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A Study on the Use of Online Museum Exhibitions Incorporating VR Content Through IPA

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Abstract: ***This study evaluates the integration of VR content into museum online exhibitions using Importance-Performance Analysis (IPA) and SPSS surveys. By analyzing VR content attributes, usability, and case studies from Chinese and South Korean museums, the research highlights the potential of VR to innovate exhibition methods and digital archiving. Key findings reveal resource allocation priorities (availability, realism, creativity, efficiency), comparative strengths/weaknesses of VR implementations, and practical applications at the National Museum of Korea. The study advocates for VR-driven 3D digital archives to enhance accessibility, preservation, and cultural dissemination.***

Keywords: VR content attributes; Museum online exhibitions; IPA; 3D digital archives.

1. INTRODUCTION

1.1 Background and Purpose

Advancements in VR and AI have prompted museums to explore immersive exhibition formats beyond traditional 2D web-based displays. While museums increasingly adopt VR to transcend spatial-temporal constraints, most current implementations remain theoretical or lack technological integration. This study addresses this gap by analyzing VR content characteristics, evaluating user satisfaction/importance through IPA, and proposing a framework for VR-based exhibitions and 3D archives at the National Museum of Korea.

1.2 Scope and Methodology

The study examines VR exhibitions at the Yanggu White Porcelain Museum (South Korea) and Hubei Provincial Museum (China), focusing on usability, realism, and creativity. Using paired t-tests and IPA, 84 validated surveys (from 92 respondents) were analyzed. Practical VR content creation for the National Museum of Korea was tested using 3DS MAX, Photoshop, and panoramic photography, prioritizing safety and cost efficiency.

2. THEORETICAL FRAMEWORK

2.1 Characteristics of VR Content

Virtual Reality (VR) refers to a phenomenon or technology that stimulates the user's senses and immerses the user in a virtual space by providing an artificially created virtual space using a computer. The commonly known characteristics of VR are as follows Table 1.

Table 1: Virtual reality feature element

Key element	Key Elements Concepts
Presence	The feeling of being in real virtual reality
Immersion	A psychological state characterized by recognizing interaction surrounded by a virtual reality environment
Emotion state	Experience Factors for Positive and Negative Emotions during Virtual Environment Experience
Affective appraisal	Emotional experience elements for virtual environment system components and content
Usability	Experience factors for how effectively and efficiently you complete tasks within a virtual environment system and how satisfied you are with the system as a whole
Health and Safety	Health and Safety Experience Factors Caused by Virtual Reality System Characteristics

The global virtual reality (VR) market is expected to grow at an annual average growth rate of 27.9% from $6.127 billion in 2020, reaching $20.93 billion in 2025.

China's virtual reality (VR) industry has grown from $14 million in 2017 to $1.4 billion in 2018. It is expected to reach $35.3 billion by 2027.

Korea's virtual reality (VR) market is expected to grow 29.6% annually from $320 million in 2020, reaching $1.173 billion in 2025.

However, challenges like cost barriers and health concerns persist.

2.2 Case Studies

Online exhibitions driven by non-face-to-face media are becoming increasingly common in museums. This article explores the digital strategies of two institutions: the Hubei Provincial Museum in China and the Yanggu White Porcelain Museum in South Korea(). The Yangkou White Porcelain Museum was established in 2006 and lacks a navigation panel that allows for direct movement between galleries, limiting the accessibility of information. Moreover, 3D roaming is still underdeveloped, and VR side-by-side viewing requires head-mounted displays (HMDs), which reduces user friendliness. The Wuhan Hubei Provincial Museum is no exception. Future development should prioritize the seamless integration of information tools and network adaptive interfaces to optimize virtual cultural experiences.

3. IPA ANALYSIS OF VR CONTENT

3.1 Methodology

IPA (Importance Performance Analysis) is the first analysis method initiated by Martiller and James (1977). IPA, a user's importance-satisfaction analysis, is an analysis method used to prepare a strategy to improve user requirements by identifying the relative relationship between factors treated as important in the study subject and satisfaction factors corresponding thereto.

The IPA is divided into four sections as shown in Figure 1.

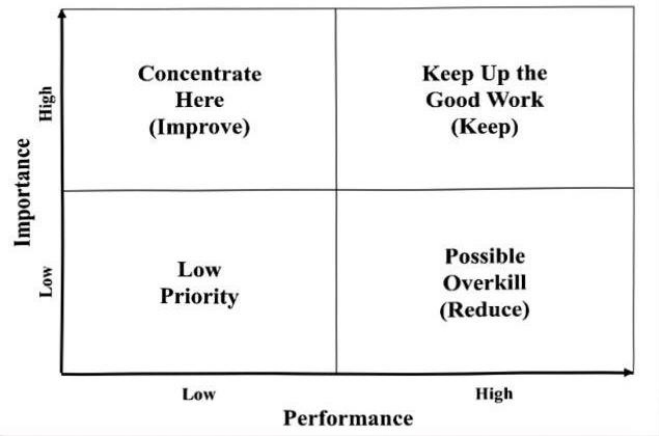

Figure 1: IPA Analysis Matrix Map

A 36-item questionnaire assessed 18 VR attributes Table 2 across six categories. Cronbach's alpha (0.970) confirmed high reliability. KMO (0.896) and Bartlett's tests Table 3 validated factor analysis.

