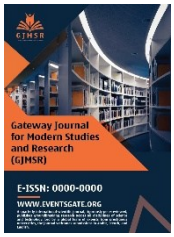
مجلة البوابة للدراسات والأبحاث الحديثة (GJMSR)، المجلد الثاني، العدد الأول، 27 فبراير 2025.
Gateway Journal for Modern Studies and Research (GJMSR), vol.2, no.1, 27 Feb. 2025
https://doi.org/10.61856/mq5rn669



Scientific Events Gate
مجلة البوابة للدراسات والأبحاث الحديثة
GJMSR
Gateway Journal for Modern Studies and Research
https://gjmsr.eventsgate.org/gjmsr/

Virtual reality technology and its role in the valorization of cultural heritage: the case of 360-degree video in virtual reality.

Dr. Hela Ben Maallem
Higher Institute of Arts and Crafts in Gabes, Tunisia,
E-mail address: hela.benmalem@isamgb.u-gabes.tn

Specialization: Audio-visual Techniques and Cinema
Research Laboratory in Arts, Music, Heritage, Environment and Society
"LR23ES11 AMPES"

Received: 13 Jan. 2025 – Accepted: 22 Feb. 2025 Available online: 27 Feb. 2025

Abstract: This study aims to highlight the innovative digital technologies employed by designers, particularly focusing on 360-degree video in virtual reality (VR) as applied to cultural heritage. This research, explored specifically, the enhancement of cultural heritage research through the VR experience: the case study: "The Magic of Guellala" (Ben Jemmaa, 2022). Indeed, this research conducted a phenomenological investigation into immersive experiences that promote interaction, presence, and engagement. The study analyzed user behaviors in relation to 360° VR videos by examining interactions with content, levels of immersion, and impacts on understanding cultural heritage. This study employed qualitative content analysis to investigate how narration influenced presence and immersion in VR environments. The results reveal that technological advancements fostered public engagement and emotional connections to heritage. Ultimately, the research emphasized the importance of understanding public preferences and needs to improve user experience in cultural heritage contexts. By consolidating the link between technology and cultural heritage, this study offers new insights into enhancing appreciation for our collective heritage through immersive experiences, thus redefining our connections with museums and archaeological sites.
Keywords: Virtual Reality Technology, 360° video in VR, Immersive storytelling, Valorization of Culture heritage, New creative modalities in design

تكنولوجيا الواقع الافتراضي ودورها في تثمين التراث الثقافي
دراسة حالة الفيديو بتقنية 360 درجة في الواقع الافتراضي

الدكتورة هالة بن معلم
المعهد العالي للفنون والحرف بقابس، جامعة قابس، الجمهورية التونسية
تخصص علوم وتقنيات السمعي البصري و السينما
مخبر البحث: فنون، موسيقى، تراث، مجتمع ومحيط LR23ES11 : AMPES

الملخص: تهدف هذه الدراسة إلى تسليط الضوء على التقنيات الرقمية الحديثة التي يستخدمها المصممون، مع التركيز بشكل خاص على تقنية الفيديو بزاوية 360 درجة في الواقع الافتراضي (VR) وتطبيقه في مجال التراث الثقافي. يهدف هذا البحث،

مجلة البوابة للدراسات والأبحاث الحديثة (GJMSR)، المجلد الثاني، العدد الأول، 27 فبراير 2025.
Gateway Journal for Modern Studies and Research (GJMSR), vol.2, no.1, 27 Feb. 2025
https://doi.org/10.61856/mq5rn669

على وجه التحديد، تعزيز بحوث التراث الثقافي من خلال تجربة الواقع الافتراضي: دراسة حالة:" سحر قلالة" (بن جمعة، 2022). استخدم هذا البحث المنهج الفمينولوجي في دراسة التجارب الغامرة التي تعزز التفاعل والحضور والمشاركة. حللت الدراسة سلوكيات المستخدم فيما يتعلق بمقاطع فيديو الواقع الافتراضي بزاوية 360 درجة من خلال فحص التفاعلات مع المحتوى، ومستويات الانغماس او الغمور، والتأثيرات على فهم التراث الثقافي. استخدمت هذه الدراسة تحليل المحتوى النوعي للتحقيق في كيفية تأثير السرد الغامر على تعزيز مستوى الحضور والغمور في بيئات الواقع الافتراضي. وكشفت النتائج أن التقدم التكنولوجي عزز المشاركة العامة والروابط العاطفية مع التراث. في النهاية، أكد البحث على أهمية فهم تفضيلات الجمهور واحتياجاته لتحسين تجربة المستخدم في سياقات التراث الثقافي. من خلال تعزيز الصلة بين التكنولوجيا والتراث الثقافي، تقدم هذه الدراسة رؤى جديدة لتعزيز ادراكنا بأهمية تراثنا الجماعي من خلال التجارب الغامرة، وبالتالي إعادة تشكيل روابطنا مع المتاحف والمواقع الأثرية.

الكلمات المفتاحية: تكنولوجيا الواقع الافتراضي، فيديو 360 درجة في الواقع الافتراضي، السرد الغامر، تثمين التراث الثقافي، طرائق إبداعية جديدة في التصميم

1. Introduction

Human civilizations are defined by their enduring impact and heritage, understood through tangible and intangible cultural legacies. Both Arab and Western researchers consider heritage studies essential for understanding history and societal development. However, traditional valorization methods often fail to offer engaging creative approaches and immersive experiences for diverse audiences. Virtual Reality (VR) has emerged as a transformative technology that has revolutionized the process of preserving cultural heritage. The necessity of using VR technology is explained by the requirement to effectively engage the public and democratize access to cultural heritage, making it more accessible and inclusive (Zhang, J. 2024). In addition, VR can simulate restoration processes, helping conservators to visualize the potential outcomes before implementation, thus improving preservation strategies (Wagner, A., de Clippele, MS., 2023). Indeed, the use of 360-degree video in VR offer a promising solution by enabling interactive exploration and deeper connections with cultural sites (Hutson, J., & Hutson, R. (2024a)).

