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Emotional Presence, User Engagement, and Cultural Memory in Virtual Reconstructions of Ukrainian Heritage: A Mixed-Methods Study

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ABSTRACT

Objective: This study examined emotional presence, perceived authenticity, user engagement, and interpretations of cultural memory during virtual reality (VR) encounters with Ukrainian heritage..

Methods and Materials: An observational mixed-methods study involved 140 adults aged 18–45 in Lviv and Kyiv, Ukraine, during 2024–2025. Participants explored virtual reconstructions of St. Sophia Cathedral, Khotyn Fortress, and St. George's Church in Drohobych. Data were collected using an 18-item questionnaire, interaction logs, spatial activity maps, and semi-structured interviews with 15 participants. Descriptive statistics, Pearson correlations, ANOVA, multiple regression, and thematic analysis were employed.

Findings: Mean scores were 4.01 ± 0.68 for emotional presence, 3.87 ± 0.72 for perceived authenticity, 3.74 ± 0.75 for educational value, and 4.09 ± 0.63 for engagement. Emotional presence correlated positively with engagement ($r = .72$, $p < .01$), authenticity ($r = .58$, $p < .01$), and interaction time ($r = .52$, $p < .01$). Reported regression results identified emotional presence as the strongest engagement correlate ($\beta = .481$, $p < .001$), although inferential inconsistencies require verification. Interviews identified emotional presence (13/15), authenticity and trust (11/15), and cultural memory (10/15) as recurring themes. Spatial interaction patterns varied descriptively across monuments.

Conclusion: VR heritage encounters elicited favorable experiential ratings and narratives of cultural continuity. However, causal improvements in memory, cultural identity, or psychological recovery were not established.

Keywords: Virtual Reality, Ukrainian Heritage, Emotional Presence, User Engagement, Cultural Memory, Mixed-Methods Research.

Introduction

Virtual reality (VR) offers ways to document, present, and encounter cultural heritage beyond the physical museum. Three-dimensional models and immersive tours can provide access to architecture and collections that are geographically distant or difficult to visit. Research on virtual heritage has examined the opportunities and limitations of these formats, including their educational value, accessibility, and design requirements (Buragohain et al., 2024; Cecotti, 2022). Their importance also concerns how people experience cultural places and attach meaning to them.

Digital preservation, three-dimensional reconstruction, and a VR museum describe related but distinct practices. Digital preservation concerns the documentation and long-term maintenance of digital heritage resources. Reconstruction creates a representation of a particular object or environment, while a VR museum provides an interactive setting for encountering digital exhibits. The metaverse refers to a broader ecosystem of connected virtual spaces and social practices. The present study concerns VR encounters with reconstructed heritage; it does not evaluate a fully interconnected metaverse platform.

The war against Ukraine has made the protection and interpretation of cultural heritage especially urgent. Virtual representations can preserve documentary information and provide symbolic access to places associated with shared history. Work on Ukrainian virtual museums shows how digital infrastructures participate in the mediation and remembering of war (Graf, 2024). Research on virtual technologies in damaged tourism areas likewise considers their potential role in representation and recovery (Petrova et al., 2025). A digital encounter, however, should not be assumed to replace a physical place or demonstrate psychological recovery.

Collective memory is sustained through social frameworks, shared symbols, and practices of remembering (Halbwachs, 1992). Narrative VR may offer particular affordances for presenting and sharing memories (Gruenewald & Chen, 2025), but immediate feelings of involvement are different from durable memory or a change in cultural identity. This distinction matters when virtual heritage is discussed in relation to cultural loss. The present study examined emotional presence, perceived authenticity, educational value, engagement, and behavioral interaction during encounters with three Ukrainian monuments. Interviews explored how participants interpreted those experiences in relation to cultural continuity and threatened heritage.

Presence Embodiment and Cultural Memory

Presence refers to the subjective experience of encountering a mediated environment as if one were there (Lombard & Ditton, 1997). Immersive hardware and a sense of presence should be distinguished: a technically immersive display does not guarantee a particular psychological response. Place illusion and the perceived plausibility of events provide a theoretical account of realistic behavior in immersive environments (Slater, 2009). Sensory features can contribute to emotional responses, although their effects depend on the experience being studied (Alshaer, 2025).

