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Hybrid Reality and Mixed Reality experiences in Italian Cultural Heritage Museums: Are they so far away?

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Abstract

This research aims to shed light on the role of the hybrid reality (HR) in museums and other cultural heritage organisations as alternative technologies to mixed reality (MR). It adopts Trunfio and Campana's (2020) visitors' experience model for mixed reality in the museum to investigate and compare how MR and HR functional elements impact visitors' experience and post-experience behaviours in cultural heritage museums. The empirical analysis interests two museums of the Italian cultural heritage in which are installed two innovative and different projects of heritage valorisation. Findings identify convergences and divergences between MR and HR adoption in cultural heritage museums, showing how traditional experiences under MR and HR conditions and 4.0 experience under HR conditions influence visitors' post-experience behaviours. Some theoretical and managerial questions draw future research, considering the differences of visitors' perception to evaluate HR and MR usability in both museums, the role of HR to create immersive but not memorable museum experience, and how MR 4.0 experience does not influence visitors' post-experiences.

Keywords: hybrid reality; mixed reality; cultural heritage museum.

1. Introduction

Immersive technologies – such as *augmented reality* (AR), *virtual reality* (VR), and *mixed reality* (MR) – in tourism and cultural heritage represent a consolidated topic for academics, managers, and policymakers to reframe physical-virtual borders of the traditional business models, visitors' experience, and post-experiences behaviours (Buhalis *et al.*, 2019; Loureiro *et al.*, 2020; Yung and Khoo-Lattimore, 2019).

Hybrid reality (HR) emerges as an alternative reality to AR, VR, and MR with similar audio-visual technical qualities (Banerjee *et al.*, 2020; Hanula *et al.*, 2019), experimenting with innovative exhibition spaces without the use of complex technological expertise or expensive hardware and software device (NEMO, 2020). HR attributes to physical heritage exhibition the role of interactive interfaces, introducing new forms of human-to-technology interaction with

the heritage and enhancing its value combining heritage valorisation and educational experience with multi-emotional and multi-sensorial immersive elements to identify advanced experiences based on edutainment, gamification, or enjoyment (Bec *et al.*, 2019; Bekele *et al.*, 2018; Little *et al.*, 2020; Schaper *et al.*, 2018; Serravalle *et al.*, 2019).

HR is mainly conceptual in literature, and its application remains an under-investigated topic in the cultural heritage domain (Anderson *et al.*, 2020; Banerjee *et al.*, 2020; Hanula *et al.*, 2019; NEMO, 2020). However, how HR impacts cultural heritage museums and how it enhances visitors' experience and how it influences post-experience represent emerging questions.

This research aims to shed light on the disruptive power of HR and MR, comparing the technological/functional elements, the experiential elements, and the post-experience elements in the museum.

Building on the consolidated literature of AR, VR, and MR, this research adopts Trunfio and Campana's (2020) visitors' experience model for mixed reality in the museum as a model composed of six technological and functional dimensions and one experiential dimension (measured by twenty-three items) to investigate the impact of HR technological and functional elements on visitors' experience and post-experience.

The empirical analysis interests two Italian cultural heritage museums in which installed two innovative and different projects of heritage valorisation. The first museum concerned an MR project, a perfect combination of AR and VR to enhance heritage valorisation by visualising a set of learning, entertainment, and emotional contents. The second museum identified an HR project resulting from an innovative strategy of heritage communication, interaction, and engagement through diverse multimedia realities, such as interactive sliders, serious gaming stations, screen displays, and cards containing NFC tags.

Findings and conclusions draw preliminary avenues of research to deepen the role of HR in the cultural heritage museum and identify their alternative, disruptive power to the MR impact on visitors' experience and post-experience.

2. Theoretical background

2.1. Mixed reality in cultural heritage

MR is an innovative generator system of digital contents in which AR and VR technicalities are perfect combined (Bekele *et al.*, 2018; Flavián *et al.*, 2019; Rokhsaritalemi *et al.*, 2020; Trunfio *et al.*, 2020). It integrates the physical heritage exhibition with digital representations of historical or imaginary events to become smart access to alternative worlds based on vivid and tangible virtual information that enhance traditional processes of knowledge acquisition and preserve and valorise the heritage value (Bae *et al.*, 2020; Bec *et al.*, 2019; Fenu and Pittarello, 2018; Little *et al.*, 2020; Schaper *et al.*, 2018; Serravalle *et al.*, 2019; tom Dieck and Jung, 2017; Trunfio *et al.*, 2020).