The literature review focuses on immersive technology and the enhancement of cultural heritage through immersive storytelling, in particular through 360-degree video (Ben Maallem, H. (2024)). This research explores practical methodologies for implementing VR, providing a detailed guide to integrating 360-degree video applications into heritage sites, creating unique immersive experiences, new intersections, approaches, and methods that redefine screens, images, and space, while focusing on understanding the three fundamental principles of virtual reality (VR): immersion, presence and interaction.

Research highlights that VR applications enable the public to experiment with a unique immersive experience, allowing them to experience cultural heritage going beyond traditional methods of engagement, interaction, and display (Zidane. A.A. (2024). This opportunity has important implications for audience engagement, as it transforms passive observation into active exploration. Moreover, these new technologies offer exciting creative possibilities allowded researchers to experiment with virtual environments and recreate both existing and demolished historical and archaeological sites, as well as symbolic sites. By providing public with immersive experiences, 360° video in Vr enhance their engagement, and foster a deeper connections with cultural heritage. Some research indicates that 360-degree videos are highly immersive (Argyriou et al., 2020). Most of them focus on quantitative experiments measuring the audience's perception of content, considering the impact of presence as an experiential quality in virtual environments and immersion related to the technical aspects of a virtual system. In this context, (Wilkinson, M., Brantley, S., & Feng, J. (2021). examine various new

https://doi.org/10.61856/mq5rn669

technologies and traditional approaches as means of enhancing immersion and strengthening presence in virtual reality, as well as the effect of different devices on viewing experiences.

However, a critical gap exists in understanding how narrative elements within 360-degree VR experiences specifically influence user immersion, presence, and emotional connection with cultural heritage. While quantitative studies have explored user perception of content, qualitative investigations into the role of narration in shaping the subjective experience of "being there" in virtual heritage environments remain limited. This research addresses this gap through a phenomenological investigation of immersive experiences facilitated by digital technologies, with a particular focus on interaction, presence, and immersion in virtual reality. The study analyzes user behaviors in relation to 360-degree VR videos, examining interactions with content, levels of immersion, and the impact on their understanding of cultural heritage. The case study is "The Magic of Guellala" (Ben Jemmaa, 2022) (Fig. 1, 2) , a 360° virtual reality video. This research is significant because it offers insights into how immersive storytelling can be strategically used to enhance user engagement and promote a deeper appreciation of cultural heritage.

This study contributes to the enhancement of cultural heritage research through 360° videos by:

1- Adopting virtual reality applications to enhance cultural heritage experiences and extending the findings to practical applications, using the case study of the 360° virtual reality video "The Magic of Guellala."
2- Employing qualitative content analysis to explore the impact of narration on the sense of presence and degree of immersion in 360-degree videos. It emphasizes the importance of immersive storytelling (Podara et al., 2021) to enhance our heritage in a modern and innovative way.
3- Highlighting the transformative power of technology in redefining our connection with museums (Frontal Relationship) and archaeological sites, focusing on public engagement and emotional connections fostered by technological advancements.

In the prospects and recommendations of the research we focus on the role of understanding public preferences, expectations, and needs in terms of providing a positive user experience feedback.


Fig.1 Captation from a 360° video showcasing the interior of the antique poetry showroom in Guellala.

https://doi.org/10.61856/mq5rn669

Fig.2 Captation from a 360° video, showcasing the second stage: drying and filtering the clays

2- Theoretical framework

This theoretical framework focuses on defining key terms (immersion, presence, interaction, storytelling) within the context of 360° video in VR for cultural heritage, and highlights the user behaviors regarding this crucial elements of virtual environment.

2-1 Concept of Immersion

Immersion, in the context of 360° video, refers to the user's experience of being submerged in a spherical visual environment, enabling panoramic viewing and engagement with the filmed scene using virtual reality headsets. An overview of the literature, reveals some significant insights regarding the construction and perception of users' immersive experiences. (Mütterlein, 2018) state that it is often associated with realism and presence, describing the user's experience in a spherical visual environment, influenced by visual realism and spatial audio. (Witmer & Singer (1998) point out that immersion is closely linked to the sensation of 'being there' in a virtual space, indicating that psychological engagement and technological factors are crucial in the definition of immersion.

The literature review shows that 360° enhances the sense of presence by by providing a panoramic view that allows users to look around freely, thereby increasing their engagement with the content. (Agrawal et al. (2019) define immersion as *"a state of deep mental involvement in which the subject may experience disassociation from the awareness of the physical world due to a shift in their attentional state"*. This definition highlights the psychological aspect of immersion, emphasizing the need for attentive commitment, which fosters a sensation of being part of a different reality. The paper also establishes links between immersion and related concepts such as presence and immersion, highlighting the importance of understanding these terms in immersive audio-visual experiences .

Murray, J. H. (2017) defines immersion as "*a metaphorical term derived from physical experience*" and points out that it results not only from intense sensory stimulation but also from captivating storytelling, even with limited sensory input.

The literature review reveals various perspectives, highlighting the psychological aspects of immersion (Szabo and Gilanyi (2020)), alongside the technical dimensions as qualities of the VR system. High-quality systems can enhance the user's sense of presence, enriching the immersive experience. These divergent reflections reveal the complexity of immersion in virtual reality, influenced by technological advancements and individual cognitive processes and contextual factors. This highlights the need to examine how these elements seamlessly combine to create immersive experiences, especially in the context of 360° video in virtual reality.

2-2 Concept of presence:

Presence refers to the feeling of being present in the virtual environment, which significantly influences user perception in VR experiences (Aitamurto, T. et al. 2018). The study explores the effect of immersive experiences on users' sense of presence, attitude changes, perspective-taking, and overall usability, explaining the potential of 360° video to engage audiences in meaningful discussions about important social issues (Souza V., et al. 2021). Presence can be influenced by graphic and sound quality, enhancing users' immersion. The authors provide an overview of presence in virtual reality (VR) and discuss measurement methods and defines presence as the psychological state of immersion of users in a virtual environment. They highlight highlight its importance for enhancing user engagement and satisfaction and review measurement methods classified under subjective (e.g., questionnaires), behavioral (observations), and physiological measures (e.g., heart rate).

