

Article

Evaluating Older Adults' Engagement with Digital Interpretation Exhibits in Museums: A Universal Design-Based Approach

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Abstract: This paper develops and presents a system for museums to evaluate behavioural and experiential gains of older adult visitors when engaging with digital interpretation exhibits. The evaluation system is based on the Analytic Hierarchy Process (AHP), utilising existing evaluation methods for museum visitors and refining them into an approach suitable for investigating older visitors. Innovatively, it incorporates the universal design (UD) in museum digital exhibits, injecting strong momentum into creating inclusive museums. An in-depth evaluation was conducted on seven exhibitions across three newly constructed Chinese cultural tourism museums with different digital characteristics, presenting the results and findings through eighty-eight digital interpretation exhibits. Qualitative and quantitative data provide a nuanced picture of digital interpretation and interaction from the perspective of older visitors. The results demonstrate the factors influencing older adults' engagement with digital interpretation exhibits in museums and how digital interpretation items attract or deter older visitors' engagement in complex exhibition environments. This study utilised universal design principles to identify the limitations and barriers in digital interpretation for older visitors, analysed the correlation between UD and digital attraction power, explored the reasons behind these outcomes, and identified design recommendations for inclusive museum digital interpretation.

Keywords: cultural heritage tourism; digital interpretation; inclusive museums; older museum visitors; universal design; visitor engagement



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1. Introduction

The global population is ageing. According to the World Health Organisation (WHO)'s projection for 2011, by 2050, the population aged 65 and above worldwide is expected to reach approximately 1.5 billion [1]. Societies worldwide are encountering an ageing population with unique social and cultural needs [2]. Additionally, data from the Seventh National Population Census reveals that the educational level of China's elderly population is expected to rise from 2020 to 2050, accompanied by an increase in cultural and spiritual needs among the ageing population [3]. Older adults are emerging as a new demographic with potential for cultural tourism and museum visits. Projections indicate that by 2030, the elderly population will surpass that of children and adolescents aged 0–14, becoming the new potential museum visitors [2].

As an activity aimed at enhancing public awareness and improving public understanding of cultural heritage and the planned dissemination of heritage and culture, the interpretation and presentation of heritage have long been regarded as one of the key tasks in the protection of national and international cultural and natural heritage, as well as an essential component of the heritage conservation process [4]. Museums are one

of the important venues for displaying heritage. Cultural tourism museums, as public cultural spaces that offer leisure and educational resources to citizens, have increasingly attracted older adults. These individuals choose to visit museums during their leisure time to fulfil various objectives, such as relaxation, pursuing hobbies, and gaining a sense of achievement [3]. Simultaneously, older adults are among the most significant domestic and international tourist groups, playing a particularly vital role in cultural tourism and consumption [5,6]. Museums provide older adults with opportunities for social interaction, experiential learning, and the acquisition of new knowledge, thereby enhancing their self-esteem and sense of identity and effectively reducing social isolation and anxiety [5,6]. Museums have the potential to play a significant role in supporting the ageing needs of older adults [7], and visiting museums can contribute to addressing “active ageing” [2]. Museums that operate on the principle of “serving all people” [8–10] must take special considerations for the elderly to better fulfil their social responsibility of providing spiritual and cultural services [11]. Digital technologies are being widely applied in the interpretation and presentation process at cultural heritage sites and museums to enhance visitor experiences and promote inclusivity, addressing this challenge [2,4,8].

In the digital era, digital technologies are widely applied to enhance museum inclusive design and visitor experience, serving as a crucial means to promote visitor diversity and the sustainable development of cultural heritage [8,12–14]. Extensive research has demonstrated positive correlations between digital media interaction, inclusive museum design, and the experiences of older adult visitors [4,11,14,15]. Digital interpretation and interaction merge traditional displays with digital technology, transforming static, singular information delivery into a multi-temporal and multisensory exhibition format that enhances visitor experience and cultural communication [16–19].

However, there is a notable lack of focus on older visitors. Specifically, to pique visitors’ interest and cater to the new generation of young tourists, museums have adopted novel and logically complex digital interpretation interactive devices that emphasise user experience [16,20]. This approach overlooks the cognitive abilities and usage habits of elderly groups regarding digital devices [3,11,21], potentially making older adults less adaptable to adopting digital technologies [14]. Extensive research on museums and digital experiences lacks empirical studies from the perspective of older visitors.

