boat movement was nice, but it wasn't as strong of an effect as the platform going up. It felt more like just watching things move past." (P36)

Some participants also noted that the variety of movement types helped create a well-balanced experience, with each mode contributing to different aspects of immersion:

"I felt like I was actually moving in the boat, and the scenery was great, but I wished it lasted a bit longer." (P33)

"The contrast between walking, floating, and the boat ride made the whole experience feel dynamic and engaging." (P41)

Overall, vertical movement was the most impactful and engaging, providing a stronger sense of presence and immersion. The physical sensations associated with elevation created a heightened emotional response, making it a defining moment in the VR experience.

4.3.3 Narrative Structure and User Experience: Guided vs. Free Exploration

Participants expressed mixed preferences regarding the balance between guided moments and opportunities for free exploration. Of the forty-three participants, twenty preferred guided experiences, 10 preferred more time for exploration, and 21 favored a balance between the two, appreciating both structure and freedom in the experience.

Those who favored guided moments emphasized that they provided direction, storytelling, and a sense of security, helping them navigate the VR environment effectively while learning about the historical context:

"I prefer the guided moments because even when you are with a guide, you still have space to turn around and explore things on your own. The guidance made it more interesting and informative." (P8)

"I liked being guided because they told the story. It's better than just reading about it like in a museum. Mona was engaging, but the cat was even better." (P19)

Some participants preferred less structured moments, appreciating the freedom to explore and engage with the environment at their own pace:

"I liked being able to go around and see the statues and the environment on my own. Some moments felt really immersive when I could just explore without following a guide." (P25)

"The moments where I was free to look around gave me a better sense of scale and presence. It felt more real." (P32)

However, the largest group of participants favored a balance between guided and open-ended moments, stating that having structured guidance helped them stay oriented while still allowing for exploration:

"The mix of both was perfect. The guided moments helped me understand the history, but I also liked having time to explore on my own and take everything in." (P41)

"It was great because I never felt lost, but I also wasn't just being pulled along. The balance between guidance and free moments made it more dynamic." (P37)

Many participants preferred being guided by the cat character over Mona, as they found the cat more natural and engaging:

"I liked being guided, but I don't know why—I preferred the cat. It felt more realistic than the human character. I think it's easier to animate an animal's movement than a person's." (P3)

"The cat was better because it felt more like part of the environment. Mona's movements were a bit unnatural, and at times she felt less believable." (P27)

Overall, the majority of participants appreciated having a mix of guidance and free exploration, allowing them to feel both oriented and immersed in the experience. Many

preferred the cat as a guide, as they found it to be a more natural and engaging presence in the virtual environment.

4.3.4 The Effect of Interaction on User Experience

The only active interaction participants could engage in during the experience was bending to pass through a low corridor. If they chose to bend, the transition felt natural, maintaining a sense of realism and immersion. If they did not bend, the screen went dark, automatically moving them to the next section, which some found disruptive or confusing.

Thirty-four out of the forty-three participants chose to bend, reporting that it enhanced their sense of presence and made the experience feel more realistic and engaging. Many noted that having to physically move reinforced their perception of being inside the virtual environment:

"It was amazing. It felt more real, like having to bend. If I don't have to, then I wouldn't do it, but it was good that they made it necessary." (P02)

"I bent because I wanted it to feel like reality. Seeing others do it also helped" (P10)

Some participants mentioned that the physical movement contributed to a greater feeling of immersion and presence, even triggering automatic responses as if they were truly inside a confined space:

"I was convinced I was going to hit my head. I crouched as low as I could before remembering that I didn't actually need to." (P24)

"I think when I make moves, the experience becomes more realistic. It's a must to move. It makes everything feel more natural." (P18)

For a few participants, this was the moment when they became fully engaged in the experience, shifting from passive observation to active participation:

"That was the part I started enjoying the experience. Before that, I thought, 'Oh, I have to listen to this tour guide,' but then I had to bend, and I realized I was actually part of it." (P25)

The participants who did not bend reported confusion when the screen went dark, as they were unsure what was expected of them:

"I didn't bend. I was lost at that moment because I couldn't continue following the guide." (P8)

"I didn't understand that I had to bend. Maybe I missed the instructions. Everything went dark, and I thought something was wrong." (P28)

Overall, the qualitative findings show that participants appreciated a balance of sensory and structural elements in the VR experience. The contrast between bright and dark environments was seen as adding realism and emotional variety, while vertical movement was described as the most memorable and engaging motion. Many participants preferred a mix of guided moments and free exploration, as it offered both direction and freedom. Even a small interactive action, such as bending to pass through a corridor, helped increase immersion by encouraging physical involvement.

2.5 Discussion

2.5.1 Implications

This study investigated the effects of sensory (luminosity, movement type) and narrative elements (narrative richness) on user experience in VR experience. The findings contribute to both theoretical and practical discussions on how these factors shape emotional responses, engagement, and overall satisfaction.

2.5.1.1 Implications for Theory

Regarding the effect of luminosity, the results showed that higher luminosity significantly increases emotional arousal and user enjoyment, aligning with prior research on brightness and emotional responses (Zhang et al., 2016). This finding also supports the Metaphor Representation Theory (Lakoff & Johnson, 1999), which suggests that

brightness is metaphorically linked to positive emotions, while darkness is associated with subdued emotional states. Similarly, prior research (Eroğlu et al., 2020; Xia et al., 2021) showed the role of brightness in emotional regulation, visual processing, and neural activity, highlighting that brighter environments tend to evoke higher arousal and positive emotional responses, while darker settings contribute to a more subdued emotional experience.

The hypothesis that higher luminosity would increase user engagement was not supported by the data. This unexpected finding can be explained by the qualitative results, which revealed that both dark and light moments contributed to user engagement. Per participants' interviews, the balance between bright and dark moments helped create a more realistic and immersive experience. Participants expressed that the brightness levels made sense in the context of the virtual environment, enhancing immersion without necessarily increasing engagement levels. This aligns with Chamilothori et al. (2019) and Xia et al. (2021), who found that real-world lighting conditions could be replicated in virtual environments to evoke similar emotional and perceptual responses, suggesting that the effectiveness of luminosity in engaging users may depend on how well it matches the context of the environment.

The study found that vertical movement significantly increased user engagement and enjoyment but did not have a significant effect on emotional arousal. As expected, vertical movement, particularly in the form of a "flying carpet," was identified by the majority of participants (36 out of 43) as the most engaging and immersive movement type. Many participants described the sense of elevation, height, and the physical sensation of movement as highly impactful. This aligns with Embodiment Theory (Tussyadiah et al., 2018), which suggests that movement in VEs helps users feel as if their virtual body is an extension of their real body in the virtual space. This alignment with physical experiences creates a sense of immersion, further validated by studies like Gall et al. (2021), which indicate that higher levels of virtual embodiment enhance emotional engagement.

However, despite the significant impact on engagement and enjoyment, vertical movement did not result in a significant increase in emotional arousal, which was contrary

to the hypothesis. This can be explained by several factors. First, horizontal movement (walking and boat travel) was perceived as less intense and more predictable, yet it still contributed to a sense of realism and immersion. Flavián et al. (2021) and Särkelä et al. (2009) have shown that movement types such as walking provide higher levels of arousal and valence due to their natural alignment with human behavior. In contrast, vertical movement, though engaging and exciting, might not evoke the same immediate physiological response.

The qualitative feedback also suggests that the sense of control and safety associated with vertical movement might mitigate emotional intensity. While many participants reported excitement and immersion, others noted a sense of discomfort or physical imbalance, which could have reduced the emotional arousal associated with the experience. Participants felt that walking, although less intense, provided a more consistent and less disorienting form of engagement.

Moreover, according to the interaction fidelity of vertical movement (McMahan et al., 2012), while vertical movement enhanced engagement, it did not necessarily lead to higher emotional arousal, suggesting that emotional arousal in VR is more sensitive to factors like interactivity and realism rather than just the intensity of the movement itself. This is consistent with findings from Usoh et al. (1999) and Soler-Domínguez et al. (2020), who found that while vertical movement can enhance immersion, it does not always result in heightened emotional arousal compared to more grounded, natural forms of movement.

The results of this study suggest that narrative richness has a significant impact on user engagement, but not on emotional arousal or enjoyment. While the hypothesis (H2) that greater narrative complexity and depth would enhance emotional responses was not fully supported, the results highlight the importance of narrative structure in enhancing user engagement.

