heritage

MDPI

Review

Unlocking Digital Heritage: Empowering Older Adults Through Extended Reality in Wellbeing, Inclusion and Learning

Stella Sylaiou [1,*], Panagiotis Dafiotis [2], Angeliki Antoniou [3], George Pavlidis [4] and Konstantinos Evangelidis [1]

[1] Department of Surveying & Geoinformatics Engineering, School of Engineering, International Hellenic University, 62124 Serres, Greece; kevan@ihu.gr
[2] School of Visual and Applied Arts, Faculty of Fine Arts, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece; dafiotis@vis.auth.gr
[3] Department of Archival, Library & Information Studies, University of West Attica, 12243 Aigaleo, Greece; angelant@uniwa.gr
[4] Institute for Language and Speech Processing, Research Center Athena, 67100 Xanthi, Greece; gpavlid@athenarc.gr
* Correspondence: sylaiou@ihu.gr

Abstract: The rise of digital heritage and immersive technologies like extended reality (XR) is reshaping how people experience culture and history. For older adults, these innovations offer exciting possibilities to explore and connect with their heritage in new ways. However, scientists and stakeholders still know little about how they engage with these technologies, what draws them in, what challenges they face, and how it impacts them emotionally and cognitively. This study aims to contribute to closing that gap by sharing insights from a survey on older adults' interactions with digital heritage through XR. By exploring their experiences, we aspire to uncover the importance of making XR tools more accessible, intuitive, and meaningful for this audience. This article also highlights how older adults can contribute their rich perspectives to cultural heritage initiatives, enhancing not only their own engagement but the broader cultural narrative. Ultimately, this work calls for thoughtful design that ensures everyone, regardless of age, can connect with, and gain knowledge from the stories that shape our world.

Keywords: digital heritage; extended reality; engagement; older adults

check for updates

Academic Editors: Kasper Rodil and Ivan A. Nikolov

Received: 7 February 2025
Revised: 17 April 2025
Accepted: 22 April 2025
Published: 24 April 2025

Citation: Sylaiou, S.; Dafiotis, P.; Antoniou, A.; Pavlidis, G.; Evangelidis, K. Unlocking Digital Heritage: Empowering Older Adults Through Extended Reality in Wellbeing, Inclusion and Learning. *Heritage* **2025**, *8*, 146. https://doi.org/10.3390/heritage8050146

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

The median age of the world population is steadily increasing [1,2], and therefore, to include the elderly in cultural experiences offered through new technologies, it is necessary to cater to their needs. Particularly in Europe, where most of the surveyed papers in this article originate, as noted by Eurostat [3], in a timespan of 50 years (2001–2050), the old-age dependency ratio is projected to be more than double. This ratio expresses the relative size of the older part of the population compared with the working-age population, and it reflects the level of support that the older adults will require within society. This trend certainly encourages an increase in studying methods to support and improve the wellbeing of a fast-growing part of the population. It is arguably no coincidence that 5 out of 24 research papers surveyed in this study come from the two countries in Europe with the highest dependency ratios (in 2019), i.e., Italy (where this ratio is projected to almost triple between 2001 and 2050) and Finland. As noted in Section 3.3, similar population trends apply to all the countries from which the articles surveyed come. Given the changing demographic landscape, it is imperative to understand how older generations interact with

digital platforms and content to provide engaging, meaningful, and user-friendly digital tools and resources. This understanding is not only about their inclusion but also about utilizing their viewpoints and valuable experiences. The preservation and interpretation of cultural heritage heavily depend on these insights, which help common historical narratives to be richer and more diverse. Digital heritage initiatives that include older adults can create an inclusive approach to cultural heritage conservation by ensuring that their voices and tales are part of the shared past [4].

Digital heritage refers to preserving, interpreting, and sharing cultural information and enhancing the heritage experience through digital methods and tools [5]. It encompasses using technology to document, archive, and make accessible a wide range of cultural heritage information to all audiences. Digital heritage involves the convergence of technology and culture to ensure that the artifacts of human history are preserved for future generations. However, cultural heritage applications are mainly designed for young people with relevant digital experience [6].

Participating in heritage helps (older) individuals gain knowledge and reasoning abilities [7] and feel happy [8], thus increasing affective [9] and cognitive engagement [10] while ensuring they are fit physically and mentally. Consequently, researchers with expertise in designing XR applications could work in synergy with cultural heritage experts, stakeholders, and end-users to better understand how older adults use digital heritage and what they think of the specific type of cultural heritage involved in each case. Such synergies will bridge gaps between specialists as well as between them and users. This approach will enable interdisciplinary researcher teams to share insights and engage in constructive dialogue, thereby empowering them to design systems that are easier to use, accessible, meaningful, and immersive, and therefore able to cater to the needs and demands of their envisaged users more effectively. The above comments reflect some of the findings of the publications surveyed, as outlined in the Discussion section and in the final conclusions.

At this point, it is essential from the outset of this article to address the multifaceted nature of cultural heritage that, even in the context of this survey, which reviews a specific number of digitized heritage-related resources, takes manifold forms. The ways in which cultural heritage in these instances of research is framed vary considerably and include not only monuments in the traditional sense, i.e., archaeological sites or heritage buildings, but also personal narratives, memories, and users' interpretation of their ethnic group's archaeological past and living traditions. A characteristic example of the wide range of cultural heritage types involved in the surveyed publications is the study by Dibeltulo et al. [11], who present a research project involving about 200 older adults from Italy who share their memories as cinemagoers of the 1950s. The authors presenting this project, which was focused on Rome, relate their research based on narratives to a conceptualization of intangible cultural heritage that is in accordance with UNESCO and manifests itself as follows: (a) oral traditions and expressions, including language as a vehicle of the intangible cultural heritage; (b) performing arts; (c) social practices, rituals, and festive events; (d) knowledge and practices concerning nature and the universe; and (e) traditional craftsmanship [12]. In a similar vein, other presented papers, such as that of Dryjanska (2015) [13], foreground digitized narratives of older adults that convey their experience of life in specific Roman neighborhoods in a bygone era. Apart from the binary categorization of tangible/intangible heritage, as Vecco [14] notes, there is a differentiation between conceptualizations of heritage between, e.g., the West and East Asia, and the characteristic example of Japanese temples whose wooden structure is renewed every 25 years approximately, for many centuries, illustrate an emphasis on heritage as the preservation of the know-how rather than the material aspect of a monument. Typically, a heritage building, sculpture, or artifact provides a testimony for the craftsmanship, artistic skills, and aesthetic

sensibilities of an era that may well be (all but) lost, as is often the case with, e.g., ancient Greek or Roman art. The conceptualization of heritage as primarily a relay of traditional knowledge is, to a certain extent, reflected in a publication by Chou et al. [15], in which traditional Taiwanese glove puppetry games are used (within VR applications) as fulcrums for intergenerational relations and cultural heritage interaction.

The above commentary illustrates the complex yet alluring nature of cultural heritage that, in turn, becomes the object of further processing through digital means, a procedure that itself bears the marks of contemporary sensibilities, conceptualizations, and aspirations. The primary aim of this study is to classify the results from our research concerning the use of digital heritage applications by older adults. The first step toward this goal involves a comprehensive review of existing academic literature based on the initial findings of a survey on extended reality (XR) technologies.

2. Materials and Methods

2.1. XR Technologies

The main objective of our article is to enhance the understanding of how older adults interact with and are influenced by digital cultural heritage applications. In an extensive survey, we aimed to identify the trends, preferences, and challenges that define older adults' engagement with cultural heritage in the spectrum of XR technologies that range from augmented reality (AR), which overlays digital elements on the real world, to fully immersive virtual reality (VR), and mixed reality (MR), which blends the physical and digital worlds, as depicted in Figure 1.

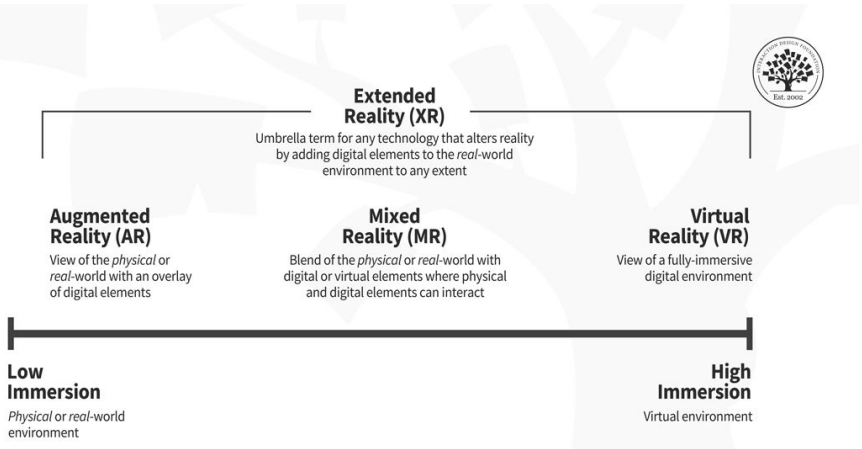


Figure 1. Representation of XR technologies according to the spectrum of immersion. Source: Laia Tremosa and the Interaction Design Foundation, CC BY-SA 4.0 [16].

The main aim of the article is to identify and classify the articles concerning research about the use of XR technologies by older adults in the framework of digital heritage. Given this focus, the literature review emphasized discovering studies related to immersive technologies and their application in cultural heritage contexts.

2.2. Search Strategy

The literature search, conducted in June 2024 in ACM Digital Library, the IEEE Xplore Digital Library, MDPI, Scopus (Elsevier), and Springer Link, aimed to identify studies focusing on the interaction of older adults with XR technologies in the framework of digital heritage. As is the case with pertinent reviews [17,18], the key terms, exclusion criteria, and online databases were identified by a group of researchers with diverse expertise. The search strategy used the terms (older adults OR elderly OR senior) AND (virtual reality OR

augmented reality OR extended reality OR mixed reality OR immersive OR immersion) AND (cultural heritage OR museum OR archaeology). The search across the specified digital libraries and repositories yielded a total of 127 papers.

After the initial identification of papers, a further screening phase assessed the relevance as well as the quality of the initially selected works to determine their pertinence and consistency. While two researchers undertook the first phase of paper identification, another two researchers worked independently to screen the publications further to ensure adherence to the scope of this review, which focuses on the engagement of older adults with immersive technologies in cultural heritage settings. Quality-related criteria were partly influenced by Kitchenham et al. [19], while the search strategy and its delineation were informed by pertinent studies in the broader field of XR-related systematic reviews [20]. Another researcher made a final evaluation of cases where discrepancies appeared amongst the opinions of the two colleagues who undertook the main screening procedure. A total of 24 papers were selected for inclusion in the research results (see Figure 2). Our exclusion criteria were related to papers that did not specifically address cultural heritage sites as their main application framework or were focused on technological solutions or medical issues.