Thus, this study aims to develop a systematic evaluation of older adults’ visiting experiences to achieve the following objectives: (1) to explore the factors and characteristics of digital interpretation exhibits that help motivate engagement and enhance visiting experiences among older adults in museums; (2) to identify the barriers and limitations in digital interpretation encountered by elderly visitors during museum visits; and (3) to provide new perspectives and recommendations for museum researchers and builders to create an exhibition environment suitable for older visitors, ensuring all can enjoy a positive experience, thereby promoting inclusive cultural tourism.

To better achieve the research objective of inclusivity, universal design principles were incorporated into this evaluation system. Everyone in society has the right to enter museums and enjoy equal services and experiences [8,10]. Museum exhibition designs are no longer created solely for individual users or specific user groups, such as children, students, or older adults. Instead, they aim to actively address the diversity of potential visitors by catering to the varied needs, demands, and interests of different age groups and visitor characteristics [16], creating a high-quality exhibition environment for all museum visitors. This museum concept follows universal design principles: creating products and environments that are usable by all people, to the greatest extent possible, without the need for adaptation or specialised design [22–27].

Compared to other public cultural architecture, the seven principles of universal design (7UD) are reflected in the physical environment of museum architecture and exhibition spaces, as well as in the content of the exhibitions, to ensure effective communication [28–31]. This study begins with an examination of the behavioural characteristics and emotional needs of older visitors. It utilises the UD evaluation checklist throughout the assessment process to meticulously analyse the design and environmental factors of digital interpretation in museums and their influence on the engagement of older visitors.

This study comprises two parts. The first part focuses on developing the evaluation system. Utilising a literature review and the Analytic Hierarchy Process (AHP) method [32], this study identifies factors related to digital interpretation that influence older visitors' behaviour and experience during exhibitions and assigns criterion weights from a structured and objective standpoint [33,34]. The second part involves empirical research, utilising a research design merging qualitative and quantitative methods. This integrates User Experience Evaluation methods [35,36] and the Post-Occupancy Evaluation Framework for built environments [37]. The innovative evaluation system has adjusted these methods to better fit investigations involving older visitors. This includes replacing traditional questionnaires [4] with laddering interviews [35], substituting scenario access [38] with contactless behavioural observations [39], to enhance this study's reliability and objectivity through heuristic expert evaluations [25].

To gain as comprehensive an understanding as possible of the behaviour characteristics and experiences of older visitors when interacting with digital interpretation in exhibition environments, this study selected three different types of cultural tourism museums in distinct Chinese tourist cities: the Shanghai Museum East Branch, the Suzhou Museum West Branch, and the Chiangnan Watery Region Culture Museum of China.

This study included 88 sets of digital interpretation exhibits, and data from 456 older visitors was recorded, with 31 visitors participating in interviews. The results are divided into three parts: (1) analysis of factors and indicators that influence older visitors' engagement in the exhibition environment; (2) analysis of the features of digital interpretation exhibits and their appeal to older visitors and their relationship with the seven principles of UD, as well as the identification of barriers and reasons for older visitors' engagement; and (3) an analysis of the interests, motivations, and needs of older visitors, along with the characteristics of digital exhibits that align with the behaviour and affective needs of older adults. The Discussion Section presents the various benefits and limitations of this comprehensive evaluation system, offering museum builders and researchers new perspectives and design recommendations for inclusive museums.

This study contributes to the knowledge in several fields, including museum cultural tourism, inclusive design, exhibition design, and multimedia interactive design. The evaluation system, which pertains to the UD paradigm for evaluating exhibition environments and visitor engagement, can be beneficial for other researchers. Furthermore, it aims to surmount barriers such as a lack of interest or motivation in cultural tourism among older visitors while addressing their psychological and spiritual needs to help them achieve a sense of happiness and fulfilment. This aligns with the contemporary shift in heritage interpretation practices, which increasingly prioritise accessibility and inclusivity in digital cultural dissemination.

2. Literature Review

2.1. Theoretical Background

To identify the theoretical framework and establish a standardised evaluation system, we conducted a systematic literature review to comprehensively examine and organise

topics such as digital media, cultural tourism, museum exhibitions, and visitor experiences [8,40]. During the data collection stage, Scopus literature data was used to set the search strategy based on three keywords: (museum, cultural tourism), (inclusive design, universal design), and (digital, visitor experience). Google Scholar was used for supplementary searches and literature supplementation.