The preference for a balance between guided and free exploration moments, as shown by 21 out of 43 participants, aligns with existing theories in immersive storytelling. Transportation theory (Green & Brock, 2000) and Flow theory (Csikszentmihalyi, 1997)

suggest that narrative engagement is strengthened when users are able to navigate a virtual environment while being emotionally involved in the story. The qualitative results of the study reveal that users appreciated the structure and guidance provided during the experience, particularly in terms of learning about the historical context. Many participants also noted that they felt more oriented and immersed when they had a balance of both structured guidance and free exploration time, suggesting that engagement is enhanced by the combination of controlled narrative delivery and user freedom.

As noted by Schmidt et al. (2023), variations in narrative structure can modulate emotional engagement, and the study participants' experiences reflect this by valuing narrative moments that felt immersive while also appreciating the ability to explore the environment on their own. This finding supports Wolfe et al. (2022), who argue that VR storytelling fosters greater empathy and emotional reactions by enabling users to become active participants in the narrative world. The engagement derived from narrative richness aligns with the notion that active participation and the flexibility to explore independently create a deeper emotional connection to the experience.

The study's results also show that narrative richness did not lead to a significant increase in emotional arousal or enjoyment. This finding could be explained by Schultze (2010), who suggested that while rich narratives foster emotional connections, the intensity of emotional arousal can be dependent on both the pacing of the narrative and the presence of dynamic emotional shifts within the story. In this study, the consistent pacing of the narrative may have lessened the emotional intensity, leading to lower levels of arousal.

Participants' preferences for being guided by the cat over Mona (the human avatar), provides important insights into the role of realism and expectation in virtual character design. While both avatars had a similar narrative role, participants reported that the cat felt more engaging and believable. This reaction can be explained through the Uncanny Valley theory (Mori, 1970), which suggests that as virtual humans approach realism but remain imperfect, they evoke discomfort or perceptual dissonance rather than empathy (Ho & MacDorman, 2010). As Mona's human-like appearance and movements were not entirely natural, participants may have perceived a mismatch between appearance and

behavior, leading to reduce immersion and emotional connection. In contrast, the cat avatar set lower expectations for realism, and its movements and expressions were perceived as more coherent and acceptable within its non-human form (Kätsyri et al., 2015).

From an embodiment perspective, this finding reinforces that coherence between appearance, behavior, and expectation is more critical to emotional engagement than realism alone (Tussyadiah et al., 2018). The cat's consistent animation and behavior may have supported a smoother sense of presence, whereas Mona's semi-realistic human form failed to meet the perceptual and social cues users typically associate with human embodiment. This interpretation is consistent with prior findings emphasizing that natural, embodied interactions enhance emotional experiences in virtual environments (Kilteni et al., 2012).

Regarding the effect of emotional arousal on engagement, the results showed that emotional arousal did not significantly affect user engagement during the interaction phase, as hypothesized. According to the existing research, heightened emotional responses, such as arousal, can increase users' attention and investment in an experience (Flavián et al., 2021 and Bilro et al., 2019). However, the lack of significance effect in this study can be explained by the fact that the interaction phase of the VR experience involved multiple segments that were all part of a continuous narrative. As emotional arousal built up throughout the experience, the effects on engagement may have been clearer after the interaction, when participants had time to reflect on the whole experience, rather than each segment.

After the interaction, however, the hypothesis that emotional arousal would positively affect user engagement was supported for all dimensions of engagement except perceived usability. This aligns with the Component Process Model (CPM) of emotion (Delplanque et al., 2009), which suggests that emotional responses play a significant role in shaping engagement through changes in motivation, attention, and affective responses. Users who experienced higher arousal during the VR experience reported feeling more engaged, with increased focused attention, novelty, and endurability. This is consistent with the findings

of O'Brien et al. (2018) that engagement in immersive environments is influenced by emotional responses, especially when those emotions are intense, sustained, and positive.

Interestingly, the results also revealed that emotional arousal did not significantly influence perceived usability. This suggests that users' perceptions of how easy or difficult it is to interact with the system were not directly impacted by their emotional arousal. This distinction highlights that usability is a more cognitive and task-specific aspect of the user experience. Emotional arousal might drive engagement, but it does not necessarily make a system feel more intuitive or easier to use.

This study also examined the relationship between emotional arousal, user engagement, and user satisfaction, showing that heightened engagement led to greater user satisfaction. This finding supports previous research by Flavián et al. (2021) and Han et al. (2021), who found that emotional engagement is a key predictor of user satisfaction and the intention to recommend immersive experiences. Users who felt more engaged during the VR experience were more likely to report positive feelings of satisfaction, which in turn increased their willingness to recommend the experience to others.

2.5.1.2 Implications for Practice

From a practical perspective, the results provide guidance for VR designers and cultural heritage institutions aiming to enhance user experiences. The significant effect of luminosity on emotional arousal and enjoyment suggests that careful manipulation of lighting can help create the desired emotional tone for different segments of the experience. A balance of bright and dark moments, matched to the narrative context, can increase immersion without overloading engagement.

The strong impact of vertical movement on engagement and enjoyment highlights the value of incorporating varied movement types, particularly those that create a sense of novelty and embodiment. However, designers should also be mindful of potential discomfort and ensure safety cues to maintain user comfort.

The findings on narrative richness indicate that combining guided storytelling with opportunities for free exploration can sustain user engagement. Cultural VR experiences

can benefit from providing clear narrative anchors like historical explanations, while allowing moments of independent discovery. Additionally, character design—such as the preference for the more natural cat guide over a human-like character—suggests that users respond better to avatars with lifelike, relatable movements.

2.5.2 Limitations and future directions

The present study provides valuable insights into the role of sensory and narrative elements in enhancing user experience in VR. However, two limitations should be considered. First, the study's focus on a single, steady-paced narrative structure with limited opportunities for user interaction may have influenced the results related to emotional arousal and enjoyment. The lack of dynamic pacing and emotional shifts in the narrative could have reduced the emotional intensity of the experience, limiting the ability to detect significant changes in emotional arousal and engagement. Future studies should experiment with different narrative structures, pacing variations, and levels of narrative control, including dynamic shifts in emotional highs and lows, to explore how these factors affect user engagement, emotional responses, and user satisfaction in VR.

Moreover, while luminosity and movement were varied across sections (light/dark and vertical/horizontal movement), other sensory elements such as sound, haptics, and environmental interactions were not independently tested. Sensory cues in VR are known to interact in complex ways, and their combined effects on user experience remain underexplored. Future studies should investigate multi-sensory integration and its impact on emotional arousal and engagement to gain a more comprehensive understanding of how these elements influence VR interactions.

Qualitative results that emerged from this study indicated that the choice of avatar significantly influenced user engagement and immersion. Many participants expressed a clear preference for the cat avatar over the human, noting that the cat's more natural movement enhanced their sense of involvement in the virtual environment. Additionally, several participants highlighted the importance of synchronizing the avatars' lip movements with their speech. These findings suggest that future research could explore how different avatar designs, including their movement, expressions, and synchronization

with speech, impact user immersion, emotional engagement, and overall narrative experience in VR.

2.6 Conclusion

Overall, this study provides valuable insights into the role of sensory elements (luminosity and movement) and narrative richness in shaping user experiences in immersive virtual environments, particularly in the context of cultural and educational VR. The findings underscore the importance of carefully balancing sensory cues and narrative structures to create engaging, emotionally impactful experiences for users.

While the study revealed important trends, such as the significant effect of luminosity on emotional arousal and user enjoyment, and the role of vertical movement in enhancing engagement, two limitations were noted, including the focus on a single narrative structure and the lack of control over other sensory components, such as sound and haptics. Nevertheless, this study paves the way for further research into multi-sensory integration, the impact of interactive storytelling, and the role of avatar design in enhancing immersion.

The results also point to the growing need for VR developers to consider not just the technical aspects of immersion but also the cognitive and emotional dimensions of user experience. As VR continues to evolve, future studies should explore the interplay between user control, social dynamics, and sensory integration to provide deeper insights into how immersive environments can be optimized for engagement, education, and entertainment. Ultimately, this study highlights the potential of VR as a powerful tool for creating rich, multi-dimensional experiences that resonate with users on both emotional and cognitive levels.

Chapter 3
Designing for Immersion: Using Narrative and Sensory Cues to Engage Users

3.1 Introduction

Immersive experiences are rapidly emerging across a wide range of fields—from classrooms and museums to medical interventions and entertainment. These experiences promise deep emotional and cognitive engagement, often aiming to transport users into alternate realities where they feel a strong sense of "being there." This state arises when users become fully immersed in the virtual environment, shifting their attention away from the external world and adapting to the immersive experience (Agrawal et al., 2020; Cummings & Bailenson, 2016).