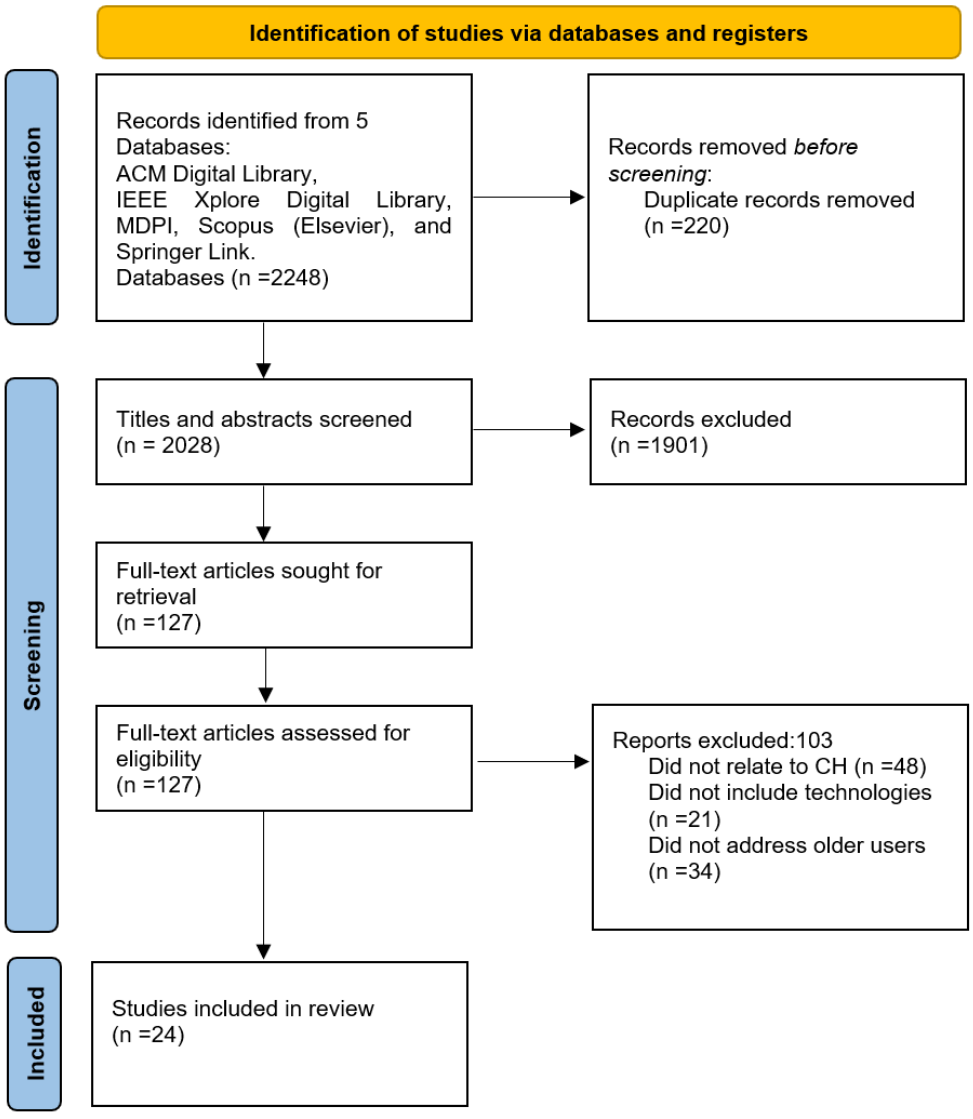


Figure 2. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram.

3. Main Results and Categorization

3.1. Results According to Categories of Surveyed Publications

The research articles surveyed were categorized in accordance with their aims, scope, and main area of research. The first category includes publications with main purpose/area of research that addresses older adults as contributors to CH (Table 1).

Table 1. Publications with main purpose/area of research of older adults as contributors to CH.

Article	Methodology: Type of Technology/Methods Employed	Context: Characteristics of Users/Region	Specific Aim(s)
Dryjanska (2015) [13]	Creation of a documentary by filmmakers based on participants' narrations. The resource created is adapted to support Virtual tourism/virtual reality and includes a virtual expert (a "virtual tourist" who functions as a guide).	64 elders from neighborhoods close to the Vatican City.	To include local elders' narrations to raise awareness of tourists about the destination and its recent past.
Dibeltulo et al. (2020) [11]	Mixed-methods ethnographic approach based on the following: - Use of social media platforms. - Cross-generational activity involving Historypin, a digital, user-generated archive of crowdsourced historical material. - Creation of online virtual archive in collaboration with the older adults involved in the project; design of the virtual environment.	Italian cinemagoers of the 1950s willing to share their memories. The project focused on Rome and involved about 200 participants from Italy.	To ensure older adults can bridge the digital divide and engage with online cultural heritage through the creation of digital platforms in which the older generations are both curators and users. Promote engagement with online CH, inclusion, and connection of elders to the virtual world.
Chou et al. (2022) [15]	This study presents (the design of) a virtual reality (VR) intergenerational game, based on glove puppetry, a traditional cultural pursuit of Taiwan.	Two groups of four younger (23 to 30) and four older participants (60 to 70). The purposeful sampling, aimed to select cases with rich information	To positively influence intergenerational relations and communication via VR game cultural elements, cultural heritage interaction, and technology learning.
Dawson et al. (2011) [21]	The 3D simulations of objects and places in virtual reality: two types of 3D projection systems—a CAVE and a Portable Video Wall.	Indigenous people of America: nine Inuit Elders involved, from the Kivalliq District and Baffin Region of Nunavut; North Canada.	Foster users' agency. To engage Indigenous peoples—and other traditional and descendant communities—in the practice of archaeological interpretation.
Cassar and Avellino (2017) [22]	Guideline proposals for effective inclusion of elders in diverse CH-related resources, including online material.	Older visitors of online and actual heritage sites; focus on Malta.	To study how seniors could be offered a more beneficial experience at heritage sites through interpreting and negotiating meanings about cultural content through which they have lived.

Furthermore, the second category is comprised of publications that relate to the enhancement of cultural heritage experiences for older adults (Table 2).

Table 2. Papers on enhancing cultural heritage experiences for older adults.

Article	Methodology: Type of Technology/Methods Employed	Context: Characteristics of Users/Region	Specific Aim(s)
Traboulsi et al. (2018) [23]	Authors conduct semi-structured interviews before and after museum visits, with focus on evaluation of technological immersive devices (interactive touch screens and videos). Moreover, observations were made of the participants' interaction with technological devices.	Older visitors of the Cagliari Archeological Museum, which underwent recently a major renovation with the inclusion of digital technologies onsite.	To answer fundamental questions on the perceived value of senior visitors in the context of cultural heritage sites by using immersive technologies and accordingly propose guidelines for stakeholders.
Colomer and Erlingsson (2018) [24]	Short review paper	Elderly users. Region of research not applicable.	To highlight the role of cultural heritage activities and relevant experiences in promoting wellbeing.
Alelis et al. (2015) [25]	This study examines how two target populations responded to seeing cultural heritage artifacts in three different modalities: augmented reality on a tablet, 3D models on a laptop, and then physical artifacts.	A total of 20 young adults (18–21 years) and 20 elderly (65 years and older). Sessions held at the University of Kent. The first eligible persons who responded were selected.	To provide an insight into the effectiveness of 3D artifacts viewed on personal devices and artifacts shown outside of the museum for encouraging emotional responses from older and younger people.

Moreover, the third category includes publications that address virtual tourism as a means for enhancing accessibility and emotional connection to CH sites (Table 3).

Table 3. Publications addressing virtual tourism as a means for enhancing accessibility and emotional connection to CH sites.

Article	Methodology: Type of Technology/Methods Employed	Context: Characteristics of Users/Region	Specific Aim(s)
Yu et al. (2023) [26]	This study investigates the use of VR and AR in virtual tourism. It explores their attributes and effects on older adults' experience, perceived advantages, enjoyment, and reuse intention using qualitative and quantitative methods.	Expert group (including researchers and professors), as well as adults aged 65 and older with virtual tourism experience or elders interested in it (Korean citizens).	To offer meaningful insights about the use of VR and AR in virtual tourism to effectively activate senior tourism.
Lai et al. (2019) [27]	It focuses on older participants, assessing their responses to various VR applications through interviews and experimental trials.	Ten older adults from the Yijia aging community in Beijing with diverse social and educational backgrounds.	To explore the potential of virtual reality in meeting the entertainment and emotional needs of older adults within the context of virtual tourism.

Table 3. *Cont.*

Article	Methodology: Type of Technology/Methods Employed	Context: Characteristics of Users/Region	Specific Aim(s)
Kosti et al. (2024) [28]	Research on the development of an art-driven methodology that combined art and technology through AI and VR to create a social virtual space for older adults. The VR immersive environment incorporated elements inspired by real-world locations familiar to the older adults, such as the Greek Cycladic architecture.	Target group was comprised of ten (10) autonomous elders aged between 60 and 85 years living independently in Paris, France, with no health issues or mental illness.	To enhance the social engagement, cognitive stimulation, and emotional wellbeing of seniors by using immersive VR environments. To address issues of isolation and social interaction of the elderly by stimulating them intellectually, instigating further thoughts and communication.
Fiocco et al. (2021) [29]	The study investigates the effects of immersive VR tourism on the psychosocial wellbeing of older adults in residential care settings. VR content was administered using the Samsung Gear VR headset, with Samsung Galaxy Note 7 mobile phones and Sony headphones.	A total of 18 participants from residential care homes in the Greater Toronto Area, Canada.	To evaluate both the immediate and longer-term benefits of VR tourism exposure on participants' psychological and social wellbeing.
tom Dieck et al. (2019) [30]	This study examines elderly tourists' perceptions of VR as it links to the consumption of tourism experiences. VR application was performed using a Samsung Gear VR Headset. The virtual experience was showcased in 3 museum locations.	A total of 23 elderly visitors at the Geevor Tin Mine Museum in the UK.	To explore the impact of virtual reality on elderly tourists' experiences and their specific requirements for its use in cultural heritage sites and to enhance their tourism experience.

The next category consists of publications that present research on improving cognitive abilities through CH experiences with emphasis on care facilities and cognitive impairments (Table 4).

Table 4. Published research with the purpose of improving cognitive abilities through CH experiences—care facilities and cognitive impairments.

Article	Methodology: Type of Technology/Methods Employed	Context: Characteristics of Users/Region	Specific Aim(s)
Luyten et al. (2018) [31]	Interactive art installation called "VENSTER" in the form of a virtual window in the physical space, which transferred the users into various interactive scenes and experiences. Research protocol was set up as an observational explorative study.	A total of 35 nursing home residents with dementia. Location: South of Netherlands.	To investigate the participants' responses to an interactive art installation and to assess if their responses vary with different types of content presented.

Table 4. *Cont.*

Article	Methodology: Type of Technology/Methods Employed	Context: Characteristics of Users/Region	Specific Aim(s)
Vishwanath (2023) [32]	The study employed a pop-up VR museum, a prototype VR application, which featured digital replicas of artifacts from the Design Museum in Helsinki, with the use of Oculus Quest 2 HMD. Evaluation was based on gameplay data analysis and questionnaires.	Tested with 254 users at the museum and taken to several elderly care homes.	The aim of this study is to understand how senior citizens engage with the Pop-up VR Museum based on their actions within the experience and self-evaluation
Yi et al. (2024) [33]	Study of elders' VR museum experience enhancement through user-centered design by utilizing methods such as surveys, questionnaires, interviews, and focus groups, alongside the KANO model and Analytic Hierarchy Process (AHP).	Older adults with cognitive disorders, study conducted in China.	To propose a theoretical model and design strategy leveraging VR immersive technologies and identify key design features through user studies to better deliver to the needs and experiences of this demographic group.
Buele et al. (2023) [34]	The study presented a bibliometric analysis in which they reviewed the progression and trends in the use of virtual reality technology in elderly care over the last 20 years.	The study was conducted by analyzing 1622 articles from the Scopus database.	To identify areas of growing interest and application of VR in improving the lives of older adults, particularly in areas such as cognition and therapeutic exercise.

Lastly, the fifth category is composed of publications that deal with the enhancement of cultural heritage experiences for older adults (Table 5).

Table 5. Publications dealing with the enhancement of cultural heritage experiences for older adults.

Article	Methodology: Type of Technology/Methods Employed	Context: Characteristics of Users/Region	Specific Aim(s)
Ress and Cafaro (2021) [35]	Explored how immersive technologies can enhance historical interpretation at an open-air museum.	Visitors of open-air museum in New Harmony, Indiana, of which about half were above the age of 56.	To propose design guidelines for immersive technologies that can support historic interpretation—specifically, the visitor's ability to experience the past.
Partarakis et al. (2016) [36]	This paper provides a review of the current trends in the CH digitalization toward widening access to digital cultural exhibits. It includes interactive technologies, touch interfaces, AR, VR, and personalized museum guides using eye-tracking.	Review.	To provide a model for accessible CH-related multimodal applications that enhance visitor engagement and satisfaction and inclusion (of users with, e.g., visual impairments, cognitive limitations, and mobility issues).