While presence is often described as the sense of "being there," this definition is subjective and can vary vary widely based on context and technology. It suggests that presence is influenced by various factors such as realism, storytelling, immersive qualities of content, and interactivity. This perspective suggests that presence is a subjective experience influenced by various factors, including the realism, the storytelling, the immersive qualities of the content and the interactivity of the environment.

Škola, F. (2023) supports this by exploring the evaluation of presence and immersion in VR using a multi-dimensional VR user experience (VR UX) questionnaire, which assesses various dimensions, including emotional response and technology adoption. Participants rated their experiences on a 7-point Likert-type scale and neurophysiological measures via electroencephalography (EEG) to measure to measure brain activity associated with these experiences, focusing on cognitive processing changes during the VR experience.

The literature indicates that a user's immersion level directly affects their sense of presence (Interaction Design Foundation, 2024), with factors like realistic visuals and engaging audio contributing to an authentic experience. Deep immersion enhances emotional and cognitive connections, leading to better comprehension and memorization. The interplay between immersion and presence is crucial for impactful storytelling and cultural heritage experiences. Ultimately, effective VR design should optimize the combination of immersion and presence to elevate user experience and engagement in virtual environments.

2-3 Concept of interaction:

The concept of interaction is closely connected to immersion and presence, referring to how users engage with elements in the virtual environment. In this context, Mütterlein (2018) highlights the crucial role of interactivity in enhancing both immersion and presence. Interaction in virtual environments based on 360° video in virtual reality (VR) reveals significant differences in user engagement compared to conventional VR. Users are fully immersed in a world captured by omnidirectional cameras (e.g. Inta 360 one X2 / X3/ X4) which stitch images together to form a seamless spherical panorama, enabling the user to explore the scene with a 360° panoramic overview without interaction with the environment as it seems to be in fully virtual settings. This aspect involves the sensory perception of being physically present in the virtual environment created by the 360° video. Users can look around in all directions—up, down, left, and right—creating a sense of spatial awareness and depth by following the storytelling guidelines.

https://doi.org/10.61856/mq5rn669

Research shows that VR headsets enhance this perceptual immersion by providing a more realistic overview than traditional screen viewing (Peeters, M. 2022). Unlike computer-generated three-dimensional images created with software like Blender, 3ds Max, or Maya, 360° video offers an immersive experience but with limitations in interactivity. It is often described as a "middle ground" between conventional VR and screen-based video technologies, providing a sense of presence without physical engagement with the environment or objects (Fadde, P. J., & Zaichkowsky, L. 2018). In this context, users essentially experience a passive viewing rather than an active participation in the virtual environment (Motive.io, 2024). Fully immersive VR, on the other hand, allows users to actively control their movements in VE and interact with objects, influencing narratives through their choices. This interactivity is supported by technologies enabling six degrees of freedom (6DoF), allowing deep engagement with the virtual environment (C-I Studios, 2024). Actions like picking up, throwing, or moving objects enhance the immersive quality of VR and foster deeper emotional connections to the experience (Stornaway.io, 2024).

Despite its limitations, 360° video can enhance the sense of presence and engagement, which is vital for cultural heritage. Users often experience high satisfaction and immersion with 360° content; however, this does not always translate to improved learning outcomes, as it relies on the content's design (Kumar, S., & Ranjan, P. 2022; Kumar, S., & Ranjan, P. 2024). In summary, while both 360° videos and VR provide immersive experiences, they differ fundamentally in interactivity (Kittel, A. et al. 2020). 360° videos offer a passive experience, whereas immersive VR allows active participation and dynamic interaction. In the case of cultural heritage applications both formats could be used to enhance user engagement and understanding but different design approaches should be followed to achieve their potential.

2-4 Immersive storytelling and audience engagement

Immersive storytelling has has emerged as a powerful tool for engaging audiences with cultural heritage. The interaction between perceptual presence and cognitive engagement is essential for achieving high levels of immersion in 360° video experiences. While advanced visual technology improves perceptual presence, the narrative quality and contextual relevance of storytelling significantly impact cognitive engagement, making experiences more memorable and engaging for the audience. Earlier literature which examined immersive storytelling and audience engagement in virtual reality environments, reveals several key findings. Podara et al. (2021) noted that interactive documentaries, that incoporate digital storytelling techniques, enhance audience engagement by providing immersive experiences into some emotional connection with heritage narratives and experiencing stories in a way that traditional media cannot achieve. This approach affords a deeper understanding of cultural contexts but also encourages active participation in heritage advocacy. This aligns with the work of (Oladokun, B. et al. (2024)), which emphasizes that immersive technologies promote collaborative engagement, enabling communities to be actively involved in the interpretation and protection of their cultural heritage via metaverse.

The interaction between perceptual presence and cognitive engagement is essential for achieving high levels of immersion in 360° video experiences. While advanced visual technology enhances perceptual presence, the storytelling’s narrative quality and contextual relevance significantly influence cognitive engagement, boosting memory retention and emotional impact, thereby making experiences more memorable for the audience. Immersive storytelling through 360° video in virtual reality (VR) offers a fascinating approach to drawing audiences into cultural heritage. (Argyriou, L et al. 2020) noted that "*Three hundred sixty–*

https://doi.org/10.61856/mq5rn669

degree video VR storytelling experiences allowed producers to create longer lasting impact to the audience though semi-interactive experiences that fall between game design and film production. This is achieved by making users to feel like taking part in the action and the narrative". Research shows that such an immersive experience can highly increase user involvement, enabling audience to deepen with cultural narratives instead of just observing them.