Head-mounted displays (HMDs) play a central role in facilitating this absorption by isolating users from their surroundings and delivering multisensory input, such as stereoscopic visuals, spatialized sound, and, in some cases, haptic feedback (Slater, 2009; Slater, 2018). However, while technological immersion can support the psychological sense of being there, it does not ensure it. The overall quality of the experience depends on how sensory and narrative elements are designed and integrated (Raybourn et al., 2019; Slater & Wilbur, 1997).

Designers, drawing on past projects and intuition, often know what seems to work. But a challenge remains: what exactly makes an experience immersive? Is it the motion effect? A particular combination of lighting, sound, and visuals? Most practitioners rely on a form of creative trial-and-error to answer these questions. However, this approach—while sometimes effective—is expensive, time-consuming, and risky. Thus, business demands often push creators back toward safe, familiar templates, reducing novelty and limiting the emotional impact of immersive experiences.

According to the two-step model of presence (Slater & Wilbur, 1997), immersive systems that offer spatial coherence and minimize real-world interference are more likely to produce a strong sense of being in the virtual environment. However, high-end systems

with advanced tracking and rendering capabilities may also introduce issues such as increased cost, calibration complexity, and user fatigue. Designers must therefore balance technological fidelity with usability and experiential goals.

Moreover, visual and narrative complexity does not automatically lead to better immersion. Research has shown that excessive detail or poorly structured environments can overwhelm the user, reducing clarity and engagement (Neo et al., 2021; Raybourn et al., 2019).

This is closely aligned with Flow Theory, a state of focused enjoyment achieved when an individual's skill level is matched by the task's challenge while feedback is immediate and coherent (Csikszentmihalyi, 1997). In immersive VR, flow is most likely to occur when sensory input is streamlined and emotionally resonant, rather than overwhelming or fragmented. For example, scenes overloaded with visual props or disconnected from the story's emotional journey may disrupt the user's sense of flow.

Studies suggest that removing unnecessary or overly familiar objects can enhance engagement and reduce cognitive load (Neo et al., 2021). Rather than striving for maximum realism, effective VR environments prioritize intentional contrast and clarity, especially when sensory transitions align with emotional pacing or narrative pacing (Metsis et al., 2019; Raybourn et al., 2019).

Designers must therefore consider how each element—whether visual, spatial, or narrative—serves the overall experience. The goal is not simply to recreate reality but to construct an environment in which users can remain emotionally and cognitively engaged.

Each immersive experience has different objectives. Some are built to create tension, others to promote learning, curiosity, or reflection. Understanding these goals is essential to selecting and sequencing sensory and narrative cues. For instance, lighting may be used to emphasize mood and guide movement; narrative may offer pacing and structure; and spatial transitions may shape emotional tone. These elements work best when they are adapted to the user's expectations and the content's purpose.

For these reasons, it is both timely and necessary to empirically examine the specific elements of immersion and determine which design variables meaningfully contribute to emotional arousal, engagement, and satisfaction. This study focuses on three of the most cited—but least formally understood—tools in the immersive designer's toolkit: luminosity, motion, and narrative structure.

One research question emerges:

Which sensory and narrative cues most effectively enhance user engagement in immersive virtual environments, and how can their integration be optimized for emotional and cognitive impact?

As we explored this question, there is a central design challenge to be considered. In immersive environments, attention is limited and overloaded by competing demands from visuals, sound, narrative, and navigation. The user's attention is a precious and limited resource. The goal is to ensure that this attention is used purposefully, delivering the highest possible return in terms of emotional arousal, curiosity, learning, and involvement. This requires thoughtful pacing and contrast, knowing when to engage users actively and when to give them time to observe, absorb, or reflect. By managing attention as a resource, designers can better shape experiences that are not only immersive but also meaningful and memorable.

The findings not only clarify what works but also offer actionable guidance for practitioners seeking to go beyond guesswork—and toward the design of immersive experiences that are emotionally resonant, cognitively coherent, and memorable.

3.2 Visual Sensory Information: Lighting Design

In immersive experiences, lighting does far more than illuminate. It directs attention, sets emotional tone, and signals movement or narrative shifts. Yet, for many designers, lighting decisions are still guided by instinct or aesthetics—bright scenes feel energetic, dark scenes feel mysterious. What this study reveals are that it's not the presence of light or darkness alone, but the contrast between them, that truly shapes user engagement.

Visual realism, as discussed by Slater et al. (2009), includes two components: geometric realism (how much virtual objects resemble real-world ones) and illumination realism (how accurately the lighting reflects natural behavior). While high-fidelity lighting may enhance believability, achieving it in real time can be expensive. Complex lighting models require heavy rendering resources and may reduce system performance or frame rates (Lin et al., 2020; Sobhani et al., 2017). Thus, designers will carefully consider when realistic lighting is necessary, and when simplified or stylized lighting may better support user experience.

Beyond visual aesthetics, lighting in VR also serves as a functional cue. It can draw attention, convey mood, and provide spatial or temporal orientation. Bright lighting following periods of darkness created a sense of emotional release and narrative progress.

In our study participants often spoke about how lighting transitions altered their behavior and attention. As some participants mentioned, "*When it was dark, I wasn't interested in looking… It felt like it was a way to tell me where I should go. In the bright scenes, I felt more free.*"

Interestingly, it wasn't just brightness that captured attention—it was the timing and rhythm of light. Several users described how brighter environments made them feel more awake and alert, while dim spaces prompted focus or reflect. "*I felt more engaged when the light was higher… I was more alert outside or on top of the pyramid*".

Another participant described how a fully lit scene pulled their gaze across the space: "*When it was completely lit, I actually looked into everything… I kept rotating and rotating*." In contrast, when a darker setting was paired with narrative voiceover, "*my concentration was on them… I didn't feel the need to keep looking around.*" This insight shows how designers can use darkness to focus the user's attention, while brightness can encourage exploration.

Rather than aiming for constant high-fidelity lighting, immersive experiences benefit from purposeful variation. Bright scenes feel expansive, transitional, and energizing. Dim

environments evoke mystery, intimacy, or emotional weight. The alternation between these states creates a narrative arc, even without changing the storyline itself.

Importantly, while the term "realism" is often discussed in lighting conversations, what users respond to most is not just because of the technical accuracy of the lighting, but whether it feels emotionally right for the moment—what one participant called "*a nice light… like sunset or sunrise. It was perfect.*" That sense of "rightness" doesn't come from fidelity alone; it comes from alignment with emotional pacing.

This insight aligns with what many experienced directors of photography or lighting designers already know: light shapes emotion. But in VR, especially in interactive, walkable spaces, the impact of light becomes even more powerful. Users don't just watch; they look with their whole body. They turn, rotate, walk forward, or pause—and every shift in brightness or color temperature carries a stronger spatial and emotional weight. In film, contrast is something you watch on a screen. But in immersive VR, you actually move through it—walking from shadow into sunlight, or from small, enclosed spaces into wide, open ones. Several participants described the lighting transitions—such as going from a dark tomb to a bright rooftop—as visually spectacular.

This means shifting the question from "how realistic is the lighting?" to "what emotional role does this lighting change play right now?". What we observed confirms that when designers use lightning intentionally, matching bright moments to narrative peaks and dark scenes to quieter or more focused segments, users notice the difference. They don't just see it; they feel it, and it helps make the experience more memorable.

Lighting is perhaps the most familiar tool in the immersive designer's toolkit, drawing from traditions in film, theater, and architecture. What this study offers is confirmation that those intuitive lighting instincts still hold, but they now carry even more emotional and spatial influence in VR. It's not just about lighting what the user sees; it's about guiding how they move, feel, and engage with the virtual world. Most importantly, lighting becomes a tool for directing user attention in ways that keep users focused and immersed.

3.3 Navigation Concerns

Movement in immersive experiences is often a means to an end. But in walkable VR exhibitions, movement isn't just about visual transitions—it involves physical or felt motion that users experience with their whole body. This makes navigation a unique and central feature of immersive VR. Unlike traditional media or seated, movement becomes more than just a way to get from one place to another. It becomes a felt experience, one that carries emotional weight, physical reaction, and psychological meaning.

The ability to navigate, look around, and move forward or vertically increases the user's sense of inhabiting a believable space. In this study, we observed two distinct types of movement—horizontal and vertical—and more importantly, two different user postures they created: one active, the other passive.

Vertical movement—especially the moment of upward elevation—placed users in a more passive stance, and they were not moving themselves, but being moved upward. This emerged as one of the most powerful and memorable elements of the entire VR experience. Many participants described it not just as a shift in perspective, but as something that defied expectations, offering a sensation that felt rare or even impossible in real life.