A visitors' experience model for mixed reality in the museum (Trunfio and Campana, 2020) integrated the academic debate on AR and VR functional elements to explore the MR impact on the diverse museum organisational aspects (six dimensions, measured by eighteen items) and immersive cultural heritage experience (one dimension, measured by five items). Additionally, Trunfio et al.'s (2020) work validated Trunfio and Campana's (2020) model, measuring two immersive museum experiences under MR conditions, such as traditional (heritage valorisation and education) and 4.0 experience (entertainment, socialisation, and

escape).

2.2. Hybrid reality in cultural heritage

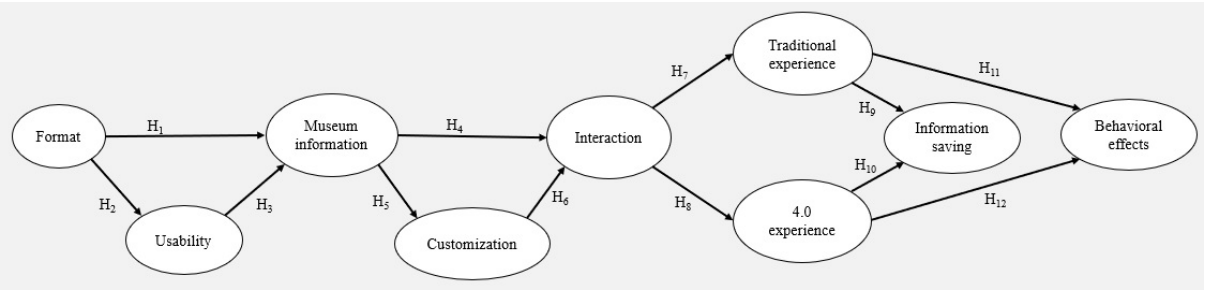
HR is a visually and immersive alternative virtual environment, e.g. *hyberspace*, covering an intermediate position between AR and VR along the reality-virtuality continuum (Anderson *et al.*, 2020; Banerjee *et al.*, 2020). It synchronises a wide set of display systems with 2D-3D high resolution and other non-immersive technological components to launch 3D spatial representations on top of the physical space with stereo audios and sounds on walls and floors to create a wrap viewing area of invisible projections (Anderson *et al.*, 2020; Banerjee *et al.*, 2020; Hanula *et al.*, 2019; Ishizawa *et al.*, 2018; Ponto *et al.*, 2014).

Exploiting AR and VR audio-visual technical qualities (Anderson *et al.*, 2020; Banerjee *et al.*, 2020), HR enriches the museum exhibition spaces with educational content and adds more value to the traditional processes of heritage storytelling with spatial visualisation, immersion, and interaction (Bekele and Champion, 2019; Little *et al.*, 2020; Rahaman *et al.*, 2019; Schaper *et al.*, 2018). HR can play a significant role in the processes of heritage preservation and valorisation (Bec *et al.*, 2019; Little *et al.*, 2020), involving visitors to perceive intuitive forms of museum information accessibility through the use of remotely virtual tours, serious games stations, and interactive sliders (Bekele and Champion, 2019; Schaper *et al.*, 2018).

2.3. Conceptual framework and hypothesis development

The research develops a conceptual framework in Figure 1 with nine constructs: six technological-functional dimensions (format, museum information, usability, interaction, customisation, and information saving) (Trunfio and Campana, 2020); two experiential dimensions (Trunfio *et al.*, 2020), traditional experience and 4.0 experience; and one behavioural effects dimension (Jung *et al.*, 2016), measured by three items (Chung *et al.*, 2015; Kim *et al.*, 2020; Wei *et al.*, 2019).

Figure 1. Conceptual framework.