Features like quizzes and other interactive elements increase the level of participation and helps evaluate what has been learned regarding to the stories. In addition, the use of VR technologies opens the way to extends the knowledge of the historical background. However, the literature highlights barriers to effectively integrating immersion into storytelling, such as the need for ready-made content that could be assimilated easily by the audience. The researchers point the need for design strategies that overcome such challenges and improve usability and even accessibility.

In summary, integrating immersive storytelling within cultural heritage not only achieves better educational objectives but also enhances user satisfaction with culture's communicative dimensions. When employed effectively, these technologies can elevate audience engagement and deepen understanding of cultural values within cultural organizations.

3- Methodological approach

3.1 Research Design

The study adopted a phenomenological approach in order to explore the lived experience and to understand the perceptions of the audience regarding the use of 360-degree VR videos, the case study of "The magic of Guellala."

This method is one of the best approaches for dealing with individuals' experiences. It was selected because phenomenological research is particularly suitable for examining individuals' subjective experiences, perceptions, and engagement of 360-degree VR videos within cultural heritage contexts. Indeed, phenomenology tries to understand actual experiences from the subject's point of view. For that, we generally use interviews or written accounts. By focusing on the audience's narratives and perspectives, the research tries to interpret the results without imposing interpretations that are externally imposed to interpret relations.

3.2 Sample selection and size

A sample of 100 users had experienced 360-degree video content in VR (The video is entitled: The magic of Guellala) and was selected to conduct a scientific analysis of the impact of this type of content on users. In scientific research, random sampling is an essential step, as it guarantees an accurate representation of the population under study. This means that every person in the population has the same chance of being selected, which reduces the risk of error, strengthens the credibility of the results, and ensures that the conclusions may be generalized to a wider population. (Qandeelji, A. E, 2024)

With this sample, it is possible to collect exhaustive data on user experiences and analyze behavioral patterns and understand how users interact with content, enabling the identification of factors influencing presence, immersion, and engagement.

https://doi.org/10.61856/mq5rn669

To perform this investigation, we envisaged a very popular area for visitors to Djerba Island: the outdoor patio of the "Guellala Museum." This emblematic museum is an environment rich in culture and history. It reflects the island's daily life and heritage and plays an essential role in preserving Djerba's cultural heritage and introducing visitors to local traditions. It is also a vector to enhance cultural

3.3 Research instruments

This study used the following research tools to collect detailed information (Table 1)

Table 1: Research tools to collect data information.

	Research Tools	Description
	1-Meta Quest 2	Headset used to facilitate immersive experience through VR: Two Headsets were provided to users
	2-Self-evaluation feedback questionnaire created in Google Forms and shared via WhatsApp	Participants analysed their performance using a rating scale and by responding on some questions
	3-Audio Recorder	Used to record audio during interviews for description and analysis.

3.4 Data collection

During the data collection phase, participants were informed of the aims and objectives of the study, and were ensured of confidentiality of their information. This method enabled participants to express their feelings, their emotions and their points of view on their experiences with the 360° video in VR comfortably. Initial observations during the video experimentation sessions offered real-time insights into participants' engagement. This observational aspect has subsequently helped to enhance the depth of the study, providing context-rich data on participants' interactions with the VR environment.

The interviews were semi-structured (see Table 2), which enabled the research objectives and hypotheses to be discussed in a predefined way. This also encouraged participants to express themselves in an authentic way, contributing to a holistic understanding of their engagement with VR technology in a cultural context. To further the data from the interviews, a self-evaluation questionnaire was directed to the participants. This questionnaire, distributed via Google Forms on WhatsApp, enabled participants to reflect on their experiences in the proposed virtual environment and to extend the initial feedback provided orally during the experiment.

The questionnaire consisted in answering 8 questions designed for self-evaluation. Participants were invited to rate the level of satisfaction and pertinence of the VR experience, on a scale of 1 to 5 (where 1 corresponded to the lowest score and 5 to the highest), in terms of degree of immersion, engagement and sense of presence in Virtual Environment. The process of triangulating the data sources, includes face-to-face interviews, participant observations, and self-report questionnaires, helped to consolidate the results and to improve the overall accuracy of the study. We have also observed some peer discussions and debriefings among participants, which helped to validate interpretations and ensure methodological accuracy throughout the data analysis process.

https://doi.org/10.61856/mq5rn669

3.5 Schedule and procedures

The research was carried out over approximately one week in the spring vacancie of mars (Tunisian Vacancie), during which we attempted to conduct the experiment with visitors of the museum. For those using VR headsets for the first time, we tried to familiarize them with the navigation controls and the characteristics of 360° vision in VR, and then they viewed the video 'The Magic of Guellala.'. This activity helped them to feel more comfortable watching the video.

The process was designed to be simple and directly aligned with the analysis of users' behavior and interaction with the content, their degree of immersion, and the assessment of the impact on their understanding of the cultural heritage of the island of Djerba and on the innovative aspect of the cultural mediation tools.

3.6 Behavioral variables

1- It refers to the user's feeling of being present within the virtual environment. The greater the sense of presence, the more effective and engaging the experience will be.

2- It relates to the extent to which the user is immersed in the experience, whether in terms of visual, audio, or interactive design.

4- Measures the extent to which the user interacts with elements in the virtual environment, such as exploring the environment following the storytelling guidelines.

3.7 Qualitative Data Analysis

In this research, interview transcripts were submitted to a rigorous manual coding process and iterative derivation of themes guided by the principles of thematic analysis (presence, immersion, interaction). These themes emerged directly from the data, capturing the richness of the narratives and ensuring an authentic representation of the lived experiences (Braun, V., & Clarke, V. (2006). This involved a careful reading of each transcript to identify recurring and significant ideas related to the VR experience. Initially, open coding was used to generate a comprehensive list of codes directly from the data. These codes were then grouped into broader themes based on their conceptual similarities (Grawitz, M. (1996)), representing key aspects of participants' perceptions. The thematic analysis was meticulously conducted by hand, ensuring deep engagement with the data and a holistic understanding of the participants' narratives. The analysis followed the guidelines of qualitative content analysis (Podara et al., 2021), making it easier to examine how the 360° video's storytelling techniques influenced immersion.