"*The vertical movement was, I think, the most intense feeling… I was actually feeling that I was going upward. At some point, I was kind of losing my balance. It was so strong."*

This was more than just excitement; it included physical reactions, emotional intensity, and sometimes even a sense of loss of control. One participant said, "*When I was high up in the air, I felt insecure, like I needed to crawl or hold onto something.*" Another described looking over the edge of the virtual platform and feeling just like they would in real life: "*I really had the same feeling of when I'm in the real world and I look down.*"

These moments highlight an important point for designers: users don't always need to control movement to feel immersed. Sometimes, being moved can create a stronger impact. Unlike walking, where users feel more in control, vertical motion created a sense of being carried, which made the experience feel more intense. When this kind of

movement was used during important parts of the story, it helped increase emotional engagement and made those moments more memorable.

That doesn't mean horizontal navigation lacks value. Several participants preferred walking for giving them a sense of agency and openness. "*I really loved it because I felt like I was more free. I could explore wherever I wanted to go... I was going out of the line sometimes.*". Walking supported curiosity and play, whereas vertical movement delivered spectacle and emotion. Both mattered and each posture served a different purpose in the experience: active for interaction, passive for absorption.

Research supports the idea that allowing participants to control their movement through an IVE enhances psychological immersion. Real walking, in particular, has been shown to increase the sense of presence and bodily engagement (Shi et al., 2019). In environments with limited physical space, vertical movement—such as elevators, stairs, or upward floating—can be used strategically to expand perceived spatial range without requiring users to travel long horizontal distances.

Movement design sets rhythm, shapes agency, and can either draw users in or pull them out. Rather than viewing these two modes as opposites, they should be seen as complementary tools in the designer's toolbox. Walking works well when users are meant to be proactive, physically involved, and making choices. Vertical movement, by contrast, works best during narrative or emotional peaks, when the goal is to focus attention inward or mark an important story moment. The most impactful movement isn't the most realistic, but the one that felt purposeful. So, it's important to use movement not only to replicate real-world behavior, but to shape how users feel and engage with the experience.

This ability to alternate between active and passive postures is one of VR's strengths. But if not sequenced carefully, it can cause confusion or overload. Participants in the current study reported moments of disorientation when required frequent head turns or large shifts in visual perspectives which occasionally disrupted the sense of continuity. This observation is supported by Mizuchi & Inamura, 2018, who found that frequent or dramatic head movements within an IVE, especially when paired with a restricted field of view, can negatively affect spatial perception and task performance. When movement

cues or viewing angles demand constant reorientation, the user's cognitive load increases, making it harder to stay engaged.

Moreover, head rotation mismatches or latency in tracking can interfere with the user's sense of spatial coherence, leading to discomfort or disconnection from the virtual world (Shi et al., 2019).

To reduce such disruptions, designers should aim to minimize unnecessary changes in head direction and avoid placing users in spatial configurations that require constant turning or looking behind. Movement should be seen as a tool for shaping both pacing and emotional tone. For example, to build tension, a slow upward motion where users can't control the movement can be very effective. To support exploration, open spaces that allow users to walk freely work better. To help users refocus, slowing down the movement and lowering the lighting can create a calm, reflective moment. The emotional impact of movement depends not just on the motion itself, but on when and how it's used in the overall experience.

When spatial transitions, motion direction, and speed are aligned with narrative pacing and user expectations, they can deepen the sense of agency and strengthen immersive engagement.

3.4 Narrative Structure

While visual and interactive cues provide the spatial and emotional context, it is the story—its pacing, structure, and delivery—that gives the experience continuity and meaning. In the current study, the structure and timing of narrative delivery significantly influenced how participants engaged emotionally and cognitively.

An important consideration is not only what story is being told, but how much information is delivered at once and offering narrative "breathing room". Moments with little or no storytelling, where users can look around, explore, and reflect on what they've heard. Excessive narration or frequent informational input can overload the user, especially in scenes that are already rich in visual detail or demand physical interaction. When users are asked to process storytelling while actively exploring or responding to sensory cues,

the combined demand can lead to cognitive fatigue. Instead, narrative elements should be carefully layered to complement, rather than compete with, visual and spatial engagement.

According to the Cognitive Load Theory, cognitive load is the mental effort required to process information (Chandler & and Sweller, 1991). In immersive VR, this load is influenced by how complicated the story is, how clearly it's delivered, and how easily users can connect it to what they already know or expect (Ayres, 2020; Sulisworo et al., 2024).

For an immersive experience to be effective, the cognitive load should be balanced, ensuring that the narrative is neither too simple nor overly complicated. If the narrative content is too dense or if too much information is delivered at once, users may experience cognitive overload, diminishing their engagement and disrupting the flow of the experience (Armougum et al., 2019).

In the context of VR, Cognitive Fit Theory also plays a crucial role in the design of narrative structures (Vessey, 1991). This theory suggests that the alignment between the information presentation (i.e., how the story is told) and the user's cognitive processes enhances understanding and performance (Brade et al., 2017). If the structure of the narrative fits well with the user's cognitive capabilities and expectations, it can improve their ability to follow the story and stay engaged. The story should be presented in a manner that aligns with how users process information, with a clear flow that guides them from one narrative point to the next without overwhelming them (Martínez-Molés et al., 2024).

The findings of this study support these theories, as participants reported greater engagement when the narrative was structured clearly, with logical pacing and well-timed emotional moments.

Many users appreciated being guided through the experience, especially when the story was delivered by a character. These guided moments gave them direction, context, and a feeling of safety. As one participant shared, "*It feels nice… I feel safe when someone says 'follow me' or 'come with me.' Then I just go and follow the flow of the story.*"

But this sense of comfort didn't mean users wanted to stand still and listen passively. Several participants mentioned that during long bits of narration, they would start wandering. "I *don't have the patience to stay there and listen to the whole conversation… I just walk around.*"

Narrative progression that followed the rhythm of the experience—aligning with visual or spatial transitions—resulted in stronger emotional responses and increased immersion. In contrast, when the story became overly complex or disjointed, participants struggled to maintain their focus, and engagement dropped. This aligns with research by Martínez-Molés and Pérez-Cabañero (2024), who emphasize that poorly structured narratives can lead to cognitive overload, as users are forced to expend additional cognitive resources to make sense of disconnected elements.

Additionally, the placement of narrative content matters. Story elements that were positioned before or after intense interactive sequences gave users time to process information and reset their cognitive attention. In contrast, scenes that mixed dense storytelling with fast-paced navigation or bright visual effects sometimes caused cognitive overload. These findings are consistent with research suggesting that narrative design should consider the rhythm of interaction and the user's attentional limits (Raybourn, 2019).

This means thinking about storytelling as something users co-experience rather than passively receive. Narratives should match the pace of interaction. If the scene is slow and reflective, there's room for longer story segments. If the user is moving through a busy or visually rich environment, narration should be lighter or spaced out.

Participants also responded to how the story was told. Many preferred being guided by the animated cat rather than the human avatar, Mona. "*I don't know why—I preferred the cat*," said one user. "*It felt more realistic… I think it's easier to animate an animal's movement than a person's.*" This points to an important design insight that narrative characters don't need to be lifelike—they need to feel natural within the environment.

Narrative design in VR should be seen as a rhythmic structure, with highs and lows, guidance and silence, story and space. Users don't want to be left alone, but they also don't want to be told everything. They want to feel like they're part of the story—and that requires just the right mix of direction and freedom.

3.5 Conclusion

In conclusion, the design of narrative and sensory cues plays a crucial role in creating immersive virtual reality (VR) experiences that engage users both emotionally and cognitively. By carefully structuring narrative elements and integrating sensory cues, designers can enhance the sense of presence, foster emotional engagement, and maintain a coherent flow within the experience. Lighting, movement, and narrative structure all contribute significantly to how users connect with the virtual environment, each playing a distinct role in guiding attention, shaping emotional tone, and supporting the overall narrative.

Lighting design plays a critical role in shaping emotional responses and guiding user attention, not only by contributing to visual realism but also by serving as a dynamic narrative tool that aligns with the emotional flow of the experience. As highlighted, effective lighting is more about its strategic placement and timing, rather than simply achieving high fidelity.

Similarly, navigation design is vital in ensuring smooth user movement within the VR environment. The study demonstrated that vertical movement and spatial transitions significantly impacted emotional engagement, particularly when they corresponded with narrative or emotional peaks. Designers must consider how movement aligns with narrative pacing to maintain user immersion. Avoiding disorienting shifts in perspective or unnecessary changes in head direction is essential for preserving a seamless experience.

Equally important is understanding when to encourage interaction and when to allow for receptive, observational moments. This alternation between active and passive user postures helps manage attention and supports emotional pacing.