Table 5. *Cont.*

Article	Methodology: Type of Technology/Methods Employed	Context: Characteristics of Users/Region	Specific Aim(s)
Mokatren et al. (2018) [37]	The study developed and evaluated a mobile museum visitor's guide that uses an eye tracker as a pointing device. The Pupil-Dev mobile eye tracker was used as a positioning tool and for focus of attention detection, both using computer vision techniques.	Participants: 22 University students, at Haifa, Israel.	To highlight the potential of integrating eye tracking with other immersive technologies to create engaging and interactive museum environments.
Moffat and Shapiro (2015) [38]	Study of a serious game with the use of affective, authentic materials such as voice recordings and historical photographs, as well as interactive storytelling and decision-making elements but without AR/VR technologies (web game with a simple graphical user interface).	Evaluation of a serious game on Holocaust created by authors, Glasgow, UK.	To explore the development and application of serious games for teaching and preserving CH, specifically through a case study focusing on the Holocaust.
Jia et al. (2023) [39]	The study investigates how interactive and sensory affordances affect the adoption of digital heritage services. The authors employed immersive technologies, particularly VR, with use of VR glasses.	A total of 207 university students participated (44% men and 56% women, location: China) in the art-related experiment.	To assess the impact of immersive technologies, such as VR, on users' experiences and perceptions.
Caggianese et al. (2014) [40]	An interactive VR system was developed using Unity3D, accompanied by a preliminary usability evaluation of the interface, which revealed a significant difference in user experience between younger and older adults.	A total of 20 volunteers in 2 age-related groups. Location: Naples, Italy.	To improve the dissemination and presentation of cultural artifacts with the use of VR.
Abeele et al. (2021) [41]	Research on immersive VR technologies for older adults.	Authors analyzed interviews with 37 older adults (via the Laddering method) of diverse education levels and cognitive abilities who experienced a first VR experience (Belgium).	To refine and contextualize design guidelines for XR applications, emphasizing accessibility, usability, and user experience

While the above categories are not watertight or mutually exclusive, they provide a clear understanding of the overarching trends within research on employing extended reality (XR) technologies in the CH for older people. The first category in which we organized the results highlights the empowerment of seniors as active contributors and interpreters—or mediators—of cultural content, drawing on their experience, perspectives, and knowledge. This goes far beyond a mentality in which older adults are seen as merely a group of people with limitations (about, e.g., movement/accessibility or, for the same matter, digital literacy). Conversely, these publications foreground older people as valuable contributors who can enrich CH by sharing knowledge and enhancing meaning-making procedures within XR platforms and applications. Various studies, such as those by Dryjanska [13] and Dibeltulo et al. [11], demonstrated the value of incorporating the memories

and experiences of older adults into digital heritage. Intergenerational collaboration in digital cultural heritage environments emerged as an essential aspect that can be studied in this context. By involving both younger and older generations, bridging the digital divide and promoting meaningful interactions between different age groups has a dual benefit.

The second category focuses on how XR can foster older people's engagement in CH. This approach prioritizes using ICT as a fulcrum to enhance seniors' inclusion, wellbeing, and effortless enjoyment of culture. The analysis also points to the need for cultural heritage environments to consider the preferences and needs of older visitors. Studies such as that by Traboulsi et al. [23] emphasize the diverse interests of senior audiences and the necessity for heritage sites to adapt to these preferences to remain relevant and engaging. In a similar vein, another cluster of publications focuses on virtual tourism for older adults to offer opportunities for meaningful and emotionally gratifying experiences of accessing otherwise hard-to-reach physical environments with cultural significance. The fourth strand addresses the issue of therapeutic use of XR within the field of CH, with an emphasis on investigating the impact of such applications on elderly users' cognitive functions or performance. The last category puts into the limelight the issue of adaptability, customization, and personalization of XR applications to the needs, characteristics, and expectations of older users. Priority is given to usability, UI, and user-friendliness, as well as to improving the flexibility of applications so that they can match audiences amongst senior users. While this emphasis on the interface seems rather technical, it is fundamental as it conveys the importance of acknowledging the specificities within this varied and ever-growing part of the population, highlighting the importance of addressing their distinct motives, expectations, sensibilities, and needs. While these five categories/strands are distinct, it is evident that they are complementary, if not symbiotic, given that the aims and aspirations of one of these categories of research can hardly be achieved without advancements in the other outlined areas of ongoing scientific investigation.

This study maps the existing research landscape to identify and foreground key directions in current investigations and promote more holistic approaches that encompass a broader range of parameters within increasingly comprehensive approaches. In this context, it is crucial to highlight research that, albeit not explicitly or exclusively focused on older adults, offers valuable insights into related studies. The work by Raptis et al. [42–44] on cognitive function, as well as the relevant research on personalization [43,44], can inform and enrich the quest for more inclusive and effective uses of XR in the domain of CH for the elderly. Raptis et al. [44], more specifically, propose a cognition-centered personalization framework for delivering cultural heritage activities tailored to the users' cognitive characteristics, something that clearly can inform pertinent research on optimal uses of XR for older users of heritage applications. Likewise, forays into the use of tools and methods, such as serious games [38,45], can further advance this field. This survey, therefore, also highlights studies that, although not specifically addressing older adults, can significantly contribute to the broader effort of fostering their engagement with XR cultural experiences, ultimately promoting inclusion, accessibility, and wellbeing.

3.2. Findings of Surveyed Publications in Accordance with Categories

Table 6 presents the key findings organized according to the category in which the publications surveyed belong. After each table, there is a summary of the key takeaways from each category, based on the preceding, specific findings of the individual papers that comprise it.

The common ground of the findings deriving from these publications is the importance of preserving; foregrounding; and sharing the knowledge, experience, and viewpoints of older people who might have invaluable insights and information to pass on to new gener-

ations through XR apps. The following table (Table 7) outlines the findings of publications on fostering CH experiences for older adults.

Table 6. Key findings from studies addressing older adults as contributors to CH.

Authors	Main Topic: Older Populations Actively Shaping Digital Cultural Heritage Content
Dryjanska (2015) [13]; Cassar and Avellino (2017) [22]	The memories of older people comprise a rich repository of cultural knowledge, and their narratives comprise intergenerational knowledge that can be preserved and disseminated effectively through digital applications.
Dibeltulo et al. (2020) [11]	The creation of dedicated online archives and the integration of social media are effective methods for engaging the elderly in digital cultural heritage.
Dawson et al. (2011) [21]	The 3D virtual experiences enhanced the participants' (Inuit elders) feelings of connectedness to their heritage as they actively contributed to the interpretation of cultural elements.
Chou et al. (2022) [15]	VR-based traditional games (played by youths and elderly users who interacted) foster intergenerational relations, communication, cultural heritage interaction, and technology learning.

Table 7. Findings of papers on fostering CH experiences for older adults.

Authors	Virtual Tourism: Enhancing Accessibility and Emotional Connection to CH Sites
Traboulsi et al. (2018) [23]	The results revealed a complex mix of acceptance (interest) and reservation (hesitation) toward these technologies among older visitors, indicating a diversity of responses to the use of immersive technologies in cultural heritage sites.
Colomer and Erlingsson (2018) [24]	Cultural heritage has an important role in supporting the wellbeing of older adults.
Alelis et al. (2015) [25]	Older and young participants found the digital modalities enjoyable and emotionally engaging. Viewing physical artifacts after digital ones did not diminish their enjoyment or emotional responses, indicating the potential effectiveness of 3D artifacts on personal devices to extend the museum experience beyond usual sites.

The common denominator amongst the findings in this category is that virtual technologies are compatible and coextensive with physical experiences of cultural sites, promoting wellbeing, while for some older users, in certain circumstances, an element of reservation might appear. The following table (Table 8) presents the findings of publications on virtual tourism with regard to older adults.

A common trend in the use of virtual tourism applications is their positive impact, as findings point to emotional benefits, increased engagement, and heightened motivation. Notably, the social dimension of shared experiences emerges as a key factor contributing to the effectiveness and positive reception of these XR-related applications. The following table (Table 9) outlines the findings of publications that address CH applications and cognitive abilities with regard to older users.

Table 8. Findings of papers on virtual tourism regarding older adults.

Authors	Virtual Tourism: Enhancing Accessibility and Emotional Connection to CH Sites
Yu et al. (2023) [26]	Positive correlation between the use of XR experiences in virtual tourism in all four main attributes of VR/AR, classified as Escape, Aesthetic, Educational and Entertainment Experience, with a strong tendency of senior participants to reuse such applications.
Lai et al. (2019) [27]	The older adults had significantly higher arousal of emotion during VR experience, especially in the game application, as well as in virtual tourism applications. Educational content should match their educational background to avoid frustration.
Kosti et al. (2024) [28]	Heightened willingness among seniors to engage with VR; the desire to create content subsequently incorporated into the VR app. Increased motivation derived from the interactive and socializing aspects of the VR app, as well as elements of feeling creative and explorative.
Fiocco et al. (2021) [29]	Immediate benefits of immersive VR tourism: a significant increase in momentary relaxation (decline in anxiousness) and a trending increase in momentary happiness was observed; significant increase in social engagement and quality of life.
Tom Dieck et al. (2019) [30]	Positive attitude toward VR and suggest that it can make heritage sites more appealing and accessible to older audiences. VR provides the older adults with perceived mobility to experience the site similarly to other visitors, enhancing social experience.

Table 9. Findings of studies addressing CH apps and cognitive abilities.

Authors	Virtual tourism: Enhancing Accessibility and Emotional Connection to CH Sites
Luyten et al. (2018) [31]	The findings indicated that the nature of the content significantly influenced the residents' engagement and the quality of their interactive experiences.
Vishwanath (2023) [32]	While senior citizens primarily engaged through narrative elements that evoked personal memories, younger users showed more interest in the interactive features of the virtual museum.
Yi et al. (2024) [33]	The research highlights the effectiveness of virtual displays and thematic exhibits in improving participants' subjective wellbeing.
Buele et al. (2023) [34]	Authors indicate a surge in research output and citations since 2013 on VR apps for older adults, particularly in areas such as cognition. The survey underscored the potential of VR in early diagnosis and management of cognitive disorders.

The actual content of XR experiences and especially interactive features can vary considerably, and the acceptance of older users is affected; accordingly, however, a common trend is that XR-based, CH-related applications improve sense of wellbeing, engagement, and cognition-related processes. Lastly, the following table (Table 10) presents the key findings of publications addressing the adaptation of CH apps to the older users' needs.

Table 10. Findings of papers addressing adaptation of CH apps to older users' needs.

Authors	Virtual Tourism: Enhancing Accessibility and Emotional Connection to CH Sites
Ress and Cafaro (2021) [35]	Immersive technologies can help visitors experience the past, but despite literature suggesting otherwise, visitors preferred learning from tour guides, indicating that technologies like AR and VR should complement, not replace, human guides.
Partarakis et al. (2016) [36]	Immersive technologies could enable natural and intuitive interactions, such as touch, gestures, and eye-tracking, to create more engaging and inclusive museum experiences.
Mokatren et al. (2018) [37]	Mobile eye-tracking technology, as an intuitive pointing device, enhances visitor experiences by providing personalized, context-aware information. This technology can be adapted to improve accessibility and the experience of seniors in CH sites.
Moffat and Shapiro (2015) [38]	The immersive aspects of the game are achieved through the use of authentic materials such as voice recordings and historical photographs, as well as interactive storytelling and decision-making elements, which engage players.
Jia et al. (2023) [39]	Interactive affordance and sensory affordance significantly enhance user adoption of digital heritage services by reducing psychological distance and improving embodied cognition. Moreover, information overload affects sensory affordance.
Caggianese et al. (2014) [40]	XR systems improve visitors' experience thanks to the opportunity of direct manipulation of a virtual representation of the artifact through, e.g., gestures. However, young users have higher usability expectations due to prior experience.
Abeele et al. (2021) [41]	Broad audiences of older adults can successfully engage with VR. This contrasts with the focus of guidelines on increasing accessibility and usability. Simplistic VR environments may not offer sufficient challenge and depth for users. This highlights the importance of moving beyond accessibility and usability concerns, leaving behind the deficit-focused perspective that calls for simplistic VR for older adults.

While intuitive, sensor-based modes of interaction can improve the user experience in VEs, and as is the case with gestural commands and manipulation of virtual objects, XR experiences should complement actual CH site visits. Older users can fully enjoy VR, and apps must not be oversimplified, as they may become less meaningful. XR apps should avoid sensory overload, though, to maintain user engagement.

3.3. Statistics Related to Surveyed Publications

Lastly, we provide some statistics, starting with an overview of the distribution of surveyed publications per year (see Figure 3) and in relation to the region in which the research took place (where applicable).