Embodied approaches emphasize the relationship between cognition, bodily activity, and the environment (Johnson & Lakoff, 2002). In a virtual heritage setting, movement, changing perspective, and manipulation may affect how a user encounters scale and spatial relations. These possibilities motivate investigation rather than establish that VR necessarily improves memory. A review of immersive procedural training illustrates the need to distinguish experiential engagement from demonstrated learning outcomes (Jongbloed et al., 2024).

Cultural meanings also shape how bodily and emotional experiences are interpreted (Seyed Alitabar, 2025). The same digital architecture may be understood differently by users with different familiarity, professional backgrounds, or personal connections to heritage. Research has examined embodied cognition and flow in relation to rural cultural identity in VR (Lin et al., 2024), and affective learning in commemorative history teaching (Mulders et al., 2026). These perspectives support examining presence,

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authenticity, and cultural connection together while keeping their measurement boundaries clear.

The study therefore addressed three questions: how users evaluated their encounters with the reconstructions; how presence, authenticity, and behavioral measures were associated with engagement; and how interview accounts related the experience to cultural memory and loss. Because the design lacked a control condition, objective memory testing, and longitudinal identity measures, it could not determine whether VR increased engagement relative to another format or strengthened collective memory over time.

Methods and Materials

Design and Sites

An observational mixed-methods study combined questionnaire and behavioral summaries with qualitative interviews. The study took place in Lviv and Kyiv, Ukraine, during 2024–2025. The three heritage objects were St. Sophia Cathedral in Kyiv, Khotyn Fortress, and the Church of St. George in Drohobych. They represented monumental sacred architecture, defensive architecture, and wooden sacred architecture, respectively. Selection reflected their cultural significance, contrasting spatial characteristics, and the availability of digital materials.

Participants and Recruitment

The sample comprised 140 adults aged 18–45 recruited purposively through university networks, museum institutions, creative-industry communities, and IT organizations. Participants permanently resided in Ukraine and identified with Ukrainian cultural tradition. Recruitment sought variation in digital competence and previous VR experience. The sample included students, museum workers, artists or creative-industry professionals, and IT developers. Demographic and experience categories are presented in Table 1.

Table 1

Participant characteristics

Characteristics	Category	n	%
Gender	Women	78	55.7
	Men	60	42.9
	Other / not specified	2	1.4
Age	18–24	46	32.9
	25–34	58	41.4
	35–45	36	25.7
Professional background	Students	52	37.1
	Museum workers	34	24.3
	Artists / creative industries	28	20.0
	IT developers	26	18.6
Level of digital competence	High	54	38.6
	Average	63	45.0
	Basic	23	16.4
Previous VR experience	Regular experience	39	27.9
	Limited experience	61	43.6
	None	40	28.6
Personal connection to Ukrainian heritage	Strong connection	48	34.3
	Moderate connection	61	43.6
	No direct connection	31	22.1

Note. N = 140. VR = virtual reality. Digital competence and personal connection were self-reported. Percentages may not total 100 because of rounding.

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Before the session, participants provided demographic information, previous VR experience, self-reported digital competence, familiarity with the monuments, and personal connection to Ukrainian heritage. A purposively selected interview subsample of 15 participants represented different professional backgrounds and levels of digital competence and VR experience. The recruitment denominator, refusals, and a prospective sample-size calculation were not specified.

Virtual Environments and Procedure

Sessions used a Meta Quest 3 headset. Elements of the interactive environments were developed using Unity and Unreal Engine 5, with Blender used for model and mesh optimization. Reconstruction materials included photogrammetry, photographs, videos, openly available resources, and the authors' materials. All participants encountered all three monuments, and presentation order was counterbalanced to reduce order effects. The exact sequence allocation and how the public tour assets were incorporated into the study environments were not detailed.