The application of Cognitive Load Theory and Cognitive Fit Theory highlights the importance of balancing the complexity of narrative content with users' cognitive capacity. When narrative elements are delivered in a clear, structured, and well-paced manner, cognitive overload is minimized, and users can remain fully immersed in the experience. This, in turn, enhances their emotional involvement and overall satisfaction. Attention, as a limited resource, must be carefully allocated across sensory, narrative, and interactive inputs. Designers who optimize the timing and layering of these elements can better sustain user engagement throughout the experience.

Ultimately, this study highlights the importance of designing with attention in mind, not just as a cognitive limit to respect, but as a resource to optimize. The goal is not to present isolated effects through lighting, narrative, or movement, but to choreograph these elements into a unified, meaningful experience. When attention is guided across emotional peaks, reflective pauses, and exploratory transitions, users are more likely to experience the journey as a unified whole rather than a sequence of separate moments.

Chapter 4
Conclusion

4.1 Reminder of the Context

The objective of this thesis was to explore how variations in sensory and narrative design influence user engagement in immersive virtual reality (VR) experiences, with a focus on educational and cultural contexts such as virtual museum exhibitions. More specifically, the study examined the effects of two key types of design elements:

(1) Sensory cues—variations in luminosity (low vs high brightness) and movement type (horizontal vs. vertical motion)
(2) Narrative richness—the complexity and depth of storytelling in VR segments

To investigate these effects, a mixed-method study was conducted at the PHI Centre in Montréal, using the immersive VR exhibition “Horizon of Khufu”. This experience, structured around a historical journey through ancient Egypt, served as the stimulus for the study. Participants wore head-mounted displays (HMDs) and explored the virtual environment in eight distinct segments that varied systematically by brightness, movement style, and narrative complexity.

A total of 43 participants (22 women and 21 men) with an average age of 31 years took part in the study. Before starting the experience, participants completed a pre-experience questionnaire. Data were collected using a combination of physiological tracking (electrodermal activity [EDA] and electrocardiography [ECG]) and self-report questionnaires. During the 45-minute VR experience, participants rated their engagement after each segment using hand signals recorded by a GoPro camera. Post-experience measures assessed their emotional response, engagement, enjoyment, satisfaction, and intention to recommend the experience.

In addition to quantitative analyses, qualitative insights were gathered through semi-structured interviews. These interviews explored participants' perceptions of brightness,

movement, narrative structure, and interaction, offering a deeper understanding of the elements that influenced their emotional engagement, and overall satisfaction.

This final chapter presents a recap of the research questions and key results, followed by a discussion of the study's theoretical contributions, practical implications, limitations, and directions for future research.

4.2 Research Questions and Main Findings

This study structured around the following research question: What is the effect of narrative and sensory cues on user experience in immersive virtual environments? Specifically, it examined how variations in luminosity, movement type, and narrative richness influenced users' emotional responses, engagement, enjoyment, satisfaction, and intention to recommend.

The findings demonstrate that sensory cues significantly shaped user experience. Bright scenes enhanced both physiological arousal and enjoyment, while vertical movement increased engagement and enjoyment compared to horizontal navigation. In contrast, narrative richness primarily influenced engagement, fostering deeper cognitive and emotional involvement without strongly affecting arousal or enjoyment.

Beyond these design elements, the study also showed that emotional arousal and valence play central roles in shaping the user journey. Higher levels of arousal and positive valence were associated with greater engagement across multiple dimensions including the focused attention, aesthetic appeal, and felt involvement, but not in perceived usability. Both arousal and valence also contributed positively to overall satisfaction, which in turn strongly increased users' intention to recommend the VR experience.

These findings highlight how sensory and narrative features shape the user experience in immersive VR environments. The results show that designing impactful VR experiences requires careful alignment of technological, emotional, and cognitive components to sustain user attention, evoke meaningful responses, and support positive behavioral intentions.

4.3 Contributions and Implications of the Study

This section highlights the theoretical contributions as well as the managerial implications stemming from the results of the study.

4.3.1 Theoretical Contributions

From a theoretical perspective, this study contributes to several domains in literature on immersive virtual reality and user experience. First, it empirically validates the role of luminosity in emotional arousal, confirming the predictions of the Circumplex Model of Affect (Russell, 1980), which identifies arousal as a core dimension of emotional experience. This is also supported by Metaphor Representation Theory (Lakoff & Johnson, 1999), which suggests that brightness is metaphorically associated with heightened emotional states. The findings showed that bright scenes evoked significantly stronger physiological arousal than dark ones. However, the results of this research did not reveal significant differences in terms of the impact of luminosity on engagement. This result is consistent with participants' qualitative feedback, which indicated that both bright and dark scenes contributed meaningfully to the immersive atmosphere without necessarily increasing engagement. As in prior studies (Chamilothori et al., 2019; Xia et al., 2021), the effectiveness of brightness depended more on how well it fit the context than on its absolute intensity, suggesting that emotional and cognitive engagement in VR is influenced by narrative and environmental coherence rather than visual brightness alone.

Second, the study enhances understanding of how movement type influences user experience, contributing to both Embodiment Theory (Tussyadiah et al., 2018) and Flow Theory (Csikszentmihalyi, 1997). The results showed that vertical movement significantly increased engagement and enjoyment, particularly through the "flying carpet" segment, where users reported a strong sense of elevation and being there. This confirms that embodied, dynamic elevation can intensify users' immersive involvement.

Third, the role of narrative richness in shaping engagement extends theories like Transportation Theory (Green & Brock, 2000) and Emotional Flow Theory (Nabi & Green, 2015). Participants valued the balance between guided narrative moments and free

exploration, especially when receiving contextual information from the embodied cat character. This aligns with prior findings (Schmidt et al., 2023; Wolfe et al., 2022) that immersive storytelling enhances cognitive absorption and emotional connection through empathy and guided pacing. However, narrative richness did not significantly influence physiological arousal. A possible explanation lies in the steady pacing of the experience, which may not have included dynamic emotional shifts needed to trigger stronger arousal (Schultze, 2010). While stories foster long-term emotional resonance, they may not elicit immediate physiological reactions unless combined with tension or dramatic variation.

Fourth, during the experience, emotional arousal did not significantly predict engagement, leading to a partial rejection of H3. However, after the experience, when engagement was measured across the whole interaction, arousal significantly predicted multiple dimensions of engagement, including focused attention, novelty, and endurability. This suggests that arousal may accumulate over time and influence users' overall perception of the experience rather than moment-to-moment engagement.

Finally, this study reinforces established links between engagement, satisfaction, and recommendation intention in immersive environments. The results fully support H4 and H5, showing that users who reported higher engagement also experienced greater satisfaction, and were more likely to recommend the experience to others. These findings are in line with previous research (Flavián et al., 2021; Han et al., 2021; Abou-Shouk et al., 2024), confirming that emotionally and cognitively engaging VR experiences contribute to loyalty, positive word-of-mouth, and continued user involvement.

4.3.2 Managerial Implications

As immersive technologies like virtual reality become more common in cultural, educational, and entertainment sectors, it is increasingly important for VR designers and developers to have scientific evidence to support the selection and sequencing of sensory and narrative cues in alignment with the emotional and cognitive goals of the experience. This helps creative teams design different types of moments—some where users explore and take action, and others where they pause and reflect—so the whole experience feels

more meaningful, emotionally engaging, and easy to follow. This study provides two practical insights for professionals aiming to deliver more impactful VR experiences.

The first implication concerns the use of lighting and movement as core elements of emotional design. The findings indicate that high luminosity can significantly enhance emotional arousal, particularly when it is used intentionally to mark transitions in the narrative or signal changes in tone. However, since brightness alone did not significantly influence engagement, it should not be applied purely for realism. Instead, designers should treat lighting as a narrative device—used to guide user focus, evoke emotional shifts, and emphasize key moments in the experience. Importantly, contrast and rhythm between dark and bright scenes were found to be more effective than consistent high brightness. Lighting should serve the emotional arc of the experience, helping to pace user attention and engagement through alternating moments of intensity and calm.

In terms of movement, vertical transitions were found to contribute to emotional engagement when well aligned with the narrative flow. However, the results also showed that vertical movement did not significantly increase physiological arousal, and in some cases, caused disorientation. This suggests that while vertical movement can enhance engagement through its novelty and symbolic effect, it must be calibrated carefully to avoid discomfort. Horizontal movement, in contrast, supported a sense of agency and exploration. Therefore, both types of motion should be strategically sequenced to support alternating user postures—active for curiosity and control, passive for absorption and emotional peaks.

The second implication concerns the design and delivery of narrative content. The study highlights the importance of narrative richness in sustaining user engagement. Participants responded more positively when the story was clearly structured, emotionally coherent, and well-paced. These findings suggest that in immersive cultural experiences, the narrative should not be treated as a separate layer but rather as a central organizing principle that interacts dynamically with sensory inputs. Narrative delivery should adapt to the rhythm of the experience.