Table 2: 18 VR attributes

Core element	Details element	Evaluation Criteria
Presence	Coexistence realism	A-1 Feeling like you're physically in the same room as the people you're experiencing virtual reality with
	Spaces	A-2 Does the environment in virtual reality feel like the real world?
	Existence	A-3 Ensure that spatial elements in virtual reality feel realistic

Immersion	Absorption	B-1 Psychologically Immerse Yourself in a Virtual Reality Environment
	Embodied Directors	B-2 Does it feel like you're fully immersed and embodied in the virtual reality environment?
	Temporal dissociation	B-3 You're so immersed in the virtual reality experience that you don't realize how much time has passed.
Emotions Emotionstate	Pleasure	C-1 How enjoyable the virtual reality experience is
	Joy	C-2 How much fun it is to experience virtual reality
	Anxiety	C-3 How anxiety-inducing are virtual reality experiences?
Emotions Evaluation (Affective appraisal)	Impression severity	D-1 How impressed I was with the virtual reality elements
	Attraction	D-2 How compelling are virtual reality elements?
	Creativity	D-3 How creative were the virtual reality elements?
Usability (Usability)	Validity	How effective was the E-1 virtual reality experience?
	Efficiency	E-2 How efficiently we were able to conduct virtual reality experiences
	Satisfied	E-3 How satisfied were you with your virtual reality experience?
Health and Safety (Health and Safety)	Simulated Motion Sickness	F-1 Dizziness caused by a perceptual difference between visually perceived motion and the sense of motion in a virtual reality system
	Comfortable	F-2 Comfort or ease attributable to virtual reality system elements
	Fatigue	F-3 Fatigue during virtual reality experiences

Table 3: Analyzing questionnaire validity based on VR characteristics

Item	Factor Loadings					
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Variance Resolution Rate	18.317	13.744	11.263	10.089	9.399	9.368
Cumulative Variance Interpretation Rate	18.317	32.060	43.324	53.413	62.812	72.180
KMO	0.896					
BTS	2690.985					
Degrees of freedom	630					
p value	0.000					

3.2 Key Findings

Quadrant I (Prioritize Improvement): Usability (E-2), realism (A-3), and creativity (D-3) required resource allocation. Quadrant II (Maintain Performance): Immersion (B-1, B-2) and satisfaction (E-3) were strengths. Quadrant IV (Reduce Focus): Emotional states (C-1, C-2) and health metrics (F-1, F-2) showed overinvestment.

The IPA results indicate that future investment and interest are required in four aspects of VR production and exhibition: availability, realism, creativity, and efficient execution. Based on this analysis, it is expected that efforts will be made to develop and improve VR content by establishing appropriate strategies.

Table 4 shows the results of the Paired t test study data of the overall VR characteristics.

Table 4: Analyzing questionnaire validity based on VR characterist

Item	Satisfaction (P)		Importance (I)		Mean difference (P-I)
	Average	Order	Average	Order	
A Presence	2.127	4	2.119	3	0.01
B Immersion	2.163	3	2.214	1	-0.05
C Emotion state	2.266	2	2.040	6	0.23
D Affective appraisal	2.024	6	2.115	4	-0.09
E Usability	2.123	5	2.202	2	-0.08
F Health and Safety	2.294	1	2.107	5	0.19

4. CASE STUDY: NATIONAL MUSEUM OF THE SOUTH KOREA

4.1 VR Content Development

The National Museum of Korea (NMK) employs a systematic approach to VR content creation, emphasizing

realism, creativity, and usability through IPA-guided workflows. High-fidelity 3D models of artifacts and spaces are generated using photogrammetry, supported by the QooCam VR camera and Skybox VR app. Shooting parameters, including eye-level angles and 334 panoramic captures from the entrance, ensure user comfort and spatial accuracy.

Post-production integrates Photoshop for background correction, 3DS MAX for heritage modeling, and E Panorama for scene synthesis. Challenges such as aliasing artifacts and frame rate instability during rendering necessitate optimized balancing of visual fidelity and performance. Interactive elements, including click-and-touch controllers, enhance artifact engagement, while the Jian-E platform enables dual-mode access: VR side-by-side and 360° panoramas.

Despite advancements, reliance on HMDs for immersive experiences and hardware-dependent rendering constraints persist. NMK's methodology highlights a user-centric fusion of technological rigor and accessibility, advancing virtual cultural heritage preservation while underscoring the need for adaptive solutions to technical limitations.

4.2 3D Digital Archive Integration

The National Central Museum (NCM) addresses limitations of conventional online exhibitions by deploying interactive 3D archival content, transcending physical boundaries to enhance visitor immersion. This innovative framework integrates VR roaming modules into the museum's digital platform, enabling navigation via 3D maps embedded with interactive icons Figure 5. Users engage dynamically with artifacts through rotatable and separable 3D models, supplemented by contextual text, video overlays, and multimedia annotations. Such features not only enrich experiential learning but also deepen human-artifact interactions, amplifying the museum's communicative efficacy.

This paradigm shift aligns with technological advancements, necessitating modernization of archival practices. Traditional preservation methods reliant on 2D imagery and physical documentation are increasingly supplanted by digital solutions. Leveraging pre-collection digitization, 3D modeling, and image processing, the museum constructs robust 3D digital archives that address contemporary demands. Key advantages include:

By synthesizing VR interactivity with archival digitization, the NCM fosters immersive, user-centric experiences while safeguarding cultural assets. This approach underscores the critical role of 3D technologies in redefining museum engagement, balancing preservation imperatives with innovative accessibility. Future efforts must prioritize interoperability and adaptive interfaces to further harmonize technological rigor with educational and cultural objectives.

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