The illustrated digital resources included the Aero3D tour of St. Sophia Cathedral, the Droneservice model of Khotyn Fortress, and the Skiron tour of St. George's Church hosted on Matterport (Aero3D, n.d.; Droneservice, 2019; Skiron, 2022). The cathedral interface provides information points, the fortress model presents the defensive complex and labels, and the church tour emphasizes its painted interior. Figure 1, Figure 2, and Figure 3 show the corresponding interfaces. The screenshots illustrate digital representations rather than measurements of users' gaze or physiological responses.

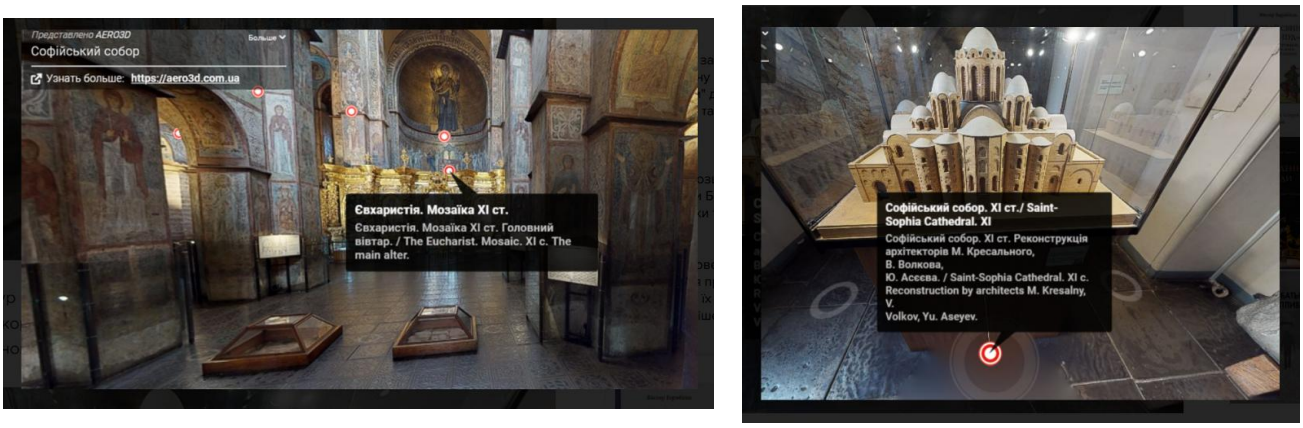

Figure 1

St. Sophia Cathedral virtual tour. Left: interior mosaics and information points. Right: a model of the cathedral displayed within the tour (Aero3D, n.d.).

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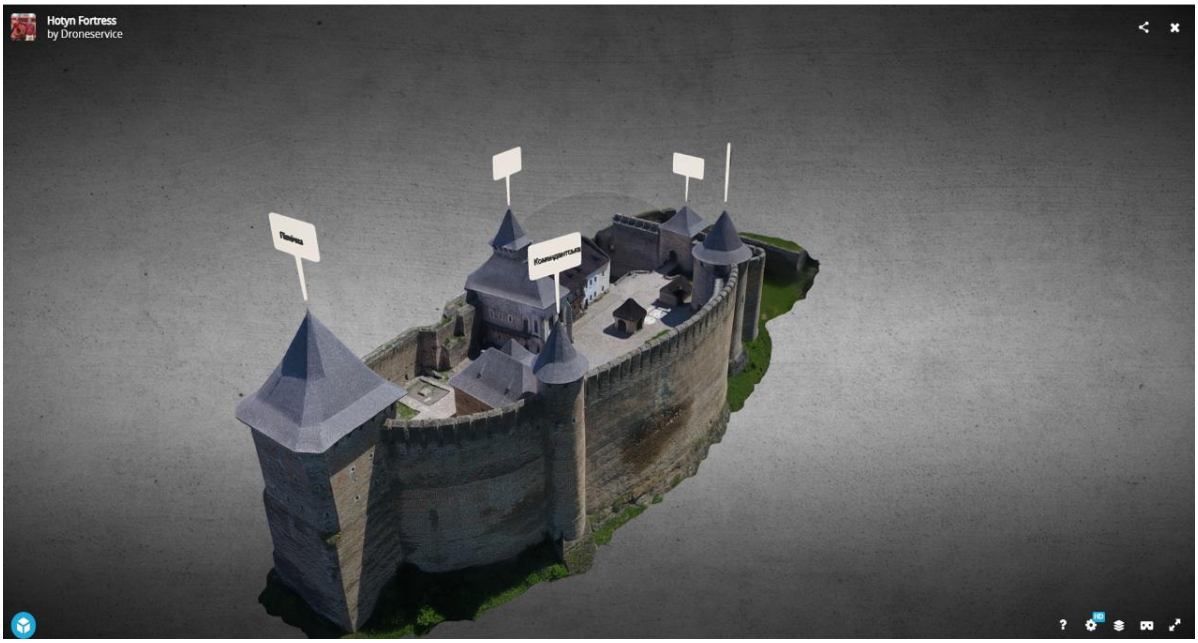