Data was then used for analysis, and conclusions, and the interpretations in the research are based on textual and contextual data. Triangulation of data—specifically between observation, self-evaluation, and interviews—did not follow the conventional matrix method. Instead, data from observations were systematically compared against interview responses and self-evaluation reports to identify convergences and divergences. Observational data served as a supplementary source to validate or challenge the themes and findings extracted from interviews and self-evaluations.

https://doi.org/10.61856/mq5rn669

4- Results and discussion

4-1 Results:

The emotional connections that VR establishes with our cultural heritage highlight the potential its potential to enhance empathy and understanding across various cultural contexts, allowing users to engage actively with the storytelling that shapes our collective history. This immersive technology enables users to experience environments that go beyond conventional visual representations (videos), immersing them into compelling historical and cultural environments. Indeed, virtual tours of heritage sites, such as those provided by museums, offer total immersion, enabling visitors to explore artworks and artifacts freely, (ByEvos, 2024) even in inaccessible spaces. This approach enhances the experience of learning and makes heritage more accessible to everyone (Virtualys, 2024).

The focus of our evaluation is on immersion and user engagement in the narratives presented by the immersive video. As we examined the storytelling, diverse perspectives on the intersection of technology, cultural appreciation, and emotional connection emerged. Each participant's feedback contributed uniquely to understanding the potential of 360° VR video for cultural enhancement. Each participant's feedback contributed uniquely to understanding the potential of 360° VR video for cultural enhancement. In fact, we are basing our analysis on the following criteria of measurement: sense of presence, degree of immersion, interaction with the virtual environment, sense of engagement and emotional connection and its impact on understanding of heritage - these five criteria will be evaluated on a satisfaction scale from 1 to 5 (Table 2). This scale will make it possible to quantify user perceptions (via the questionnaire) while providing more rich qualitative data through interviews.

4.1.1 Sentiment of presence

Studies reveal that elements such as graphics and sound quality significantly influence this feeling (Hebbel-Seeger, J. (2021). By using a questionnaire and interviews, this research will focus on collecting feedback on how users perceive their presence in the virtual environment. Participants are invited to evaluate their feeling of being actually in the virtual environment on a scale of 1 to 5. A rating of 1 might indicate that they don't feel present at all, while a rating of 5 would indicate total immersion. The results pointed out that the majority of participants, with (M= 4.0), felt present in the virtual environment, which underlines the importance of visual and audio elements in achieving effective immersion with (M= 3.82). Triangular analysis with interview feedback (Table 3) shows that participants often reported that sound immersion (Comments like “background music and ambience” mentioned by 60% of participants) and the visual quality of the 360° immersive video filmed in 4K (“Comments like the 360° vision make me feel I’m really in place” mentioned by 70% of participants) were crucial to their sense of presence and sense of empathy (feeling as if they were there). We conclude that this feeling enhances the learning experience and increases the appreciation of cultural heritage. This can affect how users respond to cultural content, as it helps to create an emotional connection with the heritage showcased.

4.1.2 Degree of Immersion

Immersion refers to the depth of involvement of the user in the experience, generally including visual, audio, and interactive aspects. The analysis of participants' responses to the questionnaire and the interview regarding the visual and audio elements that capture their attention has helped us to identify the key factors that contribute to the successful immersive experience.

Indeed, in the questionnaire, participants were invited to rate their immersion on a scale of 1 to 5, where 1 means little or no immersion and 5 refers to a higher or total level of immersion. The interview will provide insights into the visual and interactive aspects that contributed most to their immersion experience. With (M= 3.92), users report a good level of immersion, suggesting that the visual and sensorial aspects are well designed.

Table 2: Tabular representation of the number of participants who rated each self-evaluation feedback questionnaire with the 5 analysis criteria, on a scale of 1(Not at all) to 5 (Totally)

Measurement criteria	**Questions**	**1**	**2**	**3**	**4**	**5**	Estimated average M = Total score / Total number of r responses
Sentiment of Presence	Q1. On a scale of 1 to 5, to what extend do you feel present in the virtual environment?	5	10	15	20	50	4.00
	Q2. On a scale of 1 to 5, to what extend does 360° viewing, enhance your sense of presence?	6	8	20	30	36	3.82
Degree of Immersion	Q3. On a scale of 1 to 5, how would you rate your level of immersion during the experience?	3	7	20	35	35	3.92
	Q4. On a scale of 1 to 5, to what extent did the interactive elements engage you during the experience?	35	30	20	10	5	2.2
Interaction with the Virtual environment	Q5. On a scale of 1 to 5, to what extent did the narrative elements facilitate your exploration of the environment?	5	5	18	32	40	3.97
Sense of Engagement	Q6. On a scale of 1 to 5, to what extend did you feel emotionally engaged during the experience?	4	6	10	20	60	4.26

Measurement criteria	**Questions**	**1**	**2**	**3**	**4**	**5**	Estimated average M = Total score / Total number of r responses
Impact on Understanding culture Heritage	Q7. On a scale of 1 to 5, do you think this experience improved your understanding of cultural heritage?	2	3	10	25	60	4.38
	Q8. On a scale of 1 to 5, to what extent did this experience change your perception of cultural heritage?	3	5	12	15	65	4.34

65% of participants reported that the narrative elements (storytelling and background sounds) enabled them to be actively engaged with the content. Users rate their interactive experience with the virtual environment by (M=2.2) and they suggested the introduction of interactive elements, such as the ability to explore freely or interact with the content. They report that interaction may have helped the enhancement of the overall experience of immersion (responses such as "being able to touch and manipulate objects could make the experience more vibrant," mentioned by 65% of participants).