The installation of the format multimedia characteristics, such as audios, images and videos, and touch accessible through mobile devices, drives museums to reimage the visualisation processes of heritage digital storytelling, increasing museum information and knowledge access(Trunfio *et al.*, 2020; Trunfio and Campana, 2020).

The multimedia visualisation of the museum information requires the adoption and use of smart

technology interfaces (Errichiello *et al.*, 2019; Javornik, 2016; Manis and Choi, 2019; tom Dieck and Jung, 2018; Trunfio *et al.*, 2020, 2021) that respect stringent functional requirements in terms of comfortable design, a clever alternative to traditional modalities of access information, and easy to use (Trunfio *et al.*, 2020; Trunfio and Campana, 2020).

Multimedia characteristics in the museum do not only improve the exhibition spaces but all contents visualised by the visitors during the visit in terms of information on the museum services, historical atmosphere, and connection between the museum theme and the other city attractions (Trunfio *et al.*, 2020; Trunfio and Campana, 2020).

H_1. Format has a positive effect on museum information.

H_2. Format has a positive effect on usability.

H_3. Usability has a positive effect on museum information.

Overlaying real exhibition contents with immersive virtual information, museums introduce unusual non-tangible interaction points between visitors and heritage that reshape physical environments and enhance the value of the cultural heritage exhibition (Bekele et al., 2018; Hudson et al., 2019; Trunfio et al., 2021), with three museum aspects, such as servicescape, multimedia elements, and other technologies (Trunfio *et al.*, 2020; Trunfio and Campana, 2020).

Visitors can set technological interfaces with smart filters to receive personalised information and multiple language capability (Trunfio and Campana, 2020), improving the heritage discovery following their interests and preferences (tom Dieck *et al.*, 2016; Trunfio *et al.*, 2020).

H_4. Museum information has a positive effect on interaction.

H_5. Museum information has a positive effect on customisation.

H_6. Customisation has a positive effect on interaction.

Immersive technologies reframe the museum's experiential value proposition in two unusual immersive experiences (Trunfio *et al.*, 2020), such as traditional experience (heritage valorisation and educational experience) and 4.0 experience (entertainment, socialisation, and escape experiences). Moreover, experiences with high levels of memorability stimulate visitors to save museum information on personal devices or museum platforms (Trunfio *et al.*, 2020; Trunfio and Campana, 2020), transforming them into digital memories (Hudson *et al.*, 2019; Serravalle *et al.*, 2019; tom Dieck *et al.*, 2016).

H_7. Interaction has a positive effect on the traditional experience.

H_8. Interaction has a positive effect on the 4.0 experience.

H_9. Traditional experience has a positive effect on information saving.

H_{10}. 4.0 experience has a positive effect on information saving.

According to the literature (Jung *et al.*, 2016; Kim *et al.*, 2020; Tussyadiah *et al.*, 2018), museum experiences satisfied under immersive technologies conditions can influence positive or negative future behaviours. The construct of behavioural effects measures how the immersive interfaces increase the visitors' use of digital technologies in other museums or

applications (Lee *et al.*, 2020; Chung *et al.*, 2015), enhance visitors' motivation to perceive the cultural heritage museum as unique (Kim *et al.*, 2020), and stimulate a new re-visit in the museum (Wei *et al.*, 2019).

H_{11}. Traditional experience has a positive effect on behavioural effects.

H_{12}. 4.0 experience has a positive effect on behavioural effects.

3. Methodology

The research used a quantitative survey methodology to test the same conceptual framework in two Italian cultural heritage museums interested in two different projects of heritage enhancement: an MR project in a Roman Museum and an HR project in a Matera Museum.

The measurement model identified a self-administered questionnaire with face-to-face interviews after the visit to the two Italian museums. It was composed of: six Trunfio and Campana's (2020) technological-functional constructs, measured by eighteen items; two experiential constructs (Trunfio *et al.*, 2020), traditional experience and 4.0 experience, measured by five items; and one behavioural effect construct, measured adapting three items from previous research (Chung *et al.*, 2015; Jung *et al.*, 2016; Kim *et al.*, 2020; Wei *et al.*, 2019). Multi-measurement items for each construct were reflective and used a seven-point Linkert-type scale (where 1 = strongly disagree and 7 = strongly agree).