Figure 2

Khotyn Fortress digital model with labeled structures (Droneservice, 2019).

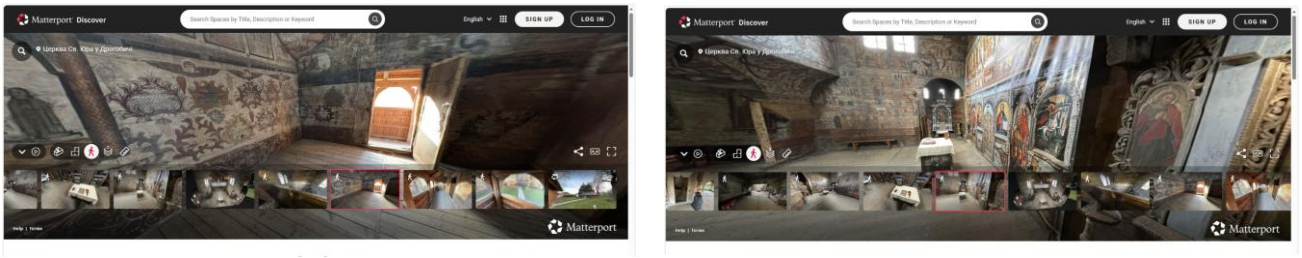

Figure 3

Two views of the painted interior of the Church of St. George in Drohobych in the Matterport virtual tour (Skiron, 2022).

Questionnaire and Behavioral Measures

The pre-session questionnaire described participant characteristics and prior attitudes toward digital heritage. The post-session questionnaire contained 18 statements covering emotional presence (five items), perceived authenticity (four), educational value (four), and overall engagement (five). Responses used a five-point scale from 1 (strongly disagree) to 5 (strongly agree). The constructs and example items are shown in Table 2. Cronbach's α ranged from .84 to .89. These were study-specific measures informed by presence and museum-experience research; a complete item set, adaptation trail, and factor-analytic evidence of construct separation were not provided.

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Table 2

Questionnaire constructs and measurement properties

Construct	Items	Example item	Scale	α
Emotional presence	5	"I felt as if I was actually present in the historical environment"	1–5 Likert	0.87
Perceived authenticity	4	"The reconstruction seemed historically authentic"	1–5	0.84
Educational value	4	"The experience improved my understanding of Ukrainian cultural heritage"	1–5	0.85
Overall engagement	5	"I was actively involved throughout the experience"	1–5	0.89

Note. N = 140. The study-specific questionnaire comprised 18 items. Responses ranged from 1 (strongly disagree) to 5 (strongly agree). α = Cronbach's alpha. Internal consistency does not establish discriminant validity or equivalence to a validated presence instrument.

Behavioral observations included screen recordings, movement trajectories, duration of interaction, points of interaction, and the number of manipulations such as moving, scaling, or selecting information layers. Reported interaction durations ranged from 6 to 18 minutes per object. How the repeated exposures were aggregated into the participant-level questionnaire and behavioral variables used in the correlation and regression analyses was not specified.

Spatial activity maps were generated from Unity movement logs using user coordinates, controller directions, and time spent near exhibits. Peak activity zones represented areas with greater dwell time or interaction activity. The study did not record eye movements or physiological gaze fixations. Accordingly, these maps describe spatial activity and cannot be interpreted as direct measures of visual attention. Zone boundaries, normalization, and the denominator for the reported time percentages were not fully specified.

