









## Design and evaluation of the user experience in an immersive web system

### Diseño y evaluación de la experiencia del usuario en un sistema web inmersivo

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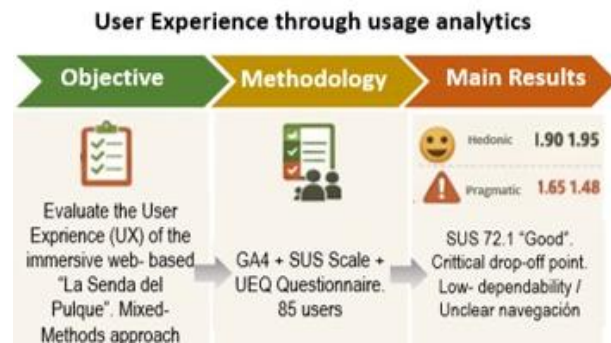


#### Abstract

This research analyzes the User Experience [UX] of the immersive virtual tour La Senda del Pulque through a mixed-methods approach that integrates web analytics [Google Analytics 4] with the SUS and UEQ instruments, involving 85 participants. The results indicate strong performance in hedonic dimensions, such as attractiveness and stimulation, while pragmatic aspects related to clarity and reliability require improvement. The SUS score was 72.1, classified as good, although with high variability. The study concludes that the success of immersive environments depends not only on visual appeal but also on solid usability, providing design recommendations and an applicable evaluation model.

#### Resumen

Esta investigación analiza la Experiencia del Usuario [UX] del recorrido virtual inmersivo La Senda del Pulque mediante un enfoque mixto que integra analítica web [Google Analytics 4] y los instrumentos SUS y UEQ, con la participación de 85 usuarios. Los resultados muestran un alto desempeño en dimensiones hedónicas, como atractividad y estimulación, mientras que los aspectos pragmáticos relacionados con claridad y fiabilidad requieren mejoras. La puntuación SUS fue de 72.1, clasificada como buena, aunque con alta variabilidad. El estudio concluye que el éxito de los entornos inmersivos depende tanto del atractivo visual como de una usabilidad sólida, aportando recomendaciones de diseño y un modelo de evaluación aplicable.



User Experience [UX], Web Virtual Reality, User Analytics

Experiencia del Usuario [UX], Realidad Virtual Web, Analítica de Uso

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## Introduction

The evolution of the web towards three-dimensional and immersive environments has transformed cultural and educational dissemination. Technologies such as WebGL and WebXR allow the creation of virtual tours [VR] accessible from the browser, democratising high-impact spatial and narrative experiences [Mystakidis, 2022]. These systems seek to generate immersion, engagement and meaningful learning [Slater & Sanchez-Vives, 2016], where User Experience [UX] design is critical.

However, a gap remains between the potential of these environments and their empirical evaluation, as many projects are evaluated using qualitative methods or superficial metrics, which neglect a granular analysis of behaviour [Díaz et al., 2020]. Web analytics applied to 3D systems is emerging as a key tool for closing this gap, transforming interaction into actionable data [Hilfert & König, 2016].

This study addresses this issue in the case of the VR ‘La Senda del Pulque’ [<https://proyectosva.com.mx/RVSP/>], designed to disseminate the cultural heritage of pulque. The objective is to comprehensively evaluate its UX using a framework that combines quantitative analytics and standardised qualitative instruments [SUS and UEQ]. Thus, the research questions are: 1] What are the behaviour patterns of users? 2] How do these patterns correlate with subjective experience? 3] Which design elements can be optimised? The work provides an applicable methodological model, actionable findings, and evidence for the field of Human-Computer Interaction [HCI].

## User Experience [UX] and Usability in Immersive Environments

User Experience [UX] is defined as a person's perceptions and responses resulting from the use or anticipated use of a product, system or service [ISO 9241-210, 2019]. In immersive environments, UX transcends traditional usability, effectiveness, efficiency, and satisfaction [Nielsen, 2012] to encompass dimensions such as presence [the feeling of ‘being there’], immersion [the objective response of the system to user actions], and emotional engagement [Slater & Sanchez-Vives, 2016].

Successful UX design in web-based virtual reality [VR] must balance cognitive load, provide intuitive 3D navigation, and maintain a coherent narrative that guides interaction without breaking the illusion of immersion [Jerald, 2015].

Standardised questionnaires have proven to be valid and reliable for evaluating these dimensions. The System Usability Scale [SUS] is a widely adopted 10-item tool that provides a quick and robust measure of perceived usability. The User Experience Questionnaire [UEQ] assesses six scales: Attractiveness, Perspicuity, Efficiency, Reliability, Stimulation, and Originality, being particularly sensitive to the affective and hedonic qualities of the interaction [Laugwitz, Held & Schrepp, 2008]. Therefore, the combination of SUS and UEQ allows for a holistic assessment that covers both pragmatic and hedonic aspects of UX.