The samples were collected during October 2019 – January 2020, acquiring 312 data from visitors experiencing the MR project and 302 data for the HR project.

The conceptual framework and related hypotheses were examined employing a covariance-based structural equation modelling (CB-SEM) analysis with a maximum-likelihood method (LM) using LISREL 8 software (Jöreskog and Sörbom, 1982).

4. Findings

Before the hypotheses test, the research evaluated the psychometric characteristics using the average variance extracted (AVE), composite reliability (CR), and Cronbach's alpha (α) in Table 1 (MacKenzie *et al.*, 2005). It verified the intra-correlations among all constructs in Tables 2 and 3 (Fornell and Larcker, 1981).

Table 1. CFA models.

Constructs	**MR project**			**HR project**		
	AVE	**CR**	**α**	**AVE**	**CR**	**α**
Format	.66	.88	.89	.70	.90	.84
Museum information	.57	.84	.83	.67	.89	.88
Usability	.81	.93	.91	.73	.89	.88
Interaction	.69	.87	.87	.84	.94	.93
Customization	.94	.97	.96	.66	.79	.76
Traditional experience	.64	.78	.76	.87	.93	.93

4.0 experience	.68	.86	.85	.86	.95	.94
Information Saving	.84	.91	.92	.93	.96	.96
Behavioral effects	.62	.83	.81	.60	.81	.80

Table 2. Correlation and discriminant validity of the MR museum.

	Constructs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	Format	**.812**								
2	Museum information	.188	**.754**							
3	Customization	.208	.121	**.969**						
4	Usability	.071	.380	.046	**.900**					
5	Interaction	.027	.145	.017	.187	**.830**				
6	Information saving	.026	.140	.017	.368	.069	**.916**			
7	Traditional experience	.023	.124	.015	.327	.061	.120	**.800**		
8	4.0 experience	.008	.045	.005	.118	.022	.187	.195	**.824**	
9	Behavioral effects	.009	.048	.006	.126	.024	.265	.133	.067	**.787**

Table 3. Correlation and discriminant validity of the HR museum.

	Constructs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	Format	**.836**								
2	Museum information	.156	**.818**							
3	Customization	.179	.168	**.812**						
4	Usability	.046	.298	.050	**.854**					
5	Interaction	.053	.344	.058	.307	**.916**				
6	Information saving	.013	.082	.014	.275	.084	**.964**			
7	Traditional experience	.008	.053	.009	.177	.055	.049	**.932**		
8	4.0 experience	-.001	-.006	-.001	-.021	-.006	-.071	-.011	**.927**	
9	Behavioral effects	.004	.028	.005	.094	.029	.189	.265	-.015	**.774**

Global fit provide a good evaluation for both models: MR project with χ^2=645.94, d.f.=287, χ^2/d.f.=2.25, GFI=.90; AGFI=.83, NFI=.90, NNFI=.93, CFI=.94, RMSEA=.063; and HR project χ^2=683.58, d.f.=287, χ^2/d.f.=2.22, GFI=.90; AGFI=.82, NFI=.90, NNFI=.93, CFI=.94, RMSEA=.068 (Bagozzi and Yi, 2012). The hypotheses testing showed the support of ten

hypotheses and the rejection of two hypotheses in both museums (Table 4).

Table 4. Hypotheses testing.

	MR project			HR project		
H.	**t-value**	**p-value**	**Support/reject**	**t-values**	**p-values**	**Support/reject**
H_1	2.64	.0025**	Supported	2.03	.02*	Supported
H_2	3.51	.0005***	Supported	2.82	.001**	Supported
H_3	1.40	.1626	Rejected	2.32	.01*	Supported
H_4	5.58	.0001***	Supported	3.36	.0009***	Supported
H_5	2.64	.0025**	Supported	5.43	.0001***	Supported
H_6	2.28	.01*	Supported	3.12	.0005***	Supported
H_7	4.62	.0001***	Supported	4.42	.0001***	Supported
H_8	5.01	.0001***	Supported	2.99	.001**	Supported
H_9	2.53	.005**	Supported	-1.11	.2679	Rejected
H_{10}	3.71	.0002***	Supported	-.13	.8967	Rejected
H_{11}	2.69	.0025**	Supported	2.77	.0025**	Supported
H_{12}	1.64	.1021	Rejected	3.96	.0001***	Supported

Note: *p-value ≤ .01; **p-value ≤ .001; ***p-value ≤ .0001.