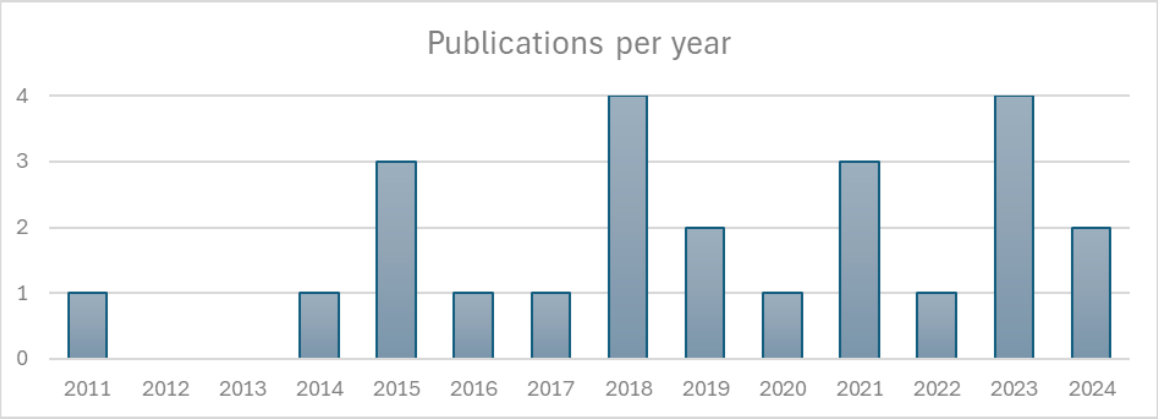


Figure 3. Publications' distribution per year.

Likewise, in Table 11, we include the regional distribution of publications, excluding from the results three (systematic) reviews for which geographic affiliation is less significant.

Table 11. Geographic distribution of surveyed publications/regions of research projects.

South of Europe-Mediterranean	Central/Northern Europe	East Asia	North America
6	7	5	3
Italy: 4 Malta: 1 Israel: 1	UK: 3 Belgium: 1 Finland: 1 Netherlands: 1 France: 1	China: 3 Korea: 1 Taiwan: 1	Canada: 2 US: 1

In all the above countries/regions, the percentage of people over 65 is high, or, as is the case with China, rising quickly [46], projected to reach high levels in the near future [2]. The demographic reversal of age structure in China's population is dramatic, as in 1976, the ratio of people 14 and under to those over 64 was 10 to 1 [2], while it reached 1 to 1 in 2024 [47]. As noted in the Introduction, European countries, particularly Italy and Finland, experienced a rapid increase in dependency ratio, i.e., the ratio between older and working-aged people, which conveys the levels of effort a society must make to cater to the needs of the elderly. While the increased research interest in CH-related digital experiences for the older adults can be correlated with the shifting age structure dynamics, as the authors of [48] note, countries such as Italy, Greece and the UK are also overrepresented in the production of publications on the uses of XR technologies in museums in the CH area (these three countries alone account for over half of the global total). This might show that in such countries, there is an overall investment in new technologies as a means for fostering audience engagement (irrespective of age) already in place, something that nevertheless can only positively influence the respective investment in research methods to include the demographic of the elderly in the employment of XR in the field of CH. The same trend applies to the number of articles produced by countries such as Italy on the use of extended reality in the transmission of heritage, according to the findings of a literature review by Dordio et al. [18], which offers an indication that investment in CH, education through new media, and catering for the inclusion of all demographics/age groups in such provisions are closely related topics.

4. Discussion

This section aims to provide a more detailed presentation of each category, providing key themes, approaches, and findings from the reviewed literature. At the same time, the last (and by no means least) Section 4.6 outlines some suggestions and guidelines for optimizing such technologies for older users. Sections 4.1–4.5 correspond to the five categories presented above, and in each case, the publications comprising them are described in more detail. As mentioned, based on the research findings and key results from papers from the broader field of XR applications, several specific design-related insights are foregrounded.

4.1. Older Populations Actively Shaping Digital Cultural Heritage Content

There is an increasing number of studies in recent literature that involve older adults not only as passive viewers/consumers of digital cultural heritage content but also actively incorporating them in the creation and evaluation process of such digital heritage experiences.

Dryjanska [13] examined how the memories of Rome's elderly population could serve as a valuable resource for capturing the city's intangible cultural heritage, offering a foundation for creating authentic narratives for tourists through a documentary format. The study utilized the social representations theory to analyze the urban landscape of Rome's former 17th Municipality, particularly areas near the Vatican. By engaging elderly participants through cognitive assessments, focus groups, and interviews, the research sought to document their personal recollections. The findings highlighted that the memories of older residents were a rich repository of cultural knowledge, underlining the significance of preserving these narratives for future generations.

These representations were then transformed into a documentary, which combined the personal narratives of elderly participants with expert commentary to enrich the experience of tourists visiting the area [13]. This approach highlights the deep emotional connections older adults have with their surroundings and underscores the value of integrating social memories into efforts to preserve and promote cultural heritage. Dryjanska's work [13] also suggests practical strategies for utilizing these narratives in tourism and the conservation of historic social knowledge and envisages the use of the final product in the context of virtual tourism with the employment of virtual reality techniques. The study found that mild cognitive impairments or lower educational levels among some participants did not hinder their ability to share meaningful and insightful memories, further reinforcing the importance of including diverse voices in the documentation and interpretation of cultural heritage.

Another study that positions older adults not just as users but as active contributors to cultural heritage is Dibeltulo et al. [11], which presents a model for enhancing elderly engagement in the digital sphere. The authors focused on the digital participation of older adults in cultural heritage activities, specifically exploring memories of cinema-going in Italy during the 1950s. Using the Italian Cinema Audiences project as a case study, the research examined strategies for fostering meaningful interactions between older adults and digital platforms. The study identified the creation of dedicated online archives and the integration of social media as effective methods for engaging the elderly in digital cultural heritage.

The work of Dawson et al. [21] further emphasizes the role of older adults in the creation and interpretation of digital cultural heritage content. Their research explored the creation and use of 3D virtual worlds for knowledge repatriation. In this study, nine Inuit Elders interacted with virtual reconstructions of traditional Inuit dwellings using a CAVE and a Portable Virtual Wall as forms of immersive digital technologies. The discussions with the participants indicated that the 3D virtual experiences enhanced their feelings

of connectedness to their heritage. A similar finding to Dryjanska's study [13], which also demonstrates the potential of such interventions to facilitate the intergenerational transmission of knowledge, is foregrounded by Cassar and Avellino [22], who also studied the role of older adults as both learners and interpreters of cultural heritage. Building on the concept of creating engaging and meaningful narratives for older audiences, this work studied the implementation of tailored experiences that resonate with their life experiences and values.

The main objective of the study by Chou et al. [15] was to explore the use of virtual reality to promote intergenerational communication through a game based on traditional Taiwanese glove puppetry. The study focused on older adults and aimed to bridge the digital gap by leveraging their understanding of traditional culture. The authors designed a VR intergenerational game that integrated cultural heritage elements, allowing older adults to share their knowledge and experience with younger participants. The game's immersive aspects, including VR hand gesture functionality for puppet control, brought together older and younger generations in an engaging environment where they could interact and learn from each other. The study's empirical findings indicated that VR games incorporating cultural elements significantly enhanced intergenerational relationships and communication. The key factors contributing to the success of VR intergenerational games included making the content appealing to older adults, simplifying the game's operational procedures, and ensuring the game provided a sense of achievement. Interviews with participants revealed that the VR game not only improved digital literacy among the older adults but also promoted a greater appreciation for cultural heritage among younger players.

4.2. Enhancing Cultural Heritage Experiences for Older Adults: The Rising Market of Older Audiences for CH Sites

Recent research efforts have concentrated on examining older audiences as a significant market segment for cultural heritage sites, including museums and archaeological locations.

Traboulsi et al. [23] narrowed down their research on the specific impacts of immersive technologies on older visitors at cultural heritage sites populations in the context of digital museum transformation. This study evaluated the perceived value of enhancements that utilized immersive technologies from the perspectives of epistemic, functional, hedonic, and social values. Through a combination of semi-structured interviews and observational methods, this work provides an in-depth analysis of how immersive technologies influence the museum experience for seniors. The results revealed a complex mix of acceptance (interest) and reservation (hesitation) toward these technologies among older visitors, indicating a diversity of responses to the use of immersive technologies in such settings. The results of this work can be utilized as guidelines for the design of immersive experiences for cultural heritage exploration targeted at older adults.

Colomer and Erlingsson [24] published a short review paper that argues that cultural heritage activities can significantly enhance the health and quality of life of older populations. The involvement of older individuals in activities like museum visits, reminiscence sessions, and the handling of historical objects can stimulate memory, promote social cohesion, and provide a sense of identity. They also discuss the therapeutic potential of cultural heritage, emphasizing its capacity to evoke positive emotions and mitigate feelings of isolation. While the authors do not directly address immersive technologies such as augmented or virtual reality, they highlight the role of sensory experiences in promoting wellbeing.

Alelis et al. [25] focused on understanding how older adults (aged 65 and older) and younger adults (aged 18–21) engaged with and emotionally responded to cultural heritage artifacts presented in three different modalities: augmented reality (AR) on a

tablet, 3D models on a laptop, and physical artifacts. The key findings revealed that both age groups found the digital modalities enjoyable and emotionally engaging. Viewing physical artifacts after digital ones did not diminish their enjoyment or emotional responses, indicating the potential effectiveness of 3D artifacts on personal devices in extending the museum experience beyond traditional settings.

4.3. Virtual Tourism for Older Adults

Yu et al. [26] examined the impact of VR and AR on enhancing the tourism experience for senior tourists, focusing on experiential quality, perceived advantages, perceived enjoyment, and reuse intention. This work acknowledged the growing demographic of older adults and their increasing interest in tourism and explored how VR and AR can mitigate physical and logistical challenges they might face. The authors used a mixed-methods approach to investigate how specific attributes of VR and AR affect seniors' emotional and behavioural responses, finding significant relationships among these technologies' attributes, experiential outcomes, and the intention to reuse such technologies in tourism.

Lai et al. [27] explored the potential of virtual reality in meeting the entertainment and emotional needs of older adults within the context of virtual tourism. The study focuses on older participants, assessing their responses to various VR applications through interviews and experimental trials. The findings indicate that VR applications, particularly those involving tourism and simple games, can enhance emotional wellbeing and offer a satisfying entertainment experience for older adults. The paper concludes with guidelines for designing VR content that is accessible and enjoyable for older adults, emphasizing the importance of aligning these applications with their physical and cognitive abilities.

Kosti et al. [28] researched the development of an art-driven methodology that combined art and technology through AI and VR to create a social virtual space for older adults. The main objective of the study was to enhance the social engagement, cognitive stimulation, and emotional wellbeing of seniors by using immersive VR environments. The study particularly focused on older adults, aiming to address issues of isolation and social interaction. Cultural heritage had a significant role in the project, as the VR environment incorporated elements inspired by real-world locations familiar to the older adults, such as the Greek Cycladic architecture.

Fiocco et al. [29] investigated the effects of immersive VR tourism on the psychosocial wellbeing of older adults in residential care settings. The main objective of the study was to evaluate both the immediate and longer-term benefits of VR tourism exposure on participants' psychological and social wellbeing. The study revealed that VR tourism significantly reduced anxiety and fatigue while enhancing social engagement and quality of life over a six-week period. Participants reported immediate feelings of relaxation and enjoyment following VR sessions, and qualitative data highlighted the potential of VR to provide meaningful and enjoyable experiences that could break the monotony of life in residential care facilities.

Tom Dieck et al. [30] explored the impact of virtual reality on elderly tourists' experiences and their specific requirements for its use in cultural heritage sites. Through interviews with 23 elderly visitors at the Geevor Tin Mine Museum in the UK, the study found that VR significantly enhances their tourism experience by providing a deeper connection to historical contexts, improving accessibility for those with mobility issues, enabling shared educational experiences, and adding novelty to museum visits. The elderly users expressed a preference for immersive, sensory-rich VR experiences with appropriate control over the pace and storytelling elements. The findings indicate a positive attitude toward VR and suggest that it can make heritage sites more appealing and accessible to older audiences.

4.4. Care Facilities and Cognitive Impairments

Luyten et al. [31] conducted a pilot study to investigate the responses of nursing home residents with dementia to an interactive art installation called "VENSTER" and to assess whether their responses varied with different types of content presented. This art installation had the form of a virtual window in the physical space, which transferred the users to various interactive scenes and experiences. The findings indicated that the nature of the content significantly influenced the residents' engagement and the quality of their interactive experiences.

Vishwanath [32] conducted a case study that employed a pop-up VR museum, which featured digital replicas of artifacts from the Design Museum in Helsinki. The VR experience was designed to be inclusive and accessible, facilitating interaction with virtual artifacts and listening to related stories, and was tested with both elderly care home residents and museum visitors. The findings highlighted that while senior citizens primarily engaged through narrative elements that evoked personal memories, younger users showed more interest in the interactive features of the virtual museum.