Interviews and Integration

Post-session semi-structured interviews with 15 participants explored presence, authenticity, navigation and usability, information overload, and the perceived role of VR in memory and cultural continuity. Focus-group discussion was also described, but its size and analytic contribution were not separately specified. Transcripts were analyzed using thematic content analysis and a semiotic interpretation of narratives about presence, memory, and reconstruction. Inductive codes were combined with theoretically informed categories. Two researchers contributed to coding and resolved differences through discussion; the extent of independent double coding and an agreement statistic were not specified. Quotations illustrate interpretations rather than establish their prevalence in the full sample.

Quantitative summaries and qualitative themes were considered together to identify convergence and differences between measured engagement and participants' accounts. Interview references to loss or symbolic recovery were treated as interpretations of experience. Clinical symptoms, therapeutic benefit, and long-term changes in memory or identity were not assessed.

Quantitative Analysis

Descriptive statistics summarized questionnaire scores and behavior. Pearson correlations examined associations among interaction time, interaction count, emotional presence, authenticity, educational value, and engagement. Separate one-way ANOVAs compared emotional presence across professional groups, digital-competence levels, and previous VR-experience categories. These were between-person comparisons; the monument activity indicators were repeated observations for the same participants and are reported descriptively. No repeated-measures inferential comparison between monuments was supplied.

A multiple linear regression modeled overall engagement using emotional presence, perceived authenticity, interaction time, personal heritage connection, previous VR experience, and digital competence. The ordinal predictors were coded 0–2: none, moderate, and strong heritage connection; no, limited, and regular VR experience; and basic, average, and high digital competence. Treating these as ordinal numeric predictors assumes equal spacing and a

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linear trend. The model used N = 140 and six predictors. Residual plots, influential observations, and multicollinearity were described as checked, but numerical diagnostics and the analysis output were not available for verification. Reported inferential statistics are retained with specific consistency limitations below.

Ethical Considerations

Participation was voluntary. Participants received information about the VR session and provided informed consent for anonymized questionnaires and behavioral tracking. Interview transcripts had personal information removed. The Academic Council of the Kharkiv State Academy of Design and Arts approved the study (Meeting No. 7, October 1, 2024). The study followed institutional standards of voluntary participation, confidentiality, and data protection.

Findings and Results

Questionnaire and Interaction Summaries

Post-session means exceeded the midpoint of the 1–5 scale for emotional presence (M = 4.01, SD = 0.68), perceived authenticity (M = 3.87, SD = 0.72), educational value (M = 3.74, SD = 0.75), and overall engagement (M = 4.09, SD = 0.63). Reported interaction time averaged 11.4 minutes (SD = 3.6), and the mean interaction count was 24.7 (SD = 8.9; Table 3). These descriptive ratings characterize the sampled encounters; no pre–post change or advantage over a comparison format was established.

Table 3

Descriptive statistics for behavioral and questionnaire variables

Variable	Scale	M	SD
Interaction time (minutes)	—	11.4	3.6
Number of interactions	—	24.7	8.9
Emotional presence	1–5	4.01	0.68
Perceived authenticity	1–5	3.87	0.72
Educational value	1–5	3.74	0.75
Overall engagement	1–5	4.09	0.63

Note. N = 140 as reported. M = mean; SD = standard deviation. Questionnaire ranges were 1–5. The method of aggregation across three monument exposures was not specified.

The activity-zone summaries differed descriptively between monuments. For St. Sophia Cathedral, mean peak-zone dwell time was 96.4 seconds, with 3.8 returns and 7.4 interactive actions. Corresponding values were 82.7 seconds, 3.1 returns, and 6.1 actions for Khotyn Fortress, and 71.3 seconds, 2.6 returns, and 5.4 actions for the church in Drohobych (Table 4). The areas were characterized as central and sacred elements, defensive and panoramic structures, and interior or structural details, respectively. Without a repeated-measures test or a fully defined normalization procedure, these differences do not establish an effect of architectural type on attention.