4.1.3 Interaction with virtual environment

The interaction with elements of the virtual environment is crucial to a successful immersive experience. Users must be able to explore the environment while following instructions from the narration, aiding them to better explore the environment. The interviews explored how users interacted with the immersive content and how it affected their engagement and understanding.

Users' ability to interact with the virtual environment is rated on a scale of 1 to 5. A rating of 1 indicates limited or no interaction, while a rating of 4 or 5 suggests active and engaging exploration. Users who followed the storytelling guidelines (the storytelling made it easier for them to explore and engage with the virtual environment) reported a high level of interaction (M= 3.97). Thus, 75% of participants appreciated the influence of immersive storytelling, while 25% preferred free exploration, considering storytelling a disruptive element. The results also revealed that most participants felt able to interact with the storytelling and emphasized that they followed the storytelling guidelines, which enriched their experience. Comments such as “the story has naturally guided me through the environment” point to this positive interaction, which is essential for reinforcing active engagement with cultural content.

4.1.4 Sentiment of engagement

The sense of engagement is related to how users become emotionally involved in the experience. Previous studies have addressed best practices and considerations for creating attractive and engaging experiences for users (Argyriou, L., Economou, D., & Bouki, V. (2020)) and (Škola, F., et al. (2020)) establishing a strong emotional connection between the user and the content, which is essential for maintaining both interest and engagement. By including questions on the emotions perceived during the experience, this research was able to identify a strong sense of emotional engagement (M= 4.26), which is in line with the work of (Vishwanath, G. (2023)) who points out that immersive experiences

generate positive emotions. Many interviewees (80%) reported a sense of amazement and excitement. Some statements, such as "I was captivated throughout the experience" and "I'm amazed by what I've just discovered through this virtual tour," illustrate this point.

4-1.5 Impact on culture heritage understanding

It is essential to evaluate how these immersive experiences affect the understanding of heritage and its enhancement. The literature suggests that immersive experiences can improve awareness of cultural heritage by making information more accessible and engaging (Sylaiou S. et al. 2019). The results of the interviews were used to measure if the users perceived a strong connection with cultural heritage after having experienced an immersive experience. The impact is measured on a scale of 1 to 5. A rate of 1 indicates little or no impact, while a rate of 4 or 5 indicates a significant understanding of cultural heritage.

With (M=4.38), participants reported that the experience improved their understanding of cultural heritage, underlining the effectiveness of immersive storytelling and confirming the research of (Falk & Dierking (2000)) who state that virtual environments can enhance cultural heritage understanding by making information more accessible and engaging. 90% of participants reported a significant improvement in their perception of Djerba's cultural heritage after the experience. 85% of them made statements such as “I learned a lot about Djerba's intangible heritage thanks to this experience” or “I'd love to visit the places I've just discovered in the experience; could you guide us?".

This highlights the effectiveness of this virtual experience in enhancing the island's local heritage and fostering a deeper appreciation of it. Our results showed that participants' reflections (via questionnaire and interview) on the immersive experience of watching a 360° VR video revealed that the sense of presence and immersion suggests that such experiences can indeed serve as attractive tools for exploring historical and cultural sites. The process of triangulating the analysis between observation, questionnaire ratings and qualitative interview responses enabled us to identify some valuable insights for improving future virtual environments.

Tables 2 and 3 highlighted users' experiences in a virtual environment based on 360° video. The results showed that the sense of presence, the degree of immersion, the interaction with the virtual environment, the sense of “engagement,” and the impact on heritage understanding are all interconnected and essential to creating an inspiring immersive experience. These insights can guide the future development of immersive virtual reality experiences in the cultural field, focusing on elements that promote interaction and a positive, engaging user experience.

Table 3: Frequencies of responses to the interview questions

Fields of Measurement	Emerging Themes	Fréquence (%)
Feeling of Presence Q1. Which specific qualities have strengthened your sense of presence?	**Visual quality:** quality of 360° view	70%
	Sound immersion: background music and ambience	60%
Degree of immersion Q2. What elements from the visuals or sounds contributed most to your immersion?	**Dynamic interaction:** suggestions "being able to touch and manipulate objects could make the experience more vibrant"	65%
	Narrative elements: the storytelling and the backgound sounds	70 %
Interaction with the Virtual Environment Q3 Did you feel that storytelling influenced your exploration?	**Free exploration:** I prefer to explore freely the environment: storytelling disrupted my discovery	25%
	Positive Influence of the storytelling: "the story has naturally guided me through the environment"	75%
Sense of Involvement Q4. What kind of feelings did you feel during your immersive experience?	**Positive feeling:** The island has a rich heritage	70%
	Feeling of marvel and excitement: "I was captivated throughout the experience", "I'm amazed by what I've just discovered through this virtual tour,"	80%
Impact on heritage understanding Q5. What new insights have you learned from this experience?	**Improving understanding of Djerba island's heritage**	90%
	Enhancement of local culture heritage: I learned a lot about Djerba's intangible heritage thanks to this experience". I'd love to visit the places I've just discovered in the experience; could you guide us?".	85%

The results also revealed that users interacted positively with the narrative content, revealing high levels of immersion and engagement. It's also interesting to mention that these immersive 360-degree

VR video experiences helped to improve users' ability to recall information related to tangible and intangible heritage. We were also able to identify very positive social interaction: the shared experiences encouraged users to discuss the content with each other, fostering a collective appreciation of cultural heritage.

4-2 Discussion

These results refine and extend existing models in VR cultural heritage experiences and propose a revised model that integrates sensory fidelity, emotional storytelling and structured interaction, highlighting the potential of immersive environments for cultural preservation and education. The findings point for a nuanced approach that emphasizes structured narratives, which help users to assimilate and retain knowledge of both tangible and intangible heritage while enhancing presence and engagement. The research also reveals that social interaction amplifies cultural understanding, demonstrating how shared VR experiences foster collective appreciation of heritage.