After eliminating entries related to virtual museums/online museums, museum guide systems, and other content unrelated to museum exhibition design, we compiled a list of 265 articles spanning the period from 2003 to 2024.

Under the context of cultural tourism, research trends in museum exhibitions and digital interpretation primarily focus on four themes: (1) multimedia and experience design in museums; (2) sustainability of cultural heritage and cultural tourism; (3) museum visitors and informal learning; and (4) evaluation of museum visitor experiences. However, there are only eight articles addressing the topic of older adults in cultural tourism and museums. All of them, including four review articles, are based on extensive research concerning digital technology or digital storytelling aimed at enhancing older adults' participation in cultural tourism. These applications are relevant to various scenarios, such as museum exhibitions, museum tourism, digital guides, community museums, and other related domains [2,9,11,14,41–44]. This represents a research gap that overlooks evaluating the digital experiences of elderly visitors during museum visits to promote inclusive cultural tourism. This clarifies the scope of this study. Our literature review explores factors influencing the interests and participation behaviours of elderly museum visitors within these topics.

2.2. Museum Visitor Research and Older Visitors

Visitors enter a museum with excitement and anticipation, eager to experience personalised forms of participation and viewing that transcend time and space, gaining inspiration, surprise, and challenge [45]. Since the inception of museum visitor research based on the museum fatigue theory in 1916 [34], scholars from various fields have increasingly focused on museum visitors and their experiences. The focus of museum exhibitions has shifted from objects to people.

Bitgood proposed three factors that influence visitors' behaviour: design factors, environmental factors, and visitor factors [46]. The behaviour exhibited during visits represents the visitor's perception of exhibition information within the museum environment, leading to behavioural responses after cognitive and emotional processing [34,47]. Thus, the exhibition environment, which impacts visitors' behaviour and experience, encompasses both the physical aspects, like exhibit configurations and exhibition technologies, and the psychological factors, including motivations, expectations, and perceptions [29].

Against this backdrop of research, studies on visitor segmentation in museums have been increasing annually. Particularly in research that utilises digital interpretation and interactive technologies to enhance visitor experiences, scholars' interests have predominantly focused on adult visitors [48] and family visitors [49,50], children [39,51,52], and students [53]. However, the visiting experience of older adults is rarely mentioned. Most tourism departments, including museums, tend to overlook senior visitors and treat them similarly to other tourists [11].

As the global average age increases and healthcare advancements enable people to enjoy longer, healthier lives, the elderly have emerged as a significant consumer demographic with considerable disposable income [11] and a key consumer group for cultural tourism services [14]. According to the WHO, individuals aged 60 or above are generally classified as the elderly in developing countries. This study utilises China's elderly population as the research sample, with 60 years or older identified as the age criterion for older

adults, corresponding to China's retirement age [54]. However, because of the continuous deterioration of cognitive abilities and mobility in older adults, older users require more time and mental effort to complete tasks compared to younger users [55]. Many digital interactive devices in contemporary exhibitions are crafted and engineered with a focus on teenagers and young users, often overlooking the cognitive patterns and usage habits of older adults concerning digital and media devices. Surveys reveal that older visitors have notably lower engagement levels with digital interpretation and interactive exhibits [3].

Visitors, including older ones, are drawn to and retain information from museum exhibitions not only because of the quality of the exhibits [29] or their positioning within the layout, but also because of the structure of the remaining available space. This space affects exploratory movements, visual engagement, and active participation with the exhibits [56]. Moreover, it pertains to the interplay of social and behavioural factors that shape how visitors perceive and utilise these elements [57]. When considering the behavioural experience of older visitors, it is essential to account not only for personal perceptions and motivational traits but also to give special attention to environmental factors, such as the information load of exhibitions, accessibility, and the recognisability of digital environments. These factors influence older visitors' attention and willingness to engage, rather than the interactivity and interest of digital exhibits [15,34].