For practitioners, this means that narrative elements must be carefully sequenced to match the cognitive and emotional rhythm of the experience. Overloading users with dense or fast-paced storytelling during highly interactive scenes can result in cognitive fatigue and reduced immersion. Instead, alternating narrative intensity with periods of stillness or spatial exploration can help users process information and maintain emotional involvement. Attention should also be paid to the alignment between narrative cues and sensory transitions, which can enhance coherence and immersion.

Ultimately, this study highlights the importance of treating user attention as a limited but valuable resource. By carefully planning how lighting, movement, and narrative pacing work together, designers can guide attention more effectively, creating experiences that are both emotionally powerful and mentally engaging.

4.4 Limitations and Future Research

The present study offers valuable insights into the role of sensory and narrative elements in enhancing user experience in VR. However, several limitations must be acknowledged. First, the experience was based on a single, steady-paced narrative with limited interactivity, which may have constrained emotional intensity and affected the ability to detect significant shifts in arousal or engagement. Future studies should explore varied narrative structures with dynamic pacing, emotional highs and lows, and greater narrative control to examine their impact on engagement and satisfaction.

Second, while this study considered luminosity and movement types, it did not isolate or test other sensory modalities such as sound, haptics, or environmental interaction. Given the known interplay between sensory channels in VR, future research should investigate multi-sensory integration to better understand how combined cues shape emotional and cognitive responses.

Lastly, qualitative findings revealed that avatar characteristics influenced user immersion. These observations point to the need for further research on avatar design.

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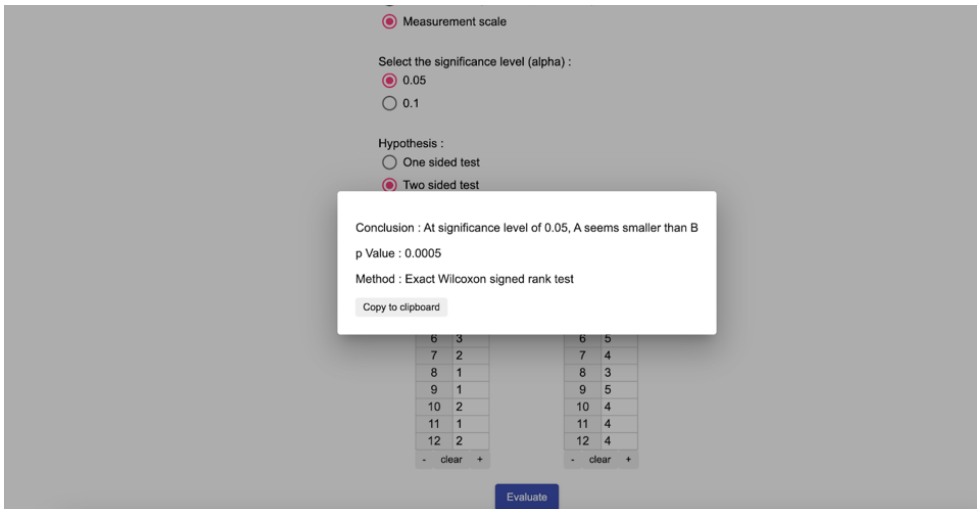
Appendix

Appendix A: Constructs and Scale Items

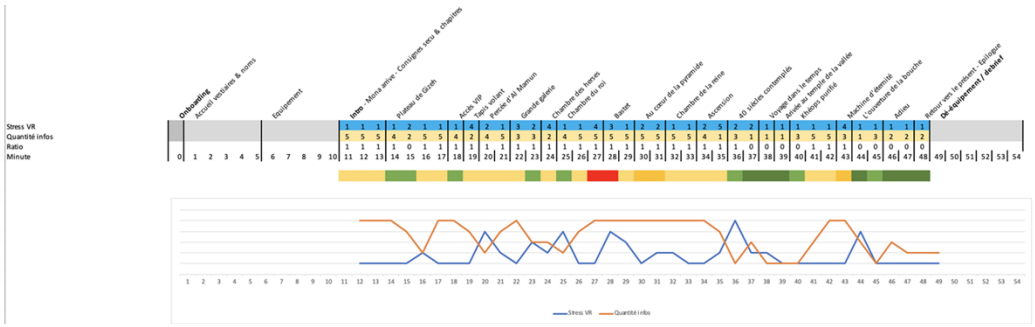
Construct Name	Acronym	Tools/Scale	Items	Source
Engagement (Real-Time)	RT_UEG	5-point scale from 1 (low engagement) to 5 (high engagement)	Participants rated engagement levels using hand signals on a 5-point likert scale, in front of a GoPro camera during the VR experience. *"Engagement refers to the extent to which you feel immersed in the experience and are consciously processing your environment and interactions in it"*	(Chang et al.,)
User Enjoyment	UEN	7-point Likert scale for each scene in the VR experience from 1 (strongly agree) to 7 (strongly disagree)	For each scene, please look at the picture and rate your level of enjoyment by indicating how much you agree with the following statement: *"I really enjoyed this scene of the experience."*	(Delignières & Pérez, 1998)
Emotional Response	ER	Measured arousal and valence using The Affective Slider, a digital self-assessment tool.		(Betella & Verschure, 2016)
User Engagement	UEG	12 items across 4 dimensions, 7-point Likert scale ranging from 1 (strongly agree) to 7 (strongly disagree)	Focused attention: *I lost myself in the immersive experience.* *The time I spent in the immersive experience just slipped away.* *I was absorbed in immersive experience.* Perceived usability: *I felt frustrated during the immersive experience.* *I found the immersive experience confusing.*	(O'Brien et al., 2018)

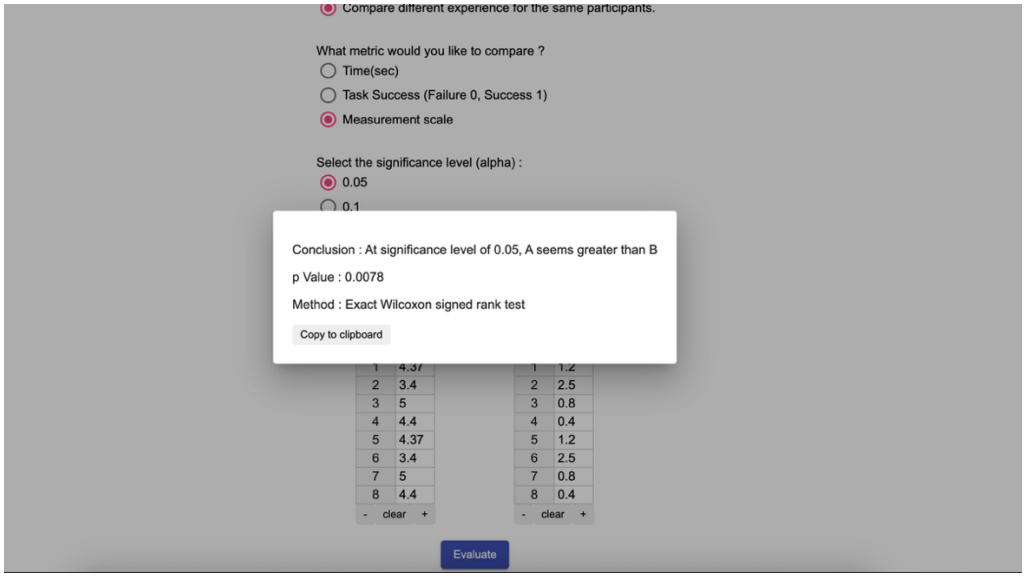
			The immersive experience was taxing. Aesthetic appeal: *The immersive experience was attractive.* *The immersive experience was aesthetically appealing.* *The immersive experience appealed to my senses.* Endurability, and novelty: *The immersive experience was worthwhile.* *My experience was rewarding.* *I felt interested in the immersive experience.*	
User Satisfaction	US	7-point Likert scale with 3 items ranging from 1 (strongly agree) to 7 (strongly disagree)	*I am satisfied with the overall visit of the immersive experience* *I enjoyed myself throughout the visit of the immersive experience* *I would be positive about participating in a similar immersive experience in the future.*	(Lee et al., 2011)
Intention to Recommend	IR	7-point Likert scale with 2 items ranging from 1 (strongly agree) to 7 (strongly disagree)	*I would say positive things about the immersive experience* *I would recommend the immersive experience to others*	(Hosany & Prayag, 2013)
Emotional Arousal	EA	Physiological Sensor (EDA/ECG)	Measured emotional arousal by tracking electrodermal activity using EDA sensors and tracking heart rate using ECG	Brissette-Gendron et al. (2020); Du Vignaux et al. (2021)

Appendix B: Luminosity Manipulation Check



Appendix C: Narrative Richness Manipulation Check





Appendix D: Questionnaires

Pre-experience Questionnaire :

Age: _____

Gender:

- Female
- Male
- Non-binary
- Other _____
- Prefer not to answer

How often do you use VR?