Yi et al. [33] studied the enhancement of museum experiences for elderly individuals with cognitive disorders using user-centered design by utilizing methods such as surveys, questionnaires, interviews, and focus groups, alongside the KANO model and Analytic Hierarchy Process (AHP). The research highlights the effectiveness of virtual displays and thematic exhibits in improving participants' subjective wellbeing. It proposes a theoretical model and design strategy leveraging VR immersive technologies. It identifies key design features through user studies to better deliver to the needs and experiences of this demographic.

Buele et al. [34] presented a bibliometric analysis in which they reviewed the progression and trends in the use of virtual reality technology in elderly care over the last 20 years. The study, conducted by analyzing 1622 articles from the Scopus database, highlighted the growing interest and application of VR in improving the lives of older adults, particularly in areas such as cognition, therapeutic exercise, and randomized controlled trials. The analysis identified key authors, influential publications, recurring keywords, and significant journals in the field. Notable findings indicated a surge in research output and citations since 2013, with pivotal studies shaping the field. The paper underscored the potential of VR in early diagnosis and management of cognitive disorders, emphasizing future research directions in spatial navigation, neuropsychological testing, and physical exercises.

Apart from the publications reviewed, a growing body of research that concerns the possible effects on wellbeing and probable health benefits, e.g., in relation to cognitive functions, is also worthy of inclusion in this discussion. Although the following papers are not strictly related to the use of CH-related XR technologies by older adults, or, for the same matter, do not address older users with cognitive disabilities, they can, nevertheless, offer considerable depth to important aspects of this discussion.

There is a consensus amongst surveyed authors that adequately designed XR experiences offer motivation for increased engagement with CH, while the use of VR can improve older users' wellbeing. Chaze et al. [49] explain that older participants found VR experiences to be enjoyable, relaxed, and happy while viewing them. Most participants were attentive/focused while viewing the VR experiences and often found them to be a source of reminiscence. They related well to others around them during most of the VR experiences, which became a point of conversation, thereby promoting social interaction. As Kupzick et al. note, [50] immersive technologies can provide a stimulating environment for older, more frail individuals, allowing them to experience an intuitive, meaningful simulation of an environment that contributes to their psychological and physiological wellbeing. Their research [50] indicates a preference for Immersive VR as opposed to 360° videos due to

their sense of presence in the virtual world and freedom of interaction. VR captivated older people for longer periods of time, implying that older people are more interested in the interaction provided by technology rather than photorealism. These findings, along with far more positive emotional responses to VR experiences, indicate the importance of interactivity and perceived sense of freedom/mobility as factors that contribute to XR's ability to have a positive effect on older users' wellbeing. In a similar vein, Fu et al. [51] found that the interests and acceptance of older adults in XR games and the positive health effects of continuous use are opportunities and space for developing such software further.

Regarding this point, although their systematic review does not address older adults with some kind of impairment, Healy et al. [52] provide some pertinent insights on the matter of how the elderly relate to and benefit from XR experiences: A "striking finding" (in their own words) from their review "is the level of agency that the IVR [Immersive VR] equipment afforded older adults while in virtual reality. It was clear that older adults experienced greater levels of agency during their IVR experience, in some cases enabling greater levels of agency than they had in the real world" [52]. Their conclusions highlight the ability of VR to engender positive emotions, something that is in stark contrast with the initially negative attitude of older adults toward immersive VR (another key finding of their survey) that, according to them, typically changes to positive after use. As Antoniou et al. note [53], this age group seems to be hesitant about the use of technology, either because they believe they lack technical skills or because they are skeptical overall about the use of novel technologies. For CH stakeholders, this negativity of older users must be taken into consideration, as is the case with the need to consider the relative ease with which this negative predisposition dissolves once IVR experiences are enjoyed by older adults. Nevertheless, when older adults with health or mental issues are involved in the planning of the XR session length (which ideally should not exceed 15 min [54]), a seated position [50], the interface, hardware involved, and the actual content of applications should be considered. For example, as Antoniou et al. posit [53] regarding content requirements, designers should avoid unnecessary details in the material used for VR and AR to avoid sensory overload. At the same time, on a separate note, dark colors seem to trigger negative emotional reactions. As Sekhon et al. [54] note, older adults with cognitive deficits tend to have a higher susceptibility to the negative side effects of prolonged technological use before, and more specifically, during XR exposure, than their cognitively healthy peers [55].

4.5. Enhancing Cultural Heritage Experiences for Older Adults

Enhancing cultural heritage experiences for older adults is particularly important, as this demographic often faces unique challenges when interacting with modern technologies. This section reviews the contributions of several studies that address such topics.

Ress and Cafaro [35] explored how immersive technologies can enhance historical interpretation at an open-air museum in New Harmony, Indiana. A visitor survey revealed that nearly a quarter of visitors were over the age of 70, highlighting the need for user-friendly technologies that are tailored to older adults. The study used this survey data to propose design guidelines for immersive technologies that can help visitors "experience the past". Despite literature suggesting otherwise, the authors report that visitors preferred learning from tour guides, indicating that technologies like AR and VR should complement, not replace, human guides.

Partarakis et al. [36] researched the need for inclusive digital and physical cultural heritage experiences, particularly focusing on the accessibility challenges faced by disabled individuals and older adults. The authors highlight the gaps in current accessibility efforts within Cultural Heritage Institutions (CHIs) and propose a systematic approach to create universally accessible cultural experiences. They review various interactive technologies,

including touch interfaces, AR, and personalized museum guides using eye-tracking to enhance visitor engagement and satisfaction. The authors emphasize the importance of multimodality and personalized interaction to cater to the diverse needs of all users, including those with visual impairments, cognitive limitations, and mobility issues. In particular, the authors discuss the potential of VR, AR, and immersive experiences to make cultural heritage more accessible. They present scenarios and personas involving older adults who benefit from personalized mobile applications that adjust font sizes and contrasts for better readability or use head-mounted displays for gaze-based interaction due to physical impairment. These immersive technologies could enable natural and intuitive interactions, such as touch, gestures, and eye-tracking, to create more engaging and inclusive museum experiences.

Mokatren et al. [37] reported on a sensor-based approach by studying the use of mobile eye-tracking technology as an intuitive pointing device in museums, finding that it enhances visitor experiences by providing personalized, context-aware information. The authors highlight the potential of integrating eye tracking with other immersive technologies to create engaging and interactive museum environments. Although the study focused on university students, the findings suggest that this technology could be adapted to improve accessibility and enrich the experience for older adults in cultural heritage settings.

A study by Moffat and Shapiro [38] aimed to explore the development and application of serious games for teaching and preserving cultural heritage, specifically through a case study focusing on the Holocaust. Key to this effort was the inclusion of testimonies from older adults, particularly Holocaust survivors, whose accounts were digitized and integrated into the game to provide an authentic and emotionally impactful narrative. The immersive aspects of the game are achieved through the use of authentic materials such as voice recordings and historical photographs, as well as interactive storytelling and decision-making elements, which engage players without relying on AR/VR technologies.

Jia et al. [39] aimed to investigate how interactive and sensory affordances affect the adoption of digital heritage services. The authors employed immersive technologies, particularly virtual reality, to assess their impact on users' experiences and perceptions. The findings revealed that interactive affordance and sensory affordance significantly enhance user adoption of digital heritage services by reducing the psychological distance and improving embodied cognition. Additionally, information overload was found to moderate the influence of sensory affordance on psychological distance, highlighting the complexity of user engagement in digital heritage contexts.

4.6. Culture-Related XR Applications for the Elderly

Design considerations

In this section, we see fit to discuss some key takeaways from this literature review with a view to offering informed recommendations for developers and stakeholders in the domain of incorporating emerging technologies to support a mutually beneficial engagement of older users with cultural heritage. The review of the literature and the respective findings accrued from the surveyed research section revealed that the active participation of older adults in the creation of narratives and content for digital experiences can significantly impact their overall acceptance and engagement. This insight is closely related to the concept of reminiscence, a therapeutic approach that leverages the act of recalling past events to enhance wellbeing, particularly among older adults [56]. Reminiscence therapy (RT) is a type of psychotherapy that involves revisiting and reflecting on past personal events, often resulting in pleasure and improved mental health. It is commonly used with older adults as a life review therapy to boost their sense of wellbeing. The integration of technology with RT has been increasingly studied, with research indicating that it can significantly amplify

its benefits and outcomes [57]. As Chaze et al. [49] note, "Reminiscence therapy has been found useful in alleviating depressive symptoms and improving psychological well-being among older adults with dementia [58]. VR shows promise as a tool to enhance cognitive function and for rehabilitation/memory exercises for individuals with dementia [59]".

It must be kept in mind, nevertheless, that when developing XR applications related to cultural heritage for elderly users, it is essential to prioritize usability, accessibility, and engagement to address cognitive and sensory needs. Due to age-related cognitive and sensory declines, XR applications must feature simplified interfaces, clear instructions, and intuitive navigation to ensure they are user-friendly for older adults. It is also essential to design these applications considering age-related conditions, such as frailty and mild cognitive impairment, to avoid physically demanding interactions and present content clearly and straightforwardly. Furthermore, health issues that are common amongst older adults, such as arthritis, can impair mobility, thereby posing another challenge in using equipment such as VR controllers. In such cases, alternatives should be considered, such as assistance from a staff member or voice-activated controls.

Cognitive impairment further influences how older adults interact with VR, necessitating that experiences be tailored to match their cognitive abilities to ensure informed participation. Furthermore, Abeele et al. [41] refine and contextualize design guidelines for XR applications, emphasizing accessibility, usability, and user experience. As such, the literature indicates the importance of technological readiness and the sensitive integration of immersion in ways that respect and prioritize the wellbeing and dignity of older adults. The following points provide a foundation for guiding the responsible and effective integration of XR technologies in ways that enhance the digital cultural experiences of older adults.

- User-centered design
    - XR applications must prioritize accessibility and inclusivity.
    - Design interfaces that consider the cognitive, sensory, and physical limitations of older adults.
    - Ensure intuitive navigation, straightforward content presentation, and engaging experiences without overwhelming users.
    - Consider the acceptance and comfort levels of older adults when using equipment. Engaging participants in the design and testing phases can help ensure these technologies are well-received and do not cause discomfort or resistance.
- Enhanced cognitive and emotional support
    - XR has the potential to enhance the feeling of reminiscence and support cognitive functions.
    - Provides virtual access to cultural heritage sites, particularly for those with mobility limitations or cognitive impairments.
- Ethical considerations
    - Ensure informed consent takes into consideration potential physical or cognitive aspects and visual/hearing impairments.
    - XR content must be designed to avoid psychological distress and maintain the wellbeing of older users.
    - Balance the benefits of immersive technologies with the potential risks.
    - Consider the dynamic and situated needs of the communities that older adults belong to, rather than focusing solely on their age-related characteristics.

Moreover, several publications highlight several issues with respect to the design considerations of culture-related XR applications that, albeit not strictly related to older users, provide insights in relation to, e.g., different interactions in 3D environments created

through the collaboration of interdisciplinary teams [60]. Furthermore, Chong et al. [61] presented a systematic review of VR applications in cultural heritage from 2007 to January 2020, categorizing 290 selected articles into four main taxonomy schemes: literature reviews, case studies, design and development, and evaluation studies. The review identified key motivations for using VR in CH, including enhancing accessibility, promoting awareness, facilitating knowledge transfer, engaging users, and improving performance. The study emphasized trends in reconstruction, optimization, preservation, system design, and technological advancements. While the review offers comprehensive insights into VR applications for CH, it does not specifically address older adults as a distinct user group.

Likewise, another cluster of publications/systematic reviews, such as that of Margett et al. (2022) [17], address older adults' use of extended reality (XR), providing insights in relation to pertinent research trends and employed technologies, as well as useful definitions of key terms such as wellbeing with regard to the elderly. Other publications in this group contribute to design considerations, as is the case with Seifert and Schlomann [62], who include gerontological recommendations for further developments in the field of XR.