In previous studies, the focus of visitor research has typically been on the outcomes of visits, such as "learning outcomes [58,59]", "satisfaction [60,61]", and "experience [4,35,62,63]". In contrast, the attention value model focuses on the conditions that generate these outcomes, specifically examining the interaction between visitors' factors, psychological processes, and environmental contexts [34,64–66]. Thus, this study uses the attention value model to focus on the characteristics of exhibition design elements and environmental features, capturing older visitors' interest points and attention traits.

2.3. Museum Exhibitions, Universal Design (UD), and Digital Interpretation

Modern museums have evolved into cultural and educational institutions that are accessible to all of society, allowing individuals of any age, culture, belief, ethnicity, or social class to become museum visitors. Some studies have introduced UD into museum and exhibition design. The aim is to promote museum visits as a cultural tourism activity, to better reflect the diversity of its potential visitors, and to take action [8,10,16,22,38]. UD, initially developed for physical products and environments, was later adapted for digital products as well. It was formalised in 1997 and considered for the evaluation of museum architecture [10,67], with the belief that it aids in creating a more inclusive museum environment for everyone. The interpretation of the seven universal design principles in an exhibition is as follows [10,15,22,31,68,69]:

- UD1: Equitable Use.

In museum design, designing inclusively aims to provide opportunities for cultural participation to visitors of all types. Exhibition design responds to the needs of everyone, encompassing both form and content.

- UD2: Flexibility in Use.

Exhibitions that utilise multiple dissemination methods can cater to the preferences of various users. Visitors are permitted to choose from several route options, sequences, and spatial–temporal arrangements. Flexibility is equally important for both the exhibition content and the exhibition space.

- UD3: Simple and Intuitive Use.

Intuitive content, operation instructions, and wayfinding systems are suitable for everyone. For each visitor, the layout, functionality, and theme of the exhibition should

be clear, with spatial configuration and information readability allowing them to see or anticipate activities and information within the space.

- UD4: Perceptible Information.

When various display modes are combined, communication becomes effective. Information is presented in a multisensory format, catering to different types of visitors and ensuring it can be understood and accepted by individuals with varying cognitive levels.

- UD5: Tolerance for Error.

The exhibition environment and configuration should be free from risks, and the erroneous behaviour of visitors should be prevented to the greatest extent possible.

- UD6: Low Physical Effort.

Exhibition design should minimise fatigue and repetitive motions. For instance, the layout should not necessitate unnecessary walking or prolonged viewing in the same posture, which may lead to fatigue and discomfort.

- UD7: Size and Space for Approach and Use.

The spatial solution for the exhibition hall must accommodate a wide range of user groups. The exhibits and configurations should be visible, accessible, and easy to reach for both standing and seated users, including individuals of varying body types, such as children and older adults.

The application of UD in museums involves designing exhibition content, environments, digital interpretation, and services to be as accessible as possible to all individuals, without requiring adaptation or specialised design. This study posits that UD principles are a crucial component of visitor engagement and inclusivity in various museums. Consequently, when evaluating the engagement behaviours of older visitors in the exhibition environment, the requirements of UD were taken into consideration.

In the past, most traditional museums worldwide presented historical information in overly formal and official, academic, and excessively high-information-load formats [11,70]. The emergence of the cultural tourism museum concept, which emphasises interactive, immersive, and personalised experiential promotional philosophies, is breaking with tradition [16,20,71]. The integration of novel, interactive digital media with exhibition design has become a defining characteristic of contemporary, newly built museums [11].

Early digital media technologies were utilised in exhibitions to expand and interpret content for visitors within limited spaces, such as through query screens, kiosks, and televisions [17,18,71]. Advancements in display technologies and the introduction of innovative digital media interpretation and interactive technologies have enabled museums to offer visitors a more diverse and interactive experience. Techniques such as digital projection, virtual reality, and 3d scanning have been applied to museum exhibitions, which employ approaches like storytelling, gamification, contextualised audiovisuals, engaging interactive games, and multi-format interactive queries for output, among other digital interpretation devices and digital spaces that emphasise interaction and experience [16,18–20,51,72–75].

Current research suggests that exhibition environments integrating digital interpretation and interaction have become increasingly complex in their structure [20]. Digital technologies add a digital dimension to the physical, spatial, temporal, and informational dimensions, creating a new information space [16,17,72], which is not merely a simplistic interpretation of the physical and digital [76]. The primary responsibility of museum exhibitions is information communication, where external visual materials and internal display content of digital installations serve as the medium connecting information with visitors [56,77]. The exhibit configuration, engagement formats, content framework, and

signage of digital media have also become concrete carriers of information that can attract visitors' attention and stimulate engagement [34,64,78,79], as well as focal points for interaction with visitor behaviour.