Table 4

Descriptive activity indicators for the three monuments

Monument	Dwell time s	Returns	Actions	Time %	Activity zone
St. Sophia Cathedral	96.4 (28.1)	3.8 (1.2)	7.4 (2.6)	34.7	Central space, sacred and symbolic elements
Khotyn Fortress	82.7 (24.9)	3.1 (1.0)	6.1 (2.3)	29.2	Defensive structures, panoramic points
St. George's Church	71.3 (22.5)	2.6 (0.9)	5.4 (2.1)	26.8	Interior details, structural elements

Note. N = 140 participants encountered all three monuments. Dwell time, returns, and actions are M (SD). The reported time-share denominator and peak-zone boundaries were not fully specified. Indicators derive from spatial and controller activity, not eye tracking. No repeated-measures significance test was supplied.

Associations and Group Comparisons

The correlation matrix showed positive associations among the six behavioral and questionnaire variables (Table 5). Emotional presence and engagement had the largest reported association (r = .72). Presence also correlated with authenticity (r = .58), interaction time (r = .52), and educational value (r = .49). Engagement correlated with interaction time (r = .47) and interaction count (r = .42). All

reported coefficients were marked significant at $p < .01$. These associations do not determine direction of influence, and overlapping self-report content may contribute to correlations between constructs.

Table 5

Correlations among behavioral and questionnaire variables

Variable	1	2	3	4	5	6
1. Interaction time (minutes)	—					
2. Number of interactions	0.48**	—				
3. Emotional presence	0.52**	0.46**	—			
4. Perceived authenticity	0.44**	0.39**	0.58**	—		
5. Educational value	0.36**	0.31**	0.49**	0.61**	—	
6. Overall engagement	0.47**	0.42**	0.72**	0.55**	0.50**	—

Note. N = 140 as reported. Entries are Pearson correlations. ** $p < .01$. Variables 1–6 correspond to the numbered row labels. The analysis unit across repeated monument exposures requires clarification.

Reported professional-group means were highest among museum workers (4.31) and lowest among IT developers (3.71). The supplied omnibus test was $F(3, 136) = 6.84$, $p < .001$, $\eta^2 = .131$. For previous VR experience, the means were 4.21 for none, 4.02 for limited, and 3.79 for regular experience, with reported $F(2, 137) = 4.71$, $p = .011$, $\eta^2 = .064$. Digital-competence comparisons were reported as $F(2, 137) = 1.92$, $p = .150$, $\eta^2 = .027$ (Table 6). These F statistics are not reproducible from the displayed group sizes, means, and SDs beyond the discrepancy expected from rounding. No verified post hoc contrasts were available, so specific significant pairwise differences cannot be claimed.

Table 6

Reported emotional presence comparisons across participant groups

Group	n	M	SD	Reported F	Reported p	Reported η^2
Professional background				6.84	< .001	.131
Students	52	3.89	0.71			
Museum workers	34	4.31	0.59			
Artists / creative industries	28	4.18	0.63			
IT developers	26	3.71	0.74			
Digital competence level				1.92	.150	.027
Basic	23	3.94	0.70			
Average	63	4.03	0.66			
High	54	4.07	0.69			
Previous VR experience				4.71	.011	.064
None	40	4.21	0.64			
Limited	61	4.02	0.67			
Regular	39	3.79	0.72			

Note. N = 140. F, p, and η^2 are retained as reported. Degrees of freedom were (3, 136) for professional background and (2, 137) for the other comparisons. The F values cannot be reproduced from the displayed n, M, and SD values within rounding precision. The digital-competence group means also do not reproduce the overall mean in Table 3. Verify the original ANOVA output; no confirmed post hoc comparisons were available.

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Regression Model

The regression was reported as $F(6, 133) = 24.37$, $p < .001$, $R^2 = .524$, adjusted $R^2 = .503$. The largest reported standardized coefficient was for emotional presence ($\beta = .481$, $p < .001$), followed by authenticity ($\beta = .263$, $p < .001$), heritage connection ($\beta = .178$, $p = .014$), and interaction time ($\beta = .142$, $p = .031$). Previous VR experience and digital competence had reported p values above .05. The coefficients are shown in Table 7.