This section closes with a brief discussion of the adverse effects that the use of XR applications might have on older users and concomitantly addresses pertinent challenges, as these transpire both from the publications reviewed and from relevant commentary from other publications mentioned, such as those in the previous paragraph. Starting with the publication of Ress and Cafaro [35], it has been observed that while older adults enjoyed these technologies, they nevertheless needed more time to adapt, so designs should minimize physical strain and allow comfortable interaction. Moreover, as Fiocco et al. [29] note in their research project, over a fourth of participants had to withdraw mainly due to medical reasons (something that underscores pertinent considerations), while most notably, one participant withdrew because they found the VR headset uncomfortable. A research project measuring VR headset comfort levels [63] found that of the older users, only some (8%) found the device somewhat or too heavy, although one participant who rated it as heavy added that this was "worth the mild discomfort". Appel et al. [63] note that most participants (85%) described the HMD as easy to accommodate, and even those who found the device heavy still found the comfort acceptable. This highlights that although hardware tolerance issues still exist, they do not distract from the overall positive contribution that such XR experiences can make. Lastly, cybersickness, as Arns and Cerney [64] explain, is not related to old age, as according to their findings, it is more frequent in younger adults (it peaks at the 24 to 26 age category) and likewise, most severe in the age bracket of 30 to 39 year olds; albeit, it is also noticed amongst the older adults. However, as Sekhon et al. [54] note, as age increases, so does the likelihood of adverse health effects from the protracted use of XR, and they state that the optimal session duration should last around 15 min (as noted in Section 4.4.) to avoid the possibility of negative side effects [65,66]. Another key factor for avoiding negative effects is highlighted by Kupzick et al. [50], who found that technical limitations, such as the poor resolution and refresh rate of the headset, mainly when a VR headset is used to render 360° video (as was the case in this research instance), can contribute to feelings of dizziness and a loss of focus amongst older users, something that arguably also affects their emotional responses.

On a different note, Fiocco et al. [29] report that one older participant in their research project withdrew due to disappointment with the virtual content and another due to frequent migraines (not related to the use of XR). It becomes evident that comfort is imperative when physical devices such as headsets are involved, as frequent health issues characterize this demographic. It also should be noted that the actual content has to be tailored to the cognitive profiles of older adults who might lose interest or might have a certain lack of motivation or tendency to focus for much time when a specific type of content is used (i.e.,

calming scenery), as transpired in the research by Luyten et al. [31]. Furthermore, there is the problem of the digital divide between younger and older generations who tend to rely on or use new technologies far less in their everyday lives; therefore, as Seifert and Schlomann [62] note, "technical solutions should clearly add value compared to offline solutions (Cotten, 2021)" [67]. Seifert and Schlomann [62] also indicate the possibility of cybersickness, which appears more often amongst older users of XR applications, with symptoms including nausea, disorientation, and headaches, quoting Davis et al. (2014) [68], who published a systematic review of cybersickness. However, it has to be clarified that the adverse effects of using devices such as HMDs in immersive VR experiences are very limited, and some researchers [63] indicate that, in fact, they can be deemed insignificant. More specifically, Appel et al. [63], who tested the emotional responses and comfort levels in connection to the use of HMDs, conclude that being exposed to immersive VR using an HMD is a feasible, safe approach to providing beneficial experiences to older adults with mobility, sensory, and/or cognitive impairments. Participants tolerated the VR hardware, were able to physically explore the virtual environments through head/body movements, and did not report any adverse side effects.

Finally, another study [69] bridges the topics elaborated in this sub-section, as it addresses XR design considerations in relation to filmmaking techniques employed in the creation of VR-based cinematic narrations to increase effectiveness and avoid adverse effects such as sensory overload.

4.7. The Relationship Between Cultural Heritage and Education: Learning Through XR Applications for and with Older Adults

Primarily, as the subtitle of this section suggests, while a number of surveyed publications aim at fostering learning about cultural heritage with emphasis on older users of XR applications, there is also a focus on cases that foreground the older adults as contributors, producers, and disseminators of knowledge either in the form of personal narratives regarding their lived experience (e.g., Dryjanska [13], Dibeltulo et al. [11]) or as interpreters of heritage-related knowledge (e.g., Dawson et al. [21]). This duality of the older adults as learners/producers or interpreters of knowledge, to a certain extent, reflects the analogous reconceptualization of museums or heritage sites as spaces where visitors (online or on-site) are not passive receivers of information but active negotiators and co-constructors of meanings and knowledge under a more inclusive and empowering educational paradigm. While much can be said about the new museology model [70], which is inextricably linked to the new visitor-centered educational paradigm, it is important to focus briefly on the educational value of narrations within a cultural heritage context. As Bedford [71] notes, "Storytelling is an ideal strategy for realizing the 'constructivist museum', an environment where visitors of all ages and backgrounds are encouraged to create their own meaning and find the place, the intersection between the familiar and the unknown, where genuine learning occurs (Hein 1998) [72]". Indeed, the active participation of the public in the interpretation of the exhibits is nowadays a key goal of CH sites (be they physical or virtual). Hooper-Greenhill [73] proposes that museums and CH sites should recognize the visitor as a co-creator of the meaning of objects and visual culture, placing greater emphasis on the participatory and interactive nature of the heritage-related experience. It is essential to integrate the voice of visitors (or, for the same matter, users of pertinent applications) into the functioning of museums/heritage-related sites or digital platforms and to foster a two-way communication in which multiple voices and narratives are heard [74]. While some of the referenced authors primarily address actual heritage sites, the same principles regarding the relation between education and cultural heritage apply to learning experiences through digital means, as inclusiveness, acknowledgment of a multitude of voices, and sharing of agency are seen as imperative, irrespective of the technological means involved. In this

context, the study by Hansen and Zipsane [75] examines the potential of older populations as museums adapt to the digital era by taking into consideration ethical and practical implications for educational engagement and commercial viability. By presenting the case of the Jamtli Museum, an open-air museum in Sweden, the study captures the varied preferences and interests of senior visitors from educational activities to initiatives aimed at social inclusion. A notable aspect of this research is its elaboration on the agency given to older people as contributors to the very contents of the specific museum's exhibitions, which relied on their experience heavily as it exhibits the lifestyle of an era (e.g., the early 1970s lived by its older visitors).

These principles are reflected in most of the surveyed publications, mainly in those that comprise the first group addressing older adults as contributors (see Table 1), as well as those belonging to the second (see Table 2) and the fifth category (Table 5) addressing ways to foster engagement with cultural heritage experiences for older adults.

The introduction of digital technologies in museums/cultural sites has proven to be crucial in supporting learning, with numerous studies confirming this finding; however, some issues that need attention are also highlighted by them. Pavlović [76] notes that the results of her extensive literature review show a clear connection between the development of new digital technologies and the learning process, especially in museums. The survey by Pavlović [76], which maps research aiming to support learning in relation to culture, cites Ismaeel and Al-Abdullatif (2016, p. 38) [77], who conclude that virtual museums can play an important role in the future of education, especially when it comes to content related to culture and tradition. The researchers emphasize, nevertheless, that the creation of virtual museums with the aim of enhancing learning requires interdisciplinary approaches, in which educators should play a central role in the design process of these applications.

Pavlović [76] (p. 174) also refers to the conclusions of a literature review in the same field, written by Daniela [78], which also analyzed virtual museum visits from a learning perspective. In this research [78], a total of 36 virtual museum applications were examined, with interesting conclusions. First, it was confirmed that virtual museums can contribute substantially to the development of the learning process in museums, offering a new dimension to museum education. However, the results of this study also suggest that "the strength of virtual museums is in information architecture, but less attention is paid to the educational value of the material, which points to the need to change the principles of virtual museum design and emphasizes the role of teachers in using virtual museums as learning agents" [78].

These findings highlight, firstly, the need for inclusive interdisciplinary approaches in designing digital culture-related resources such as virtual environments, most notably with the participation of educationalists, and secondly, the importance of focusing on the educational aspect, with emphasis on their ability to encourage active learning and engagement, rather than treating such digital resources as repositories of information. These insights are shared by the majority of the papers surveyed in this article, primarily those that address ways of enhancing the engagement of older users through culture (see Tables 2 and 7), as well as those that aim to adapt the design of such applications to the profile(s) of senior adults (see Tables 5 and 10). A systematic review by Dordio et al. [18] concludes that emerging technologies are making a significant impact in the field of education, particularly in the dissemination of cultural heritage. One of the advantages of these technological tools is their polyvalence and versatility, as they can be adapted to different educational contexts, to different population groups, and to various types of cultural heritage. The findings of the present literature review corroborate these conclusions.

4.8. User Profiles and Individual Characteristics of the Elderly Who Engage with Digital Heritage

It would do no service to any study on a demographic such as older adults to assume that they comprise a homogenous part of the population with similar tendencies across the globe. On the matter of heterogeneity with regard to digital media use among older adults, Taipale et al. [79] refer to the work by Bagchi et al. [80], who studied the effect of national cultural characteristics on the adoption of ICTs at the turn of the 21st century. Their results show that technology acceptance is at a higher level in individualistic countries (e.g., Finland and Canada) as opposed to countries with more collective cultures (such as Mexico, Spain, or Uruguay). Understandably, older people tend to use more traditional media (e.g., books, newspapers, or TVs) in comparison with younger generations that rely more on digital technologies, so there are (as the previous sentence illustrates) several factors that should be taken into consideration to better understand the relationship of older people with new media apart from their age. This would help shed light on other differentiating characteristics amongst them, which, in turn, influence their degree of XR application. Schroeder et al. [81], through a systematic review, map out the salient factors that influence older adults' intention to use digital technologies. Their mapping review found that older adults' intention to use technology was driven by six different categories: Demographics and Health Status; Emotional Awareness and Needs; Knowledge, Competence, and Perception; Motivation; Social Influencers; and Actual Technology Features. The model proposed in this survey underscores the multiple factors that affect older adults' motivation to use new technologies, in turn highlighting the fact that older adults should be perceived as a homogenous population if their relationship with digital tools is to be better understood. In their model, educational background is essential and relates to demographics and knowledge factors. As already noted, education levels can greatly influence the way a CH-related application is experienced, given the example of users mentioned by Lai et al. [27], who did not enjoy some educational material, as opposed to other older adults with higher education backgrounds, who did not report negative feelings. Although this example might not be strictly related to digital media as such (demanding material can be frustrating irrespective of the medium employed), however, adaptability to the user profile is a distinguishing feature of new, interactive technologies that, in such cases, could be taken advantage of by designing customized experiences tailored to users' profiles.

5. Conclusions

By conducting a literature review, this document has highlighted several key findings regarding the engagement of older populations with digital cultural heritage applications. Firstly, it highlights the significant role and potential of immersive technologies such as VR and AR in enhancing the CH experience for older adults. Our research suggests that the incorporation of these technologies can address physical and cognitive limitations, providing a more inclusive and engaging experience. The findings indicate that older adults are receptive to these technologies, especially when designed with their specific needs in mind. The results of our study have also revealed that older adults can play an active role not just as consumers but also as contributors to cultural heritage content. This participatory approach not only enriches the cultural heritage content with authentic narratives but also promotes a sense of belonging and engagement among older adults.

Apart from the main task of mapping the landscape of research in the specific field, this study aspires to contribute to the ongoing discussion by foregrounding some key findings and suggestions that transpire from this systematic literature review. This reflects the scope of the last (but not least) category of publications that elaborates on optimal ways of adapting VR/AR applications to older people's needs and profiles. As mentioned in the main text, the five categories used to organize the 24 papers surveyed are not

watertight or mutually exclusive. The overarching theme is how XR technologies can foster the engagement of the elderly with culture in ways that benefit them emotionally and cognitively. In this context, the importance of empowering older individuals to weave their contributions (e.g., narratives) into the fabric of (digital) cultural heritage is paramount. The input of older individuals should be perceived as an invaluable element that benefits both senior users emotionally, cognitively, and socially, as well as the quality of the digital resources that include their contributions. This approach that perceives the older adults as both beneficiaries and potential benefactors could informally be described as a win–win situation. Some interesting and insightful findings from this survey include the understanding that older users should not be perceived as needy people for which watered-down versions of CH resources or experiences should be designed and provided; on the contrary, some specific considerations on issues of physical comfort, sensory overload, and possible cybersickness should be taken into consideration. Nevertheless, older users are fully capable of enjoying immersive VR experiences and can be disappointed when confronted with applications whose content is not mentally challenging or sophisticated. A necessary precondition for such mutual enrichment and enhancement through the inclusion of older users' perspectives and experiences is that the applications should be aptly designed to match the elderly's needs, and for the same purpose, to enable them to offer their stories and views in interactive ways. Moreover, the focus is often on ensuring that CH-related XR experiences can be friendly and accessible for older adults. However, there is a danger of underestimating older users' expectations in relation to new technologies as a way to share, engage with, interpret, and relay cultural heritage. Older users can engage with digital CH resources from a position of strength, given their experience, rather than weakness, due to physical or health issues and limitations.