In the realm of the physical environment, the spatial configuration, route arrangement, scale, and colour scheme of digital interpretation are pivotal in determining whether it can capture visitors' attention [29,34,49,64,65,80,81]. The visual materials and content of digital interaction are crucial in deciding whether visitors will remain and engage deeply [64–66,82,83]. Previous studies have emphasised the influence of exhibition factors on visitor experience. Nevertheless, research into the digital experiences of older visitors remains necessary to promote inclusive design in museums.

2.4. Museum and Visitor Experience Evaluation

From the perspective of museums, exhibition features—including content texts, visual materials, objects, accessibility, and digital interpretations—combine to produce the intended exhibition, which reflects how the museum hopes visitors will perceive it [35,63,81]. Whether these outcomes meet the design expectations is determined through exhibition evaluation, which essentially consists of visitor feedback [35]. Extensive research has been conducted on the evaluation of museum exhibitions and digital technologies. Nonetheless, these prevalent evaluation practices are not without their issues [35].

Firstly, evaluations from satisfaction surveys and visitor studies have accumulated a significant amount of data on the complex identities of visitors. However, they rarely explore the specific ways these visitors interact with exhibits and exhibitions [84]. Li (2024) evaluated children's interaction with digital exhibits, focusing on the quality of children's engagement with multimedia exhibits rather than the comprehensive digital experience based on the exhibition environment [39]. Whether visitors are attracted to digital exhibits and decide to interact is influenced by both the overall exhibition environment and their attentional characteristics [29,56,66]. Thus, this study aims to propose an evaluation system that evaluates older visitors' experience of digital interpretation and presentation technologies within the exhibition context, considering the impact of environmental factors with the intervention of digital technologies on older visitor engagement behaviours.

Secondly, another theme that emerged from our literature review indicates that user experience (UX) is the most pertinent topic in the realm of digital interaction within museums. Norman (1981) proposed the user experience (UX) perception in the field of product design, dividing user experience into three levels: visceral level, behavioural level, and reflective level [85]. At the visceral level, the sensory perspective, such as vision, hearing, smell, taste, and touch, often belongs to instinct, representing the instinctive response of the user when stimulated. The behavioural level controls the operational aspects of physical actions, while the reflective level is governed by the cognitive system, which is responsible for interpreting and processing information, such as learning and memory [35,85]. This concept has been widely applied in the field of design, including museum exhibitions and digital media design. Mason (2020) used this as the theoretical foundation to propose a museum experience design methodology [16], while King (2024) employed UX theory as the basis to develop an evaluation method for museum exhibition experiences [35]. UX encompasses a range of evolving concepts, including aesthetic and hedonic emotional variables, placing a greater emphasis on the psychological dimensions of visitors, and it has been widely utilised in the evaluation of museum visits [35]. The relevant research findings once again underscore the diversity of experiences within museum environments, encompassing learning, enjoyment, satisfaction, a sense of value, and emotions [39,58]. Zhang (2018) investigated the relationship between motivation, a museum's physical environment, and satisfaction based on UX questionnaire surveys [36]. Liu (2022) assessed visitors' experiences and attitudes

towards digital heritage interpretation using a questionnaire-based UX [4]. Nevertheless, there has been limited research into the interplay between motivation, digitally interpreted environmental composition, and behavioural experience within user experience research, frequently neglecting the impact of environmental factors and individual characteristics (both physical and psychological) on the experiential outcomes.

However, scholars studying environmental behaviour often explore preferences and behaviours holistically [86]. The behavioural characteristics of visitors in exhibition environments are considered key indicators for evaluating the effectiveness of exhibitions, and behavioural observation is regarded as the most commonly used method for museum audience research [37,49]. Taiwanese scholar Shiang (2015) combined traditional museum behavioural observation methods with visitors' behaviours using the IAE (Ignore, Attend, and Engage) Scale to quantitatively analyse the relationship between visitors' behaviour preferences and exhibition environments [87]. "Attraction power (AP)" and "Holding Power" are significant metrics utilised by museum scholars to study visitor behaviour [49,88]. Lo (2023) applied exhibition appeal to assess various types of visitors' participation with digital technologies in natural history museums [80], while LI (2024) used "Average Holding Time" to evaluate children's digital engagement in science museums [39]. Although the existing research has identified the impact of environmental factors on specific types of visitor behaviours, there remains a lack of standardised systems to investigate the underlying causes of visitor actions, thus overlooking the inclusive nature of museums designed for all.