## Virtual Tours as Educational and Cultural Tools

Immersive virtual tours have established themselves as powerful tools for heritage preservation, distance education, and scientific dissemination [Champion, 2021]. Unlike passive 360° videos, interactive VR allows for user agency and encourages constructivist and exploratory learning. Thus, their pedagogical effectiveness is linked to their ability to generate authentic learning contexts and facilitate spatial understanding of otherwise inaccessible environments [Díaz, Saldaña & Avila, 2020].

The creation of these environments for the web, sometimes referred to as ‘WebVR’ or ‘WebXR,’ removes barriers to access by requiring only a modern browser, thereby democratising its reach. However, this accessibility poses technical challenges, such as optimising graphic resources for different bandwidths and implementing adaptive interaction interfaces that work on both touchscreen and desktop devices [Pirker & Dengel, 2021].

## Web Analytics Applied to the Evaluation of Interactive 3D Systems

Traditional web analytics has focused on metrics for 2D sites, such as page views, bounce rate, and time on page.

However, 3D and immersive environments require a specialised metrics framework that captures significant events within the virtual space: user position and trajectory, interactions with objects, sequences of actions, and time spent in specific areas [Hilfert & König, 2016].

Process mining applied to interaction logs allows us to reconstruct the user's 'path,' identify common patterns, and detect bottlenecks or points of confusion [Díaz, Saldaña & Avila, 2020]. Key metrics derived include:

- a] Completion rate, which refers to the percentage of users who complete the journey or reach narrative milestones,
- b] Interaction heat maps, through the visualisation of areas of the 3D environment that attract the most attention or interactions,
- c] Navigation patterns, obtained through common movement sequences, revealing the understanding of spatial architecture, and,
- d] Interaction time per module, established as the indicator of engagement and perceived complexity of each segment.

The integration of this quantitative analysis with qualitative methods [questionnaires, think-aloud] allows for data triangulation, which offers a richer and more validated understanding of the UX [Lallemant, Gronier & Koenig, 2015]. This mixed approach is adopted in the present study to evaluate the virtual tour 'La Senda del Pulque' [The Pulque Trail].

## Methodology

Thus, a mixed sequential explanatory design was adopted, where quantitative analytical data was first collected, followed by qualitative data through questionnaires.

1. **Case Study:** The VR 'La Senda del Pulque' is a responsive web application developed with Three.js. It features five narrative modules on the pulque process, with hotspot navigation, 3D object manipulation, and a stylised realistic aesthetic.

2. **Population and Sample:** A non-probabilistic sample of  $n=85$  participants [45 students, 25 educators, 15 general public] was recruited. Criteria: over 18 years of age, basic experience in web navigation.

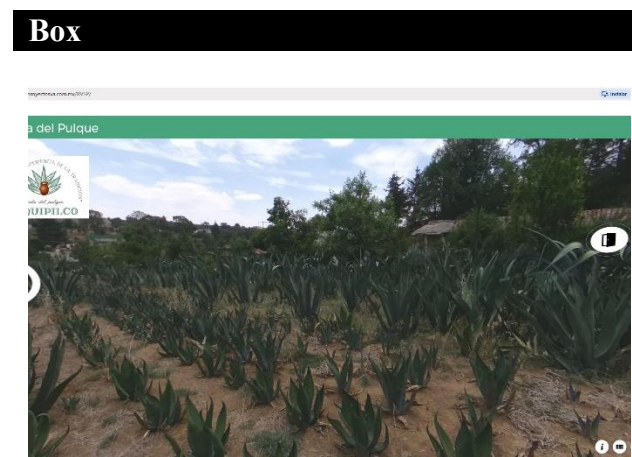
3. **Instruments and Procedure**

- Phase 1 [Analytics]: Google Analytics 4 was implemented with custom events [e.g., `module_viewed`, `hotspot_activated`] for 2 weeks.
- Phase 2 [Questionnaires]: Immediately after interaction, users responded to the SUS [ $\alpha=0.87$ ] and UEQ [ $\alpha=0.91$ ].

4. **Data Analysis**

Descriptive and inferential analysis of the analytics metrics was performed using R and GA4. SUS and UEQ scores were calculated and compared with benchmarks, and triangulation was performed using Spearman correlations between behavioural metrics and UEQ scales.

The system evaluated corresponds to an immersive virtual web tour that integrates 360° panoramic environments aimed at exploring the productive landscape of the maguey.



**Figure 1**

Main interface of the immersive virtual web tour La Senda del Pulque [available at: <https://proyectosva.com.mx/RVSP/>]. The image shows a 360° panoramic view of a maguey field, corresponding to one of the central modules of the system. This environment allows users to explore the productive landscape through immersive navigation and is a key component for evaluating the user experience, usability, and level of interaction within the virtual tour.

*Own work*

## Results

After data cleaning, n=73 responses from the SUS and n=65 from the UEQ were analysed.

### 1. Perceived Usability [SUS]

The overall SUS score was 72.1 [SD=18.4], classified as 'Good' [percentile 65-70], but with high variability. The strongest items were ease of use [Item 3: M=3.4] and perceived safety [Item 9: M=3.2]. The main weakness was intention to use frequently [Item 1: M=2.5]. Approximately 15% of users reported a poor experience [SUS<50].