Table 7

Reported multiple regression predicting overall engagement

Predictor	B	SE	β	t	p
Emotional presence	0.447	0.061	.481	7.33	< .001
Perceived authenticity	0.231	0.058	.263	3.98	< .001
Personal connection to heritage	0.143	0.057	.178	2.51	.014
Interaction time (min)	0.025	0.011	.142	2.17	.031
Previous VR experience	0.049	0.041	.082	1.20	.233
Digital competence level	0.031	0.043	.049	0.72	.473
(Constant)	1.284	0.312		4.12	< .001

Note. N = 140. B = unstandardized coefficient; SE = standard error; β = standardized coefficient. Reported $R^2 = .524$; adjusted $R^2 = .503$; $F(6, 133) = 24.37$, $p < .001$. Ordinal predictors were coded 0–2. The intercept and coefficients do not reproduce the outcome mean from the stated predictor summaries; some ordinal-predictor β values also require verification. Coefficients remain provisional pending verified analysis output.

The intercept and coefficients do not reproduce the reported mean engagement when combined with the stated predictor means and 0–2 codings. Some standardized coefficients for the ordinal predictors are also inconsistent with the supplied distributions and outcome SD. The model summary and coefficients therefore require verification against the original analysis before being used for prediction or substantive ranking of predictors. Presence was conceptually defined as a subjective state of being there, while engagement concerned broader behavioral and cognitive involvement; discriminant validity between the measures was not established.

Interview Themes

Three interconnected themes were described in the interviews. Emotional presence occurred in 13 of 15 accounts, authenticity and trust in 11, and the role of VR in collective digital memory in 10. These counts refer to overlapping themes within the interview subsample. They do not quantify psychological effects or represent population prevalence.

Participants described presence in experiential terms. One stated, "I forgot that I was sitting on a chair — it seemed to me that I was actually standing inside the cathedral." Another described the encounter as "it was not about contemplating history, but about being inside it." These accounts convey subjective involvement; no neural or physiological mechanism was measured.

Authenticity involved visual plausibility and narrative coherence. A museum worker commented, "It felt credible, in that it had its own internal logic." Another participant emphasized the importance of interpretation: "Without explanation, you admire it as a beautiful image—but you don't understand what you're facing." These accounts distinguish perceived credibility from independently demonstrated historical accuracy.

The third theme connected threatened heritage with symbolic continuity. One participant described the experience as "returning to something that might not exist tomorrow." Another said, "When I was inside St. Sophia Cathedral in Kyiv, I thought, this is how we keep it alive, even if it burns down." These quotations concern anticipation of loss and preservation of meaning. They do not establish that the illustrated monuments had been destroyed or that VR produced recovery from grief or trauma.

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Discussion and Conclusion

Presence Authenticity and Engagement

The study combined favorable post-session ratings, positive associations among experiential variables, and interview accounts of involvement in Ukrainian heritage. Emotional presence was strongly correlated with engagement, and authenticity was associated with both. These patterns are compatible with presence theory and with accounts of narrative VR as a medium for memory-related experience (Gruenewald & Chen, 2025; Lombard & Ditton, 1997; Slater, 2009). The statistical inconsistencies in the group comparisons and regression nevertheless prevent treating the reported model as a verified explanation of engagement.

The results do not demonstrate that immersion itself caused stronger memory or identity. The questionnaire assessed perceived educational value rather than objectively tested learning, and personal connection to heritage was a background rating rather than a validated change measure of cultural identity. Research on embodied cognition and cultural identity provides relevant hypotheses for future work (Johnson & Lakoff, 2002; Lin et al., 2024). Studies of immersive training and commemorative history further indicate why assessment of learning and affect should be explicit and distinct (Jongbloed et al., 2024; Mulders et al., 2026).

The descriptive professional and experience-group patterns may reflect prior knowledge, expectations, cultural familiarity, or novelty. Those possibilities were not separately tested. In particular, higher mean presence among inexperienced users cannot establish that lack of VR experience improves immersion. Future analyses should verify the group summaries, specify planned comparisons, and account for potential confounding before interpreting professional or experience differences.