Evaluating digital technologies and user experience in museums involves various assessment methods, including exhibition walkthroughs, non-contact behavioural observations, UX evaluations, satisfaction questionnaires, interviews, and so forth. These are commonly used techniques [4,17,35,37,89]. In recent years, measurement tools for evaluating the digital interpretation information space and visitor experience have also incorporated Semantic Differential scales. However, these scales rely on verbal assessments, making their outcomes susceptible to the influence of respondents' educational backgrounds and comprehension abilities, which can easily introduce biases [35]. Considering the comprehension abilities, knowledge backgrounds, and psychological defensiveness of older adults, this study avoids using assessment tools that require text reading, such as questionnaires and semantic analysis scales. Instead, it employs non-contact observation and semi-structured and ladder interviews, conducts evaluations based on scales and checklists, and identifies the influence of various factors through expert questionnaires.

Built upon the discussions of the aforementioned topics, this study proposes a novel evaluation procedure and system designed to assess digital interpretation and interaction within exhibition settings. It specifically targets the engagement behaviours and visiting experiences of older visitors when they encounter digital interpretation exhibits. The evaluation encompasses whether they are attracted to digital interpretation, choose to engage with it, and experience positive interactions. The system considers the interplay between the individual characteristics of older adults and the environmental contexts. It integrates UD, thereby bolstering inclusive design in museums and offering pertinent suggestions for enhancement.

Figure 1 illustrates the composition of the evaluation system. Based on the specificity of the exhibition environment, which comprises digital media interpretation, literature research, and expert evaluation results, the system selected three assessment indicators: indicator 1—exhibition design features, encompassing digital interpretation and interactive exhibits within the exhibition environment, which include physical attributes and information space characteristics; indicator 2—exhibition of environmental characteristics constituted by digital interpretation, encompassing both the psychological and physiologi-

cal levels; and indicator 3—behavioural preferences and characteristics of older visitors. Three experts were invited to evaluate the factors influencing the engagement in digital interpretation of older adults. Ultimately, based on the three major indicators, an evaluation hierarchy comprising 25 factors across 9 dimensions was established. It was used in subsequent research, as shown in Figure 2. Please see Appendix A, Table A1, for details.

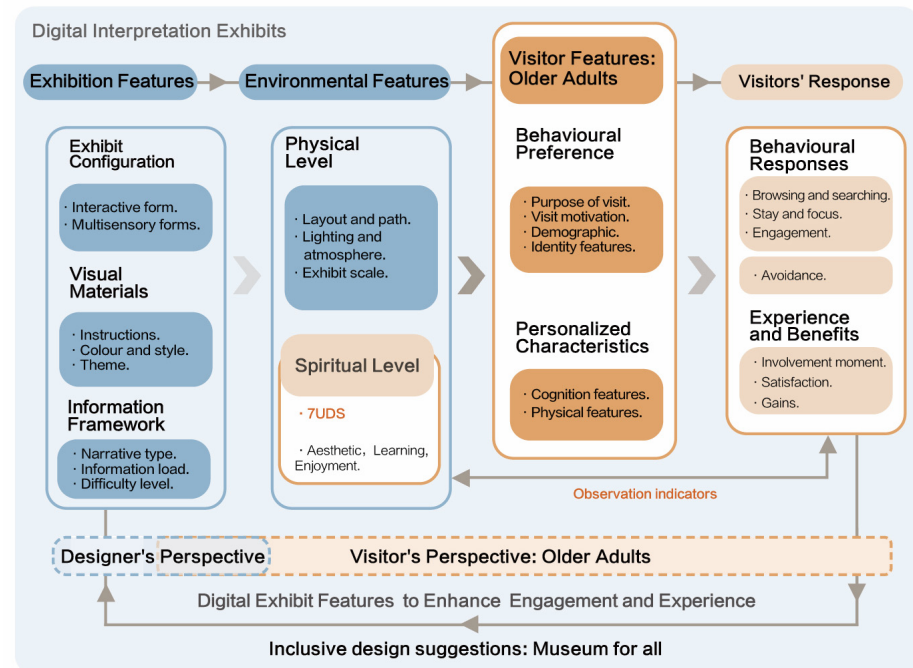


Figure 1. Evaluation system for digital interpretation in exhibition environments.