Furthermore, as Dickinson et al. [82] note, older adults have greater digital literacy than ever before, and the process of developing inclusive technologies for use must also consider general stigmatizing stereotypes that portray older adults as incapable of adapting to advancements. Moreover, XR can foster wellbeing for older people with physical or even cognitive decline [82], given that even such problems cannot stand in the way of enjoying or sharing narratives and savoring experiences. Conversely, XR can enhance perceived mobility and connect the elderly with other users, such as family members, using onsite digital applications, e.g., in a museum, as they enjoy a similar and shared experience, thereby fostering social interaction [30]. There is also another promising aspect—that of intergenerational interaction, which is often a pivotal element of CH applications and encourages communication and sharing of cultural knowledge [15], something that is mutually beneficial for both young and older users who interact in the context of such digital platforms.

Finally, the review identified studies that contain design considerations and guidelines for developing digital cultural heritage applications targeted at older audiences. These include the need for user-friendly interfaces, adaptive technologies that are tailored to various cognitive styles, and the integration of sensory affordances to enhance engagement and immersion. As a concluding remark, while the field of XR apps for engaging older audiences with CH appears narrow, the way to move forward in the quest to facilitate inclusive access to culture necessitates a comprehensive and interdisciplinary approach that spans across the categories listed in this article and beyond.

Author Contributions: Conceptualization, S.S. and G.P.; methodology, S.S. and A.A.; validation, S.S., P.D., A.A., G.P. and K.E.; resources, S.S.; data curation, S.S., P.D. and A.A.; writing—original draft preparation, S.S., A.A., G.P. and K.E.; writing—review and editing, P.D., S.S., A.A. and K.E.; supervision, S.S.; project administration, S.S.; funding acquisition, S.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research project is implemented in the framework of H.F.R.I called "Basic research Financing (Horizontal support of all Sciences)" under the National Recovery and Resilience Plan "Greece 2.0" funded by the European Union—NextGenerationEU (FIREFLY—Fostering Virtual Heritage Experience For Elderly, H.F.R.I. project number 15497).

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Ritchie, H.; Rodés-Guirao, L.; Edouard Mathieu, E.; Gerber, M.; Ortiz-Ospina, E.; Hasell, J.; Roser, M. Population Growth Published online at OurWorldinData.org. 2023. Available online: https://ourworldindata.org/population-growth (accessed on 15 April 2025).
2. Ritchie, H.; Roser, M. Age Structure online at OurWorldinData.org. 2019. Available online: https://ourworldindata.org/age-structure (accessed on 15 April 2025).
3. Eurostat Ageing Europe–Statistics on Population Developments. Eurostat. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Ageing_Europe_-_statistics_on_population_developments (accessed on 15 April 2025).
4. García-Mieres, H.; Parra, L.; Paz-Vázquez, L.M.; Castaño, E.; Pedrosa, I. Bridging Generations: The Power of Digitization and Social Innovation in Preserving Rural Cultural Heritage. *Innov. Eur. J. Soc. Sci. Res.* **2024**, *1*, 1–14. [CrossRef]
5. MacDonald, L. *Digital Heritage*; Routledge: London, UK, 2006.
6. Thomas, L.; Briggs, P. An Older Adult Perspective on Digital Legacy. In Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational, Helsinki, Finland, 26–30 October 2014; pp. 237–246.
7. Arias-Ferrer, L.; Egea-Vivancos, A. Thinking Like an Archaeologist: Raising Awareness of Cultural Heritage through the Use of Archaeology and Artefacts in Education. *Public Archaeol.* **2017**, *16*, 90–109. [CrossRef]
8. Sanagustín-Fons, M.V.; Tobar-Pesántez, L.B.; Ravina-Ripoll, R. Happiness and Cultural Tourism: The Perspective of Civil Participation. *Sustainability* **2020**, *12*, 3465. [CrossRef]
9. Smith, L. *Emotional Heritage: Visitor Engagement at Museums and Heritage Sites*; Routledge: London, UK, 2020.
10. Chatterjee, H.; Camic, C.M. Cultural Heritage and Well-Being: A Conceptual Framework. *J. Cult. Herit.* **2015**, *16*, 1–10.
11. Dibeltulo, S.; Culhane, S.; Treveri Gennari, D. Bridging the Digital Divide: Older Adults' Engagement with Online Cinema Heritage. *Digit. Scholarsh. Humanit.* **2020**, *35*, 797–811. [CrossRef]
12. UNESCO. *Convention for the Safeguarding of the Intangible Cultural Heritage*; UNESCO: Paris, France, 2003; Available online: https://ich.unesco.org/en/convention (accessed on 15 April 2025).
13. Dryjanska, L. A Social Psychological Approach to Cultural Heritage: Memories of the Elderly Inhabitants of Rome. *J. Herit. Tour.* **2015**, *10*, 38–56. [CrossRef]
14. Vecco, M. A definition of cultural heritage: From the tangible to the intangible. *J. Cult. Herit.* **2010**, *11*, 321–324. [CrossRef]
15. Chou, W.-H.; Li, Y.-C.; Chen, Y.-F.; Ohsuga, M.; Inoue, T. Empirical Study of Virtual Reality to Promote Intergenerational Communication: Taiwan Traditional Glove Puppetry as Example. *Sustainability* **2022**, *14*, 3213. [CrossRef]
16. Tremosa, L. Beyond AR vs. VR: What Is the Difference Between AR vs. Mr vs. VR vs. XR? *The Interaction Design Foundation.* Available online: https://www.interaction-design.org/literature/article/beyond-ar-vs-vr-what-is-the-difference-between-ar-vs-mr-vs-vr-vs-xr (accessed on 15 April 2025).
17. Margrett, J.A.; Ouverson, K.M.; Gilbert, S.B.; Phillips, L.A.; Charness, N. Older Adults' Use of Extended Reality: A Systematic Review. *Front. Virtual Real.* **2022**, *2*, 760064. [CrossRef]
18. Dordio, A.; Lancho, E.; Merchán, M.J.; Merchán, P. Cultural Heritage as a Didactic Resource through Extended Reality: A Systematic Review of the Literature. *Multimodal Technol. Interact.* **2024**, *8*, 58. [CrossRef]
19. Kitchenham, B.A.; Budgen, D.; Brereton, P. *Evidence-Based Software Engineering and Systematic Reviews*, 1st ed.; Chapman and Hall/CRC: Boca Raton, FL, USA, 2015. [CrossRef]
20. Innocente, C.; Ulrich, L.; Moos, S.; Vezzetti, E. A framework study on the use of immersive XR technologies in the cultural heritage domain. *J. Cult. Herit.* **2023**, *62*, 268–283. [CrossRef]
21. Dawson, P.; Levy, R.; Lyons, N. 'Breaking the Fourth Wall': 3D Virtual Worlds as Tools for Knowledge Repatriation in Archaeology. *J. Soc. Archaeol.* **2011**, *11*, 387–402. [CrossRef]
22. Cassar, G.; Avellino, M. Active Ageing in Practice—Seniors as Interpreters and Learners of Cultural Heritage. *Int. J. Educ. Ageing* **2017**, *4*, 5–17.

23. Traboulsi, C.; Frau, M.; Cabiddu, F. Active Seniors' Perceived Value within Digital Museum Transformation. *TQM J.* **2018**, *30*, 530–553. [CrossRef]
24. Colomer, L.; Erlingsson, C. Use of Cultural Heritage to Enhance Older People's Well-Being. In Proceedings of the 2018 International Conference on Cultural Heritage, Matera, Italy, 23–25 May 2018; Springer: Berlin/Heidelberg, Germany, 2018; pp. 1–5. [CrossRef]
25. Alelis, G.; Bobrowicz, A.; Ang, C.S. Comparison of Engagement and Emotional Responses of Older and Younger Adults Interacting with 3D Cultural Heritage Artefacts on Personal Devices. *Behav. Inf. Technol.* **2015**, *34*, 1064–1078. [CrossRef]
26. Yu, J.; Kim, S.; Hailu, T.B.; Park, J.; Han, H. The Effects of Virtual Reality (VR) and Augmented Reality (AR) on Senior Tourists' Experiential Quality, Perceived Advantages, Perceived Enjoyment, and Reuse Intention. *Curr. Issues Tour.* **2023**, *27*, 464–478. [CrossRef]
27. Lai, X.; Lei, X.; Chen, X.; Rau, P.-L.P. Can Virtual Reality Satisfy Entertainment Needs of the Elderly? The Application of a VR Headset in Elderly Care. In *Cross-Cultural Design. Culture and Society*; Rau, P.-L.P., Ed.; Springer: Cham, Switzerland, 2019; pp. 159–172. [CrossRef]
28. Kosti, M.V.; Benayoun, M.; Georgakopoulou, N.; Diplaris, S.; Pistola, T.; Xefteris, V.-R.; Tsanousa, A.; Valsamidou, K.; Koulali, P.; Shekhawat, Y.; et al. Connecting the Elderly Using VR: A Novel Art-Driven Methodology. *Appl. Sci.* **2024**, *14*, 2217. [CrossRef]
29. Fiocco, A.J.; Millett, G.; D'Amico, D.; Krieger, L.; Sivashankar, Y.; Lee, S.H.; Lachman, R. Virtual Tourism for Older Adults Living in Residential Care: A Mixed-Methods Study. *PLoS ONE* **2021**, *16*, e0250761. [CrossRef]
30. tom Dieck, M.C.; Jung, T.; Michopoulou, E. Experiencing Virtual Reality in Heritage Attractions: Perceptions of Elderly Users. In *Augmented Reality and Virtual Reality: The Power of AR and VR for Business*; tom Dieck, M.C., Jung, T., Eds.; Springer International Publishing: Cham, Switzerland, 2019; pp. 89–98. [CrossRef]
31. Luyten, T.; Braun, S.; Jamin, G.; van Hooren, S.; de Witte, L. How Nursing Home Residents with Dementia Respond to the Interactive Art Installation 'VENSTER': A Pilot Study. *Disabil. Rehabil. Assist. Technol.* **2018**, *13*, 87–94. [CrossRef]
32. Vishwanath, G. Enhancing Engagement through Digital Cultural Heritage: A Case Study about Senior Citizens Using a Virtual Reality Museum. In Proceedings of the 2023 ACM International Conference on Interactive Media Experiences, Nantes, France, 12–15 June 2023; pp. 150–156. [CrossRef]
33. Yi, X.; Liu, Z.; Li, H.; Jiang, B. Immersive Experiences in Museums for Elderly with Cognitive Disorders: A User-Centered Design Approach. *Sci. Rep.* **2024**, *14*, 1971. [CrossRef]
34. Buele, J.; Labre-Tarco, V.E.; López-Albuja, M.A.; Tapia-Ramos, V.; Palacios-Navarro, G. Advancements in Virtual Reality for Elderly Care: A Two-Decade Journey. In Proceedings of the 2023 IEEE Seventh Ecuador Technical Chapters Meeting (ECTM), Ambato, Ecuador, 10–13 October 2023; pp. 1–6. [CrossRef]
35. Ress, S.A.; Cafaro, F. "I Want to Experience the Past": Lessons from a Visitor Survey on How Immersive Technologies Can Support Historic Interpretation. *Information* **2021**, *12*, 15. [CrossRef]
36. Partarakis, N.; Klironomos, I.; Antona, M.; Margetis, G.; Grammenos, D.; Stephanidis, C. Accessibility of Cultural Heritage Exhibits. In *Universal Access in Human-Computer Interaction. Interaction Techniques and Environments*; Antona, M., Stephanidis, C., Eds.; Springer International Publishing: Cham, Switzerland, 2016; Volume 9738, pp. 444–455. [CrossRef]
37. Mokatren, M.; Kuflik, T.; Shimshoni, I. Exploring the Potential of a Mobile Eye Tracker as an Intuitive Indoor Pointing Device: A Case Study in Cultural Heritage. *Future Gener. Comput. Syst.* **2018**, *81*, 528–541. [CrossRef]
38. Moffat, D.C.; Shapiro, A. Serious Games for Interactive Stories about Emotionally Challenging Heritage. In Proceedings of the 2015 Digital Heritage Conference, Granada, Spain, 28 September–2 October 2015; Volume 2, pp. 709–712. [CrossRef]
39. Jia, W.; Li, H.; Jiang, M.; Wu, L. Melting the Psychological Boundary: How Interactive and Sensory Affordance Influence Users' Adoption of Digital Heritage Service. *Sustainability* **2023**, *15*, 4117. [CrossRef]
40. Caggianese, G.; Gallo, L.; Pietro, G.D. Design and Preliminary Evaluation of a Touchless Interface for Manipulating Virtual Heritage Artefacts. In Proceedings of the 2014 Tenth International Conference on Signal-Image Technology and Internet-Based Systems, Marrakech, Morocco, 23–27 November 2014; pp. 493–500. [CrossRef]
41. Abeele, V.V.; Schraepen, B.; Huygelier, H.; Gillebert, C.; Gerling, K.; Van Ee, R. Immersive Virtual Reality for Older Adults: Empirically Grounded Design Guidelines. *ACM Trans. Access. Comput.* **2021**, *14*, 1–30. [CrossRef]
42. Raptis, G.E.; Fidas, C.; Avouris, N. Effects of Mixed Reality on Players' Behaviour and Immersion in a Cultural Tourism Game: A Cognitive Processing Perspective. *Int. J. Hum.-Comput. Stud.* **2018**, *114*, 69–79. [CrossRef]
43. Raptis, G.E.; Fidas, C.; Avouris, N. Do Game Designers' Decisions Related to Visual Activities Affect Knowledge Acquisition in Cultural Heritage Games? An Evaluation from a Human Cognitive Processing Perspective. *J. Comput. Cult. Herit.* **2019**, *12*, 1–25. [CrossRef]
44. Raptis, G.E.; Fidas, C.; Katsini, C.; Avouris, N. A Cognition-Centered Personalization Framework for Cultural-Heritage Content. *User Model. User-Adap. Interact.* **2019**, *29*, 9–65. [CrossRef]
45. Anderson, E.F.; McLoughlin, L.; Liarokapis, F.; Peters, C.; Petridis, P.; De Freitas, S. Developing Serious Games for Cultural Heritage: A State-of-the-Art Review. *Virtual Real.* **2010**, *14*, 255–275. [CrossRef]