Activity Patterns and Museum Design

The monument summaries suggest different patterns of spatial activity around sacred elements, defensive structures, and painted interiors. They can inform questions about navigation and interpretive design, but they are not eye-tracking evidence. Longer dwell time can reflect interest, difficulty, uncertainty, or navigation constraints; it cannot by itself demonstrate deeper psychological contact. Comparable zone definitions, normalization by exposure time, and within-person analyses are needed before attributing differences to architecture.

Interview comments about missing explanation support attention to interpretive context. Photorealism and perceived authenticity should be complemented by clear provenance, historical interpretation, and an indication of reconstructed or uncertain elements. Ethical digital-heritage scholarship highlights the contested meanings and responsibilities involved in representation (Rouhani, 2023). Design should allow users to engage with context and uncertainty rather than rely on visual persuasion alone. This is consistent with reviews of cultural heritage applications and the challenges of metaverse-based preservation (Buragohain et al., 2024; Cecotti, 2022).

Digital Memory Cultural Loss and Interpretation

Interview accounts connected virtual access with a wish to sustain cultural meaning under threat. Collective-memory theory provides a framework for interpreting that connection (Halbwachs, 1992), while research on Ukrainian virtual museums examines the production of mediated wartime memory (Graf, 2024). Work on virtual heritage intimacy and avatar-based memorials offers further comparative perspectives on emotional and memorial practices in digital settings (Fu et al., 2025; Zhang, 2026). These studies concern different media and populations and do not validate a therapeutic effect in the present sample.

Cultural beliefs and narratives may influence how people interpret bodily experience and emotional meaning (Seyed Alitabar, 2025). In this study, interviews suggest that the digital environment could provide a symbolic setting for continuity and anticipated loss. That interpretation remains distinct from an observed strengthening of collective identity, which would require validated measures, follow-up, and evidence beyond immediate accounts.

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The findings should not be presented as trauma treatment or grief therapy. Any future clinical adaptation would require a separate rationale, evidence of benefit and harms, and attention to cultural context and human support. Such requirements are consistent with concerns about embodied, culturally situated, and relational experience in digital mental health (Seyed Alitabar, 2026). The current contribution is to cultural experience and museum interpretation, not demonstrated clinical efficacy.

Limitations and Future Research

Purposive recruitment and the concentration of participants in educational, cultural, creative, and technical networks limit generalizability. All participants resided in Ukraine and identified with its cultural tradition; results cannot establish how displaced populations, older adults, international visitors, or people with different heritage relationships would respond. The small qualitative subsample captured a range of accounts without establishing representativeness or saturation.

The study-specific questionnaire had satisfactory reported internal consistency, but full item documentation and evidence of construct separation were unavailable. Self-report overlap, expectations, and novelty may contribute to the observed associations. Without a control group, objective memory tests, or longitudinal follow-up, the design cannot establish improvement in learning, preservation of memory, or change in cultural identity. No eye tracking, autonomic recordings, or other physiological outcomes were collected.

The inferential statistics require verification because the displayed ANOVA summaries and regression coefficients are not internally reproducible. Further uncertainty concerns aggregation across three exposures, ordinal predictor coding, the definition of peak activity zones, and the denominator of the time-share measure. These limitations affect interpretation and should be resolved using the original codebook, participant-level data, and analysis output.

Future studies should document the digital assets and their provenance, use validated and clearly differentiated psychological measures, and predefine exposure times and analytic units. Repeated-measures models can compare monuments while accounting for the same participants' multiple encounters. Controlled and longitudinal designs should test knowledge, memory persistence, and cultural-identity outcomes separately. Cross-cultural work and community participation would also help assess whose narratives are represented and how uncertainty or loss is communicated.

Conclusion

In a purposive sample of 140 Ukrainian adults, VR encounters with three heritage sites received favorable ratings for presence, authenticity, educational value, and engagement. Behavioral summaries described spatial activity, and interviews linked the experience to perceived credibility and symbolic cultural continuity. Presence and engagement were positively associated, but inconsistencies in the ANOVA and regression reporting require verification. The findings support further investigation of virtual heritage as an experiential and interpretive medium; they do not establish causal improvements in memory, cultural identity, or psychological recovery.

Declaration of Interest

The authors declare no conflicts of interest.

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Author Contributions

All authors contributed equally to this study.

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