- Never
- Rarely – 1-2 times a year
- Occasionally – 3-6 times a year
- Sometimes – About once a month
- Frequently – 2-3 times a month
- Usually – About once a week
- Every time – Multiple times a week

What types of VR experiences have you used before? (Select all that apply)

- Gaming and Entertainment
- Healthcare and Therapy
- Education and Training
- Architecture and Design
- Tourism and Travel
- Sports and Fitness
- Social Interaction and Communication
- Other: _____

How interested are you in ancient Egyptian history and culture? (Please select one)

- Not at all interested
- Low interest
- Slightly interested
- Neutral
- Moderately interested
- Very interested
- Extremely interested

Post-experience Questionnaire:

During the Experience:

“Engagement refers to the extent to which you feel immersed in the experience and are consciously processing your environment and interactions in it”

- 1 finger (show your index finger only)
- 2 fingers (show your index and middle fingers)
- fingers (show your index, middle, and ring fingers
- fingers (show all fingers except the thumb)
- fingers (show all five fingers, including the thumb)

After the Experience:

For each scene, please look at the picture and rate your level of enjoyment by indicating how much you agree with the following statement:

'I really enjoyed this scene of the experience.'

Rate each scene from 1 to 5, where: (1) Strongly Disagree - (7) Strongly Agree



Meeting with Mona

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree or Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○



Gallery

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree or Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○



The King's Chamber

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree or Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○



The Horizon of Khufu

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree or Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○



Giants

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree or Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○



On the boat "The Royal Barge"

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree or Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○



The Funerary Temple

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree or Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

Please rate the immersive experience using both sliders. **Don't think too much** about it, just rate **how you felt** during the experience.



Move the slider to rate your level of Pleasure: (how pleasant or unpleasant you felt)

0 1

Please rate the immersive experience using both sliders. **Don't think too much** about it, just rate **how you felt** during the experience.



Move the slider to rate your level of Arousal: (how calm or excited you were)

0 1

I felt interested in the immersive experience.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

The immersive experience was rewarding.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

The immersive experience was worthwhile.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

I was absorbed in the immersive experience.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

The time I spent in the immersive experience just slipped away.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

I lost myself in the immersive experience.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

I found the immersive experience confusing.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

I felt frustrated during the immersive experience.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

The immersive experience was taxing.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

The immersive experience was attractive.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

The immersive experience appealed to my senses.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

The immersive experience was aesthetically appealing.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

I am satisfied with the overall visit to the immersive experience.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

I enjoyed myself throughout the visit of the immersive experience.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

I would be positive about participating in a similar immersive experience in the future.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

I would say positive things about the immersive experience.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

I would recommend the immersive experience to others.

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
○	○	○	○	○	○	○

Appendix E : Published Article

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August 2025

Exploring the Impact of Narrative and Sensory Information on User Engagement in Virtual Environments

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Exploring the Impact of Narrative and Sensory Information on User Engagement in Virtual Environments

Emergent Research Forum (ERF) Paper

Keywords

Luminosity, Movement, Emotional Response, User Engagement, Virtual Reality, Immersive Experience

Introduction

Virtual Reality (VR) is revolutionizing various fields, including education, entertainment, and cultural heritage, by offering immersive and interactive experiences (Suh & Prophet, 2018). Museums, in particular, are integrating VR to enhance visitor engagement by allowing users to explore historical and cultural narratives beyond physical constraints (Chang et al., 2018). Immersive system affordances play a critical role in shaping user experience and engagement in virtual environments (Mutreja et al., 2024). Immersion is central to understanding how VR environments shape users' perceptions and behaviors, as it involves both perceptual and psychological dimensions. It can be organized in three dimensions including the property of the system, the response to an unfolding narrative, and the response to challenges. Immersive systems provide a stronger sense of being there, where users feel that they are physically present in the virtual world (Lee, 2020). On the other hand, subjective immersion refers to the emotional and cognitive engagement users feel when they are absorbed in the virtual world (Agrewal et al., 2019). Research suggests that immersion is shaped not only by technological aspects like interaction fidelity and presence but also by physiological, cognitive, and social factors (Winkler et al., 2020). This study investigates the effects of luminosity, movement, and narrative richness on user engagement in museum-based VR experiences. By integrating self-reported and physiological engagement measures in a mixed-methods study of immersive user experience, it aims to provide empirical insights into optimizing VR storytelling for cultural and educational applications. Therefore, the main objective of this study is to explore how narrative and sensory cues shape users' lived and perceived experiences in immersive virtual environments. Hence:

RQ: What is the effect of narrative and sensory cues on user experience in immersive virtual environments?

Theoretical Foundation and Hypotheses Development

Sensory Information and emotional responses

Brightness has been associated with emotional activation through metaphor theory and embodiment perspectives, where light environments evoke positive valence and darker settings lower arousal (Lakoff & Johnson, 1999; Zhang et al., 2014). Embodiment theory provides a framework to understand how technological mediation integrates users' perceptual and motor systems, creating a sense of being within a virtual body or environment (Tussyadiah et al., 2018). The Circumplex Model of Affect categorizes emotions based on two dimensions: arousal, or the intensity of emotional activation, and valence, the degree of positivity or negativity in an emotional state (Russell, 1980).

Positive emotions have long been associated with bright environments, while darker settings are often linked to depressive or subdued states. Humans metaphorically map brightness to positive emotions and darkness to negative emotions in the pleased/depressed dimension (Zhang et al., 2014).

High-fidelity VR environments with varying brightness levels can evoke emotional responses by enhancing arousal comparable to real-world settings (Xia et al., 2023). These emotional reactions, driven by sensory cues such as luminosity, are expected to influence engagement and satisfaction outcomes within immersive experiences. Therefore, we hypothesize:

H1: Luminosity will positively influence the user's emotional response (arousal) in the immersive environment.

Movement in VR, as a fundamental aspect of interaction, improves virtual embodiment and shapes users' sense of presence, engagement, and emotional arousal (Soler-Domínguez et al., 2020). Incorporating real-world references in vertical movement improves spatial orientation and user confidence. While horizontal movement, such as walking, aligns more naturally with human behavior, vertical movement, when designed thoughtfully, can provide unique advantages for exploring expansive VEs (Nguyen-Vo et al., 2018). Thus, movement type is another critical sensory cue that contributes to emotional arousal, which in turn may shape how deeply users interact with and respond to VR content.

H2: Movement type (horizontal vs. vertical) will have a significant effect on the user's emotional arousal in the immersive environment

Narrative richness in immersive experiences

Narratives have been an integral part of human culture, providing a powerful means to connect, engage, and evoke emotions. Immersive storytelling enables users to explore, interact, and become a part of the story world, fostering a deeper emotional connection and engagement for shaping a positive experience (Dumlu & Demir, 2020).

Transportation theory explains narrative immersion as a form of deep mental involvement in a story, wherein users temporarily detach from the physical world and feel cognitively and emotionally embedded in the story world (Zhang et al., 2014). Narrative richness, defined by story depth and informational complexity, enhances emotional engagement and user absorption by structuring emotional flow (Schmidt et al., 2023). VR enables users to explore, interact, and become a part of the story world, fostering a deeper emotional connection and engagement for shaping a positive experience (Irshad & Perkis, 2020). Thus:

H3: Narrative richness will positively correlate with greater emotional arousal in the immersive environment.

Emotional response and User engagement

Emotions play a fundamental role in shaping cognitive processing, decision-making, and interaction within immersive environments (Schreiner & Riedl, 2019). These affective reactions significantly influence user engagement, as heightened emotions enhance the sense of presence and interaction within a virtual environment (Flavián et al., 2021). The Component Process Model of emotion suggests that emotions arise from synchronized changes in multiple subsystems, including appraisal, motivation, physiology, expression, and subjective feeling. In VR, engagement is closely linked to emotional arousal, attention, and body movements, which can be measured through physical sensors or observed through how users interact with the environment (Somarathna et al., 2023).

H4: Greater emotional arousal will lead to higher perceived user engagement during the immersive experience.