These results align with existing literature. For instance, our findings on the impact of visual and aural elements on sense of presence support Witmer and Singer's (1998) assertion of the importance of these elements in fostering the effectiveness and engagement of the user experience with cultural content. We also observe support for (Slater, M., & Wilbur, S. (1997) and (Slater M. (2018) work on the importance of interactive and narrative quality for overall immersion.

The role of immersive narrative in enhancing user experience supports Hutson and Hutson's (2024) claims that immersive storytelling makes interactions more meaningful and contextual while fostering engagement and encouraging exploration. Furthermore, emotional engagement in our study is consistent with (Vishwanath's (2023)) findings on immersive experiences evoking positive emotions and stronger connections. Lastly, the enhancement in understanding cultural heritage reinforces (Falk and Dierking's (2000)) suggestions about the virtual environment's potential for individual enrichment.

5. Conclusion

This study aims to provide an in-depth and nuanced understanding of user experiences in a virtual environment. By adopting a phenomenological approach, we analyzed key variables such as presence, immersion, interaction, and engagement, and their impact on the understanding of cultural heritage. The results revealed that these factors are interconnected and play a crucial role in heritage enhancement. Qualitative data have enhanced the quantitative results by providing context and personal perspectives, and have identified how the sense of presence and degree of immersion contribute to creating an enriching experience, while highlighting the importance of engagement in optimizing the positive impact of these virtual environments. The insights obtained will help to guide the future development of immersive virtual reality experiences in the cultural field. By adjusting design elements according to these results, we will be able to improve the quality of interactions and enrich the user experience. In the development of future immersive experiences, it will be possible to improve the rendering of 360° VR videos by adding three-dimensional interactive elements to the filmed scene to promote interaction with the virtual environment.

Finally, this study has contributed to our understanding of the dynamics of virtual environments and offered some practical suggestions for optimizing these experiences and fostering positive engagement with cultural heritage. Overall, future research may explore how different user groups, such as older users and children, engage with VR heritage content. For elderly users, studies could focus on how

VR enhances emotional connections, nostalgia and cognitive engagement while addressing accessibility challenges such as simplified interfaces or adaptive controls for inclusive accessibility. For children, research could examine the impact of immersive storytelling on their learning, curiosity and cultural awareness, balancing interactivity and ergonomic considerations of the interface, but also the expectations of these potential users (the serious game in the contexte of cultural heritage). Customized VR content, aligned closely to the specific needs of these groups (a user-centered approach), could further enhance engagement and inclusion, offering valuable insights for the design of more accessible and impactful cultural heritage experiences.

6.References

Agrawal, S., Simon, A., Bech, S., Bærentsen, K., & Forchhammer, S. (2019). Defining immersion: Literature review and implications for research on immersive audiovisual experiences. Journal of Audio Engineering Society, 68(6), 404–417. https://doi.org/10.17743/jaes.2020.0039

Aitamurto, T., Zhou, S., Sakshuwong, S., Saldivar, J., Sadeghi, Y., & Tran, A. (2018). Sense of presence, attitude change, perspective-taking and usability in first-person split-sphere 360 video. In Proceedings of the Conference on Human Factors in Computing Systems (CHI'18) (Article 545, 12 pages). ACM. https://doi.org/10.1145/3173574.3174119

Argyriou, L., Economou, D., & Bouki, V. (2020). Design methodology for 360° immersive video applications: The case study of a cultural heritage virtual tour. Personal and Ubiquitous Computing, 24, 843–859. https://doi.org/10.1007/s00779-020-01373-8

Ben Jemmaa, M. (2022). The magic of Guellala. [Film]. Higher Institute of Arts and Crafts of Gabes, University of Gabès. Supervised by Ben Maallem Hela, assistant-professor in ISAM Gabes.

Ben Maallem, H. (2024). The virtual environment as a setting for cultural heritage mediation. In C. Stephanidis, M. Antona, S. Ntoa, & G. Salvendy (Eds.), HCI International 2023 – Late Breaking Posters (Vol. 1957). Springer. https://doi.org/10.1007/978-3-031-49212-9_61

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77-101.DOI: 10.1191/1478088706qp063oa.

ByEvos. (2024). Visites virtuelles et animation VR pour musées et centres culturels. Retrieved from https://byevos.fr/visite-virtuelle-et-animation-vr-pour-musees-et-centres-culturels/

C-I Studios. (2024). 360-degree video: Immersive experiences and virtual reality. Retrieved from https://c-istudios.com/360-degree-video-immersive-experiences-and-virtual-reality/

Fadde, P. J., & Zaichkowsky, L. (2018). 360° Virtual Reality: A SWOT Analysis in Comparison to Virtual Reality. Frontiers in Psychology, 11, Article 563474. https://doi.org/10.3389/fpsyg.2020.563474

Falk, J. H., & Dierking, L. D. (2000). Learning from museums: Visitor experiences and the making of meaning.

Grawitz, M. (1996). Méthodes des sciences sociales. Dalloz, Coll. « Précis Droit public. Science politique ».

Hebbel-Seeger, J. (2021). LectureCast as 360 Degree Video: What Impact Do Immersion and Presence Have on Learning? Athens Journal of Education, 8(1), 23-38. https://doi.org/10.30958/aje.8-1-2

Hutson, J., & Hutson, P. (2024). Storytelling. In Inclusive Smart Museums. Palgrave Macmillan. https://doi.org/10.1007/978-3-031-43615-4_2

Hutson, J., & Hutson, R. (2024a). Dynamic storytelling through immersive technologies: Engaging audiences with cultural narratives. International Journal of Heritage Studies, 30(1), 12-29.