5. Discussion, conclusions, implications, limitations and future research lines

Building on advanced forms of human-to-technology interaction in tourism and cultural heritage, this research develops and tests the same conceptual framework to draw new scenarios on the MR and HR experiences in Italian cultural heritage museums. They allow identifying convergence and divergence between MR and HR adoption, immersive museum experiences, and visitors' behavioural effects in cultural heritage museums.

Between the technological-functional relationships, MR and HR combine a standard set of multimedia characteristics to experiment with innovative solutions of museum information visualisation and interaction through the support of usability and customisation (Errichiello *et al.*, 2019; Fenu and Pittarello, 2018; Schaper *et al.*, 2018; tom Dieck *et al.*, 2016; Trunfio *et al.*, 2020, 2021). However, the rejection of H_3 in the museum under MR conditions identifies the first difference between MR and HR, opening spaces for future theoretical advances and investigations.

In the MR project, the museum information visualisation is strongly interrelated to the usability of friendly technology interfaces to promote smart access to augmented and virtualised heritage contents (Anderson *et al.*, 2020; Banerjee *et al.*, 2020; Flavián *et al.*, 2019; Trunfio *et al.*, 2020, 2021). This implication confirms how access to MR environments in cultural heritage museums is strongly interconnected to usability requirements (Errichiello *et al.*, 2019; tom Dieck *et al.*, 2016; Trunfio *et al.*, 2020; Trunfio and Campana, 2020).

Conversely, usability does not play a relevant role in the HR project based on technological

interfaces installed in the museum landscape (Anderson *et al.*, 2020; Banerjee *et al.*, 2020; Ponto *et al.*, 2014). The usability evaluation of HR interfaces correlates with the technical ability to create a comfortable digital environment with easy to use and alternative access to the museum information (Banerjee *et al.*, 2020; Ishizawa *et al.*, 2018; Ponto *et al.*, 2014).

Between technological-functional and experiential relationships, MR and HR reframe the experiential museum value proposition by creating immersive environments in cultural heritage museums. They confirm the combination of heritage valorisation with education in traditional experience, a central and highly significant immersive museum experience in both museum contexts (Trunfio *et al.*, 2020). Besides, entertainment, socialisation, and escape in the 4.0 experience generated by the disruptive power of immersive technologies in cultural heritage (Trunfio *et al.*, 2020).

Focusing attention on the relationship between immersive experience and information saving, the museum under HR conditions shows the rejection of H_9 and H_{10}, drawing a second difference between MR and HR.

These results are strongly coherently with the theoretical assumptions that propose HR as an interface to create an indistinguishable space between what is real or digital in the heritage exhibition (Anderson *et al.*, 2020; Banerjee *et al.*, 2020), driving visitors not to perceive immersive museum experiences with the 'wow' effect, generating lower levels of memorability in the museum information saving (Hudson *et al.*, 2019; Trunfio *et al.*, 2020).

Last, but not least, contribution regards the relationship between visitors' experience, such as traditional experience 4.0 experiences and post-experience behaviours. In the museum under MR conditions, the combination of AR and VR promotes a significant influence on visitors only in terms of traditional experience (heritage valorisation and education) and not with 4.0 experiences (entertainment, socialisation, and escape), disconfirming the previous studies partially (Jung *et al.*, 2016). In opposite, scenarios unexpected emerge in the museum under HR conditions in which both traditional and 4.0 experience influence with very significant value visitors' post-experiences behaviours.

The current research concerns the investigation of only Italian cultural heritage museums, requiring the test of the same model and hypotheses in other Italian or foreign museums. Some questions remain open, such as: How does H_{12} result accept extremely significant value in the museum under HR conditions and not under MR conditions? How long do visitors memorise their experiences, and to which extent do they impact their future behaviours? How does the simultaneous use of the MR and HR reframe museum exhibition spaces in extended reality?

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