User Engagement is often considered a precursor to immersion, as it initiates the sustained attention and involvement necessary for users to become fully immersed (Somarathna et al., 2023). In immersive environments engagement is a multidimensional construct, encompassing behavioral, cognitive, and emotional dimensions as it is the extent of a user's affective, cognitive, and behavioral investment in an experience. In the Process Model of Engagement, user engagement is conceptualized as a stage-based process including point of engagement, sustained engagement, disengagement, and reengagement (O'Brien et al., 2018).

Throughout this process, key engagement attributes—focused attention, perceived usability, aesthetic appeal, endurability, novelty, and felt involvement—fluctuate based on the user's evolving interaction with the system.

Focused attention reflects cognitive absorption and the ability to lose track of time, while perceived usability relates to effort, control, and the presence of negative affect during interaction. Aesthetic appeal refers to the visual and sensory attractiveness of the interface, whereas endurability represents a user's willingness to re-engage with and recommend an experience. Novelty sustains engagement by stimulating curiosity and interest, while felt involvement captures the sensation of being drawn into the experience.

Higher emotional arousal leads to stronger user engagement as individuals become more absorbed in experiences that elicit intense emotions. Similarly, emotional peaks and shifts within immersive narratives sustain engagement by maintaining user attention and investment. Positive emotions (e.g., joy and excitement) foster sustained engagement, while negative emotions (e.g., fear and tension) capture immediate attention but may reduce long-term engagement (Bilro et al., 2019). Therefore:

H5: Greater user engagement will lead to higher positive valence in the immersive experience.

H6(abcd): Greater emotional valence will positively influence focused attention (H6a), Perceived usability (H6b), Aesthetic appeal (H6c), Endurability, novelty, and felt involvement (H6d)

Engagement, Satisfaction, Behavioral intentions

User satisfaction is a key determinant of user behavior in tourism and digital experiences (Hapsari et al., 2016). Satisfaction arises from fulfilling user expectations and creating enjoyable, meaningful interactions. In immersive environments, satisfaction is closely linked to engagement, as users who find VR experiences compelling are more likely to feel positive about the overall experience (Talukdar & Yu, 2024). Satisfaction also plays a critical role in user intention to recommend. A satisfied user is more likely to engage in positive word-of-mouth behavior, sharing their experience with others (Han et al., 2021). This leads us to posit the following hypotheses:

H7: Perceived user engagement will positively correlate with overall user satisfaction

H8: Higher User satisfaction will positively correlate with user intention to recommend immersive experiences to others

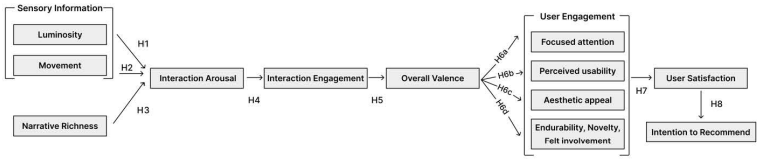


Figure 1. Research Model

Research Design

This research was conducted on the immersive VR exhibition *Horizon of Khufu*[1] shown in at a large metropolitan city in north america. It employed a correlational within-subjects design. All participants experienced the full narrative, which was structured into eight segments, each varying in luminosity (high/low brightness), movement type (horizontal/vertical), and narrative richness (high/low). These sensory and narrative attributes were defined through pretest and objective criteria. Brightness was verified through photometric analysis and confirmed via a 5-point participant-rated pretest. Movement types were categorized based on whether the scene involved horizontal or vertical locomotion, such as walking or elevation. Narrative richness was defined by the amount and depth of story content, verified through content analysis provided by the exhibition producers. Participants (N=43, out of 48 recruited) reported normal vision and no disabilities. All of them had prior experience with VR and were required to be at least 18 years old and be fluent in English. The sample consisted of 22 females and 21 males. Participants reported a low average VR usage frequency (M = 1.88) on a 7-point Likert scale, indicating that most of them rarely used VR. Their primary engagement with VR was for gaming and entertainment experiences. Participants expressed a moderate-to-high interest in ancient Egyptian history and culture (M = 5.09), so most of them were interested in the topic. Participants were recruited through emails sent to members of the authors' institution research panel. These emails provided detailed information about the study. The study was approved by the authors' institutional ethics board. Participants gave written and verbal consent and received free VR entry (valued at CA$50) as compensation.

[1] Horizon of Khufu. https://www.youtube.com/watch?v=CBo0ht1SonY

Physiological arousal was measured using Electrodermal Activity (EDA) sensors and Heart Rate Variability (HRV) recorded via ECG. Emotional responses were assessed after the experience using the Affective Slider, which includes arousal and valence dimensions (Betella & Verschure, 2016). Real-time engagement was recorded through hand signals on a 5-point scale, prompted by a vibration cue after each segment and captured by a GoPro. Post-experience engagement was assessed using the short-form User Engagement Scale (O'Brien et al., 2018), which includes 12 items across four dimensions: focused attention, perceived usability, aesthetic appeal, and endurability/novelty. User satisfaction was measured using a 3-item scale from Lee et al. (2011), and intention to recommend the experience was assessed with two items adapted from Hosany & Prayag (2013). All self-report items were rated on 7-point Likert scales.



Figure 2. Narrative and Sensory Cues Variations in Selected Immersive Experience

Preliminary Results

Our preliminary results suggest that movement type, luminosity, and narrative richness play a significant role in shaping user engagement in immersive VR. Higher luminosity was associated with an increased HRV ratio ($t = 4.23$, $p < .0001$), suggesting heightened physiological arousal in response to brightness. Compared to horizontal movement, vertical movement resulted in higher engagement ($t = 4.88$, $p < .0001$). Additionally, greater narrative richness led to increased engagement ($t = -2.45$, $p = 0.0149$), emphasizing the importance of storytelling in immersive experiences. The complete results will be shared during the conference presentation.

Conclusion and Expected Contributions

This study contributes to VR and user experience research in three ways. First, it contributes to theory by emphasizing the importance of storytelling and narration besides technological advancements in VR. While much research focuses on hardware and interaction fidelity, this study highlights how narrative richness and sensory integration play a critical role in shaping user engagement thereby contributing to the cumulative tradition of VR research in information systems. Second, it contributes to practice by providing insights into how sensory and narrative structures interact to shape user experience in VR environments, particularly in cultural and educational contexts such as museums. By examining luminosity, movement, and narrative richness, this research offers valuable guidance for designing engaging and emotionally impactful immersive experiences. Finally, this study offers practical recommendations for VR developers, helping them create experiences that are not only technically immersive but also cognitively engaging and emotionally meaningful.

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Appendix F: Ethics Confidence of Approval

HEC MONTRÉAL

Comité d'éthique de la recherche

July 29, 2024

To the attention of: Shabnam Hajian

Re: Ethics approval of your research project

Project No.: 2025-6043
Title of research project: Exploring the Impact of Narrative and Sensory Information on User Engagement and Presence in VR: The Case of the "Horizon of Khufu Experience"

Dear Shabnam Hajian,

Your research project has been evaluated in accordance with ethical conduct for research involving human subjects by the Research Ethics Board (REB) of HEC Montréal.

A Certificate of Ethics Approval attesting that your research complies with HEC Montréal's *Policy on Ethical Conduct for Research Involving Humans* has been issued, effective July 29, 2024. This certificate is **valid until July 01, 2025.**

Please note that you are required to renew your ethics approval before your certificate expires using Form *F7 – Annual Renewal*. You will receive an automatic reminder by email a few weeks before your certificate expires.

If any changes are made to your project before the certificate expires, you must complete *F8 – Project Modification* and obtain REB approval before implementing those changes. If your project is completed before the certificate expires, you must complete Form *F9 – Termination of Project* or *F9a – Termination of Student Project*, as applicable.

Under the *Policy on Ethical Conduct for Research Involving Humans*, researchers are responsible for ensuring that their research projects maintain ethics approval for the entire duration of the research work, and for informing the REB of its completion. In addition, any significant changes to the project must be submitted to the REB for approval before they are implemented.

You may now begin the data collection for which you obtained this certificate.

We wish you every success in your research.

REB of HEC Montréal

HEC MONTRÉAL

Comité d'éthique de la recherche

CERTIFICATE OF ETHICS APPROVAL

This is to confirm that the research project described below has been evaluated in accordance with ethical conduct for research involving human subjects, and that it meets the requirements of our policy on that subject.

Project No.: 2025-6043

Title of research project: Exploring the Impact of Narrative and Sensory Information on User Engagement and Presence in VR: The Case of the"Horizon of Khufu Experience"

Principal investigator: Shabnam Hajian

Date of project approval: July 29, 2024
Effective date of certificate: July 29, 2024
Expiry date of certificate: July 01, 2025

Maurice Lemelin
Président
CER de HEC Montréal

Signé le 2024-07-29 à 10:34