Interaction Design Foundation. (2024). The biggest and most authoritative library of open-source UX design resources. Retrieved from https://www.interaction-design.org/literature

Kittel, A., Larkin, P., Cunningham, I., & Spittle, M. (2020). 360° virtual reality: A SWOT analysis in comparison to virtual reality. Frontiers in Psychology, 11, Article 563474. https://doi.org/10.3389/fpsyg.2020.563474

Kumar, S., & Ranjan, P. (2022). Impact of immersive virtual reality content using 360-degree videos in undergraduate education. ResearchGate. https://www.researchgate.net/publication/359075320_Impact_of_Immersive_Virtual_Reality_Content_Using_360-degree_Videos_in_Undergraduate_Education

Kumar, S., & Ranjan, P. (2024). Evaluation of the effectiveness of museum education in virtual environments with 360° videos. Revista Romaneasca pentru Educatie Multidimensionala, 16(1), 113-137. https://doi.org/10.18662/rrem/16.1/814

Motive.io. (2024). Comparing 360 video vs. virtual reality. Retrieved from https://www.motive.io/blog/360-video-vs-virtual-reality/

Murray, J. H. (2017). Hamlet on the holodeck: The future of narrative in cyberspace. MIT Press. Cited in Sarvesh Agrawal, Adèle Simon, Søren Bech, Klaus Baerentsen, Søren Forchhammer. Defining Immersion: Literature Review and Implications for Research on Immersive Audiovisual Experiences. Audio Engineering Society, Oct 2019, New York, United States. ffhal-02512570

Mütterlein, J. (2018). The three pillars of virtual reality? Investigating the roles of immersion, presence, and interactivity. In Proceedings of the 51st Hawaii International Conference on System Sciences. DOI: 10.24251/HICSS.2018.174.

Oladokun, B.D., Ajani, Y.A., Ukaegbu, B.C.N., & Oloniruha E.A.(2024). Cultural preservation through immersive technology: The metaverse as a pathway to the past.Heritage Science, 12(4), Article 22 . https://doi.org/10.1515/pdtc-2024-0015

Peeters, M. (2022). The potential of immersive virtual reality for the study of event perception. Frontiers in Virtual Reality, 3, Article 697934. https://doi.org/10.3389/frvir.2022.697934

Podara, A., Giomelakis, D., Nicolaou, C., Matsiola, M., & Kotsakis, R. (2021). Digital storytelling in cultural heritage: Audience engagement in the interactive documentary New Life Sustainability, 13(3),1193. https://doi.org/10.3390/su13031193

Qandeelji A.E.(2024). Research methodology [PDF]. Retrieved from https://books.pinsr.ps/upload/2024/02/1952652596_88.pdf

Slater M.(2018). Immersion and the illusion of presence in virtual reality.British Journal of Psychology, 109(3),431–433 .https://doi.org/10 .1111/bjop .12305

Slater M ., & Wilbur S.(1997) .A framework for immersive virtual environments(FIVE): Speculations on the role of presence in virtual environments.Presence: Teleoperators and Virtual Environments, 6(6),603–616 .https://doi.org/10 .1162/pres .1997 .6 .6 .603

Souza V ., Maciel A ., Nedel L ., & Kopper R.(2021) .Measuring presence in virtual environments: A survey.ACM Transactions on Graphics, 40(4), Article 1–18 .https://doi.org/10 .1145 /3466817

Škola F ., Rizvić S ., Cozza M ., Barbieri L ., Bruno F ., Skarlatos D ., & Liarokapis F.(2023) .Virtual reality with 360-video storytelling in cultural heritage: Study of presence , engagement , and immersion.Journal of Cultural Heritage, 54,1–12.DOI :10 .3390/s20205851

Stornaway.io. (2024). How to use 360 VR to immerse and engage your audience. Retrieved from https://www.stornaway.io/immerse-your-audience-in-360-virtual-reality-experiences/

Sylaiou S, Kasapakis V, Dzardanova E, Gavalas D (2019)
Assessment of virtual guides' credibility in virtual museum environments, In international conference on augmented reality, virtual reality and computer graphics. Springer, Cham, pp 230–238, DOI:10.1007/978-3-030-25999-0_20

Virtualys (2024). Mise en valeur du patrimoine. from https://www.virtualys.fr/3d_rv/Notre-expertise/Immergez-vous-et-interagissez-avec-votre-environnement-virtuel/Mise-en-valeur-du-patrimoine

Vishwanath G.(2023) .Enhancing engagement through digital cultural heritage: A case study about senior citizens using a virtual reality museum.In P.Le Callet , M.Perreira Da Silva , T.Vigier , K.Tahiroglu , N.Murray , G.Valenzise , & M.Wang(Eds.),IMX '23: Proceedings of the 2023 ACM International Conference on Interactive Media Experiences (pp .150–156) .ACM .https://doi.org /10 .1145 /3573381 .3596154

Wagner A ., de Clippele MS.(2023) Safeguarding Cultural Heritage in the Digital Era – A Critical Challenge.International Journal for Semiotic Law, 36,1915–1923 .https://doi.org /10 .1007/s11196 -023 -10040-z

Wilkinson M ., Brantley S ., & Feng J.(2021) A mini review of presence and immersion in virtual reality.Virtual Reality, 65(1),1–12 .https://doi.org /10 .1177 /1071181321651148

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. Presence: Teleoperators and Virtual Environments, 7(3), 225–240. https://doi.org/10.1162/105474698565686

Zhang J ., Wan Yahaya W.A.J ., & Sanmugam M.(2024) The impact of immersive technologies on cultural heritage: A bibliometric study of VR , AR , and MR applications.Sustainability, 16(15),6446 .https://doi.org /10 .3390/su16156446

Zidan, A. A. (2024, February 19). Digital cultural heritage: Theory and practice. International Federation of Library Associations and Institutions (IFLA). https://www.ifla.org/news/digital-cultural-heritage-theory-and-practice/

NB: To enhance the clarity and readability of this paper, AI-assisted tools (Grammarly, sider, DeepL) were used for language refinement and sentence reformulation. These tools were employed to improve grammar, syntax, and style, ensuring effective communication of the research findings. However, the original content (research, analysis, and interpretation) and intellectual contribution remain the author own.