### 2. User Experience [UEQ]

The UEQ results show a clear dichotomy:

- Exceptional Hedonic Strengths: The Stimulation [M=1.95, 95th percentile] and Attractiveness [M=1.90, 90th percentile] scales received excellent ratings.
- Pragmatic Opportunities: The Perceptual Clarity [M=1.65, 50th percentile], Efficiency [M=1.58, 45th percentile] and especially Reliability [M=1.48, 40th percentile] scales were average or below average.

### 3. Data Triangulation

- Time and Engagement: The average interaction time was 2 min 08 s. A moderate positive correlation was found between session time and UEQ Stimulation [ $\rho=0.42$ ,  $p<0.01$ ].
- Navigation and Clarity: Only 56% followed the complete linear route. Twenty-eight per cent skipped module 3. Users with low Perspicuity were more likely to skip modules [ $p<0.05$ ].
- Abandonment and Reliability: Forty per cent of unfinished sessions were abandoned during the transition between modules 4 and 5, which involved a complex 3D object. These users reported low Reliability [UEQ] and inconsistency [SUS item 6].

## Discussion

The results reveal that 'La Senda del Pulque' offers a hedonically successful [motivating, attractive] experience, confirming its potential for cultural dissemination. However, the pragmatic experience is uneven, with friction in reliability, clarity, and efficiency.

This pattern is consistent with the literature: technical inconsistency in 3D web environments can break immersion. The 'Good' but not excellent usability [SUS=72.1], together with the low intention of frequent use, suggests that pragmatic frictions limit recurrent adoption and long-term impact [Hassenzahl, 2008].

Implications for design:

- Reinforce wayfinding: Improve visual cues, add an explicit progress map, and clarify the narrative value of each module to guide user intent [Champion, 2021].
- Prioritise Reliability and Feedback: Conduct thorough testing on complex interactions [e.g., 3D object in module 4-5], optimise performance, and implement immediate and clear feedback for all actions.
- Inclusive Design: Offer alternative navigation modes and integrated tutorials to accommodate users with varying levels of familiarity with 3D environments.

## Conclusions

This study successfully applied a mixed methodological framework for the comprehensive evaluation of UX in web-based VR. Its main contributions are:

1. Empirical evidence of a prominent hedonic strength and an accurate diagnosis of pragmatic weaknesses in a real-world case study.
2. A triangulated analysis model demonstrating the usefulness of combining behavioural analytics with subjective perceptions to locate specific problems and prioritise interventions.
3. Actionable design recommendations focused on improving reliability, clarity, and inclusivity.

In response to the research questions:

- 1] Navigation patterns show significant deviations from the expected route.
- 2] These patterns correlate with perceptions of low clarity [perspicuity] and reliability.
- 3] The elements to be optimised are feedback mechanisms, the robustness of complex interactions, and guidance cues.

In terms of limitations and future work, this study is based on a convenience sample and analytics metrics from an initial period, although one limitation to note is the lack of detailed demographic data to segment the analysis. Therefore, future research could conduct a longitudinal study measuring UX before and after implementing the suggested design improvements, incorporate techniques such as remote eye-tracking or think-aloud protocols for a more granular analysis of friction points, and explore the differential impact of the virtual tour on different learning profiles.

In conclusion, this work goes beyond mere evaluation to offer an evidence-based action plan. It confirms that the future of immersive web experience design for education and culture depends not only on more advanced technology, but also on rigorous UX engineering that ensures that the magic of immersion is backed by solid, clear, and reliable interaction for each user.

## Annexes

Virtual tour of the pulque trail  
<https://proyectosva.com.mx/RVSP/>

## Declarations

## Conflict of interest

The authors declare that they have no conflicts of interest. They have no known competing financial interests or personal relationships that might have appeared to influence the article reported in this paper.

## Author contribution

*Flores-Azcanio, Nancy P.*: Conceptualisation of the study, design and development of the immersive virtual tour, integration of the web-based virtual reality environment, interpretation of the results and drafting of the manuscript.

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*Echevarria-Chan, Ivonne*: Design, application and validation of usability and user experience assessment tools [SUS and UEQ questionnaires], as well as data collection.

*Ortiz-Quiroga, Hugo*: Support in project management and coordination, support in the operational implementation of the study, organisation of the information collected and review of the manuscript.

## Availability of data and materials

### Panoramic report

SUS Questionnaire [Usability]  
[Cuestionario SUS \[respuestas\].xlsx](#)

User Experience Questionnaire  
[CUESTIONARIO UEQ \[User Experience Questionnaire\] \[respuestas\].xlsx](#)

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## Abbreviations

<b>GA4</b>	Google Analytics 4
<b>HCI</b>	Human–Computer Interaction
<b>ISO</b>	International Organization for Standardization
<b>SUS</b>	System Usability Scale
<b>UEQ</b>	User Experience Questionnaire
<b>UX</b>	User Experience
<b>VR</b>	Virtual Reality
<b>WebGL</b>	Web Graphics Library
<b>XR</b>	Extended Reality

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**Discussions**

Champion, E. [2021]. [Virtual heritage: A guide](#). Ubiquity Press.