46. He, J.; Sui, D.; Li, L.; Lv, X. Fueling the Development of Elderly Care Services in China with Digital Technology: A Provincial Panel Data Analysis. *Heliyon* **2024**, *11*, e41490. [CrossRef]
47. Available online: https://www.statista.com/statistics/270163/age-distribution-in-china/ (accessed on 15 April 2025).
48. Silva, M.; Teixeira, L. eXtended Reality (XR) Experiences in Museums for Cultural Heritage: A Systematic Review. In *Intelligent Technologies for Interactive Entertainment*; Lv, Z., Song, H., Eds.; INTETAIN, 2021; Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering; Springer: Cham, Switzerland, 2022; Volume 429. [CrossRef]
49. Chaze, F.; Hayden, L.; Azevedo, A.; Kamath, A.; Bucko, D.; Kashlan, Y.; Dube, M.; De Paula, J.; Jackson, A.; Reyna, C.; et al. Virtual reality and well-being in older adults: Results from a pilot implementation of virtual reality in long-term care. *J. Rehabil. Assist. Technol. Eng.* **2022**, *9*, 20556683211072384. [CrossRef]
50. Kupczik, L.; Farrelly, W.; Wilson, S. Appraising Virtual Technologies' Impact on Older Citizens' Mental Health-A Comparative between 360° Video and Virtual Reality. *Int. J. Environ. Res. Public Health* **2022**, *19*, 11250. [CrossRef] [PubMed]
51. Fu, Y.; Hu, Y.; Sundstedt, V.; Forsell, Y. A Systematic Literature Review of Extended Reality Exercise Games for the Elderly. In *Biomedical Engineering Systems and Technologies. BIOSTEC 2022. Communications in Computer and Information Science*; Roque, A.C.A., Gracanin, D., Lorenz, R., Tsanas, A., Bier, N., Fred, A., Gamboa, H., Eds.; Springer: Cham, Switzerland, 2023; Volume 1814. [CrossRef]
52. Healy, D.; Flynn, A.; Conlan, O.; McSharry, J.; Walsh, J. Older Adults' Experiences and Perceptions of Immersive Virtual Reality: Systematic Review and Thematic Synthesis. *JMIR Serious Games* **2022**, *10*, 35802. [CrossRef] [PubMed]
53. Antoniou, A.; Vassilakis, C.; Kantianis, G.; Sylaiou, S.; Kolokithas, G. Virtual Cultural Experiences for the Elderly: Formative Studies and First Findings Regarding Cultural Content. *Appl. Sci.* **2025**, *15*, 1820. [CrossRef]
54. Sekhon, H.; Dickinson, R.A.; Kimball, J.E.; Cray, H.V.; Alkhatib, F.; Preston, A.; Moore, I.; Trueba-Yepez, A.F.; Fahed, M.; Vahia, I.V. Safety Considerations in the Use of Extended Reality Technologies for Mental Health with Older Adults. *Am. J. Geriatr. Psychiatry* **2024**, *32*, 648–651. [CrossRef]
55. Maeng, S.; Hong, J.P.; Kim, W.H.; Kim, H.; Cho, S.-E.; Kang, J.M.; Na, K.-S.; Oh, S.-H.; Park, J.W.; Bae, J.N.; et al. Effects of virtual reality-based cognitive training in the elderly with and without mild cognitive impairment. *Psychiatry Investig.* **2021**, *18*, 619. [CrossRef]
56. Chiang, K.-J.; Chu, H.; Chang, H.-J.; Chung, M.-H.; Chen, C.-H.; Chiou, H.-Y.; Chou, K.-R. The Effects of Reminiscence Therapy on Psychological Well-Being, Depression, and Loneliness among the Institutionalized Aged. *Int. J. Geriatr. Psychiatry* **2010**, *25*, 380–388. [CrossRef]
57. Lazar, A.; Thompson, H.; Demiris, G. A Systematic Review of the Use of Technology for Reminiscence Therapy. *Health Educ. Behav.* **2014**, *41*, 51S–61S. [CrossRef]
58. Gonzalez, J.; Mayordomo, T.; Torres, M.; Sales, A.; Meléndez, J.C.; Brodaty, H. Reminiscence and dementia: A therapeutic intervention. *Int. Psychogeriatr.* **2015**, *27*, 1731–1737. [CrossRef]
59. Strong, J. Immersive virtual reality and persons with dementia: A literature review. *J. Gerontol. Soc. Work.* **2020**, *63*, 209–226. [CrossRef]
60. Gaugne, R.; Barreau, J.B.; Lécuyer, F.; Nicolas, T.; Normand, J.M.; Gouranton, V. eXtended Reality for Cultural Heritage. In *Handbook of Cultural Heritage Analysis*; D'Amico, S., Venuti, V., Eds.; Springer: Cham, Switzerland, 2022. [CrossRef]
61. Chong, H.T.; Lim, C.K.; Rafi, A.; Tan, K.L.; Mokhtar, M. Comprehensive systematic review on virtual reality for cultural heritage practices: Coherent taxonomy and motivations. *Multimed. Syst.* **2021**, *28*, 711–726. [CrossRef]
62. Seifert, A.; Schlomann, A. The Use of Virtual and Augmented Reality by Older Adults: Potentials and Challenges. *Front. Virtual Real.* **2021**, *2*, 639718. [CrossRef]
63. Appel, L.; Appel, E.; Bogler, O.; Wiseman, M.; Cohen, L.; Ein, N.; Abrams, H.B.; Campos, J.L. Older Adults With Cognitive and/or Physical Impairments Can Benefit from Immersive Virtual Reality Experiences: A Feasibility Study. *Front. Med.* **2020**, *6*, 329. [CrossRef] [PubMed]
64. Arns, L.L.; Cerney, M.M. The Relationship Between Age and Incidence of Cybersickness Among Immersive Environment Users. In Proceedings of the 2005 IEEE Proceedings of Virtual Reality, VR, Bonn, Germany, 12–16 March 2005; IEEE: New York, NY, USA, 2005; pp. 267–268.
65. Cinalioglu, K.; Lavín, P.; Bein, M.; Lesage, M.; Gruber, J.; Se, J.; Bukhari, S.; Sasi, N.; Noble, H.; Andree-Bruneau, M.; et al. Effects of virtual reality guided meditation in older adults: The protocol of a pilot randomized controlled trial. *Front Psychol.* **2023**, *14*, 1083219. [CrossRef]
66. Matsangidou, M.; Solomou, T.; Frangoudes, F.; Ioannou, K.; Theofanous, P.; Papayianni, E.; Pattichis, C.S. Affective out-world experience via virtual reality for older adults living with mild cognitive impairments or mild dementia. *Int. J. Environ. Res. Public Health* **2023**, *20*, 2919. [CrossRef]
67. Cotten, S.R. Technologies and Aging: Understanding Use, Impacts, and Future Needs. In *Handbook of Aging and the Social Sciences*; Carr, D., Ferraro, K.F., Eds.; Academic Press: New York, NY, USA, 2021.

68. Davis, S.; Nesbitt, K.; Nalivaiko, E. A Systematic Review of Cybersickness. In Proceedings of the 2014 Conference on Interactive Entertainment IE2014, New York, NY, USA, 2 December 2014; Association for Computing Machinery: New York, NY, USA, 2014; pp. 1–9. [CrossRef]
69. Gödde, M.; Gabler, F.; Siegmund, D.; Braun, A. Cinematic Narration in VR—Rethinking Film Conventions for 360 Degrees. In *Virtual, Augmented and Mixed Reality: Applications in Health, Cultural Heritage, and Industry*; Chen, J., Fragomeni, G., Eds.; VAMR 2018; Lecture Notes in Computer Science; Springer: Cham, Switzerland, 2018; Volume 10910. [CrossRef]
70. Vergo, P. *The New Museology*; Reaktion Books: London, UK, 1989.
71. Bedford, L. Storytelling: The Real Work of Museums. *Mus. J.* **2001**, *44*, 27–34. [CrossRef]
72. Hein, G.E. *Learning in the Museum*; Routledge: London, UK, 1998.
73. Hooper-Greenhill, E. *Museums and the Interpretation of Visual Culture*; Routledge: London, UK, 2000.
74. Cameron, D.F. *The Museum: A Temple or the Forum*; University of Calgary Press: Calgary, AB, Canada, 2004.
75. Hansen, A.; Zipsane, H. Older People as a Developing Market for Cultural Heritage Sites. *J. Adult Contin. Educ.* **2014**, *20*, 137–143. [CrossRef]
76. Pavlović, D. Digital Tools in Museum Learning—A Literature Review from 2000 to 2020. *Facta Univ. Ser. Teach. Learn. Teach. Educ.* **2022**, *5*, 167–178. [CrossRef]
77. Ismaeel, D.A.; Al-Abdullatif, A.M. The Impact of an Interactive Virtual Museum on Students' Attitudes Toward Cultural Heritage Education in the Region of Al Hassa, Saudi Arabia. *Int. J. Emerg. Technol. Learn. (iJET)* **2016**, *11*, 32–39. [CrossRef]
78. Daniela, L. Virtual Museums as Learning Agents. *Sustainability* **2020**, *12*, 2698. [CrossRef]
79. Taipale, S.; Oinas, T.; Karhinen, J. Heterogeneity of traditional and digital media use among older adults: A six-country comparison. *Technol. Soc.* **2021**, *66*, 101642. [CrossRef]
80. Bagchi, K.; Hart, P.; Peterson, M.F. National culture and information technology product adoption. *J. Glob. Inf. Technol. Manag.* **2004**, *7*, 29–46. [CrossRef]
81. Schroeder, T.; Dodds, L.; Georgiou, A.; Gewald, H.; Siette, J. Older Adults and New Technology: Mapping Review of the Factors Associated with Older Adults' Intention to Adopt Digital Technologies. *JMIR Aging* **2023**, *6*, e44564. [CrossRef] [PubMed]
82. Dickinson, R.; Fahed, M.; Sekhon, H.; Faruque, S.; Kimball, J.; Gupta, S.; Handa, I.; Alkhatib, F.; Singh, A.; Vahia, I. Extended Reality and Older Adult Mental Health: A Systematic Review of the Field and Current Applications. *Amer. J. Geriatr. Psych.* **2024**, *32*, S130. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.