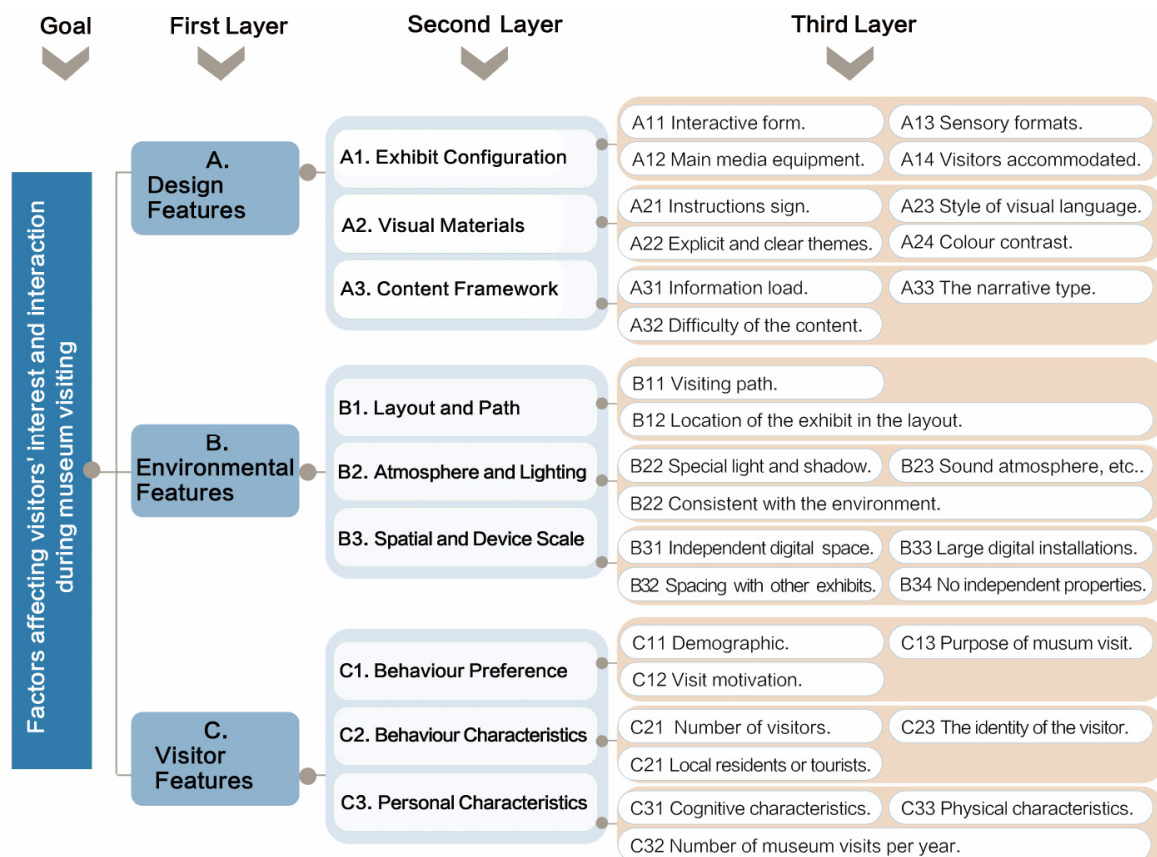


Figure 2. The factors of digital interpretation influencing visitors' interests and interactive behaviours.

3. Materials and Methods

3.1. Case Studies and Research Scope

3.1.1. Case Studies

This study was conducted in three newly built cultural tourism museums in mainland China. The criteria for selecting the cases were as follows: (1) museums that were constructed in China within the past five years, focusing on cultural heritage and communication, which extensively employ digital interpretation and interactive technologies; (2) museums situated in famous tourist cities and those that are community-based with a foundation of local visitors; and (3) museums recognised by the China Museums Association as being among the most popular in China. Table 1 presents the information and characteristics of these museums.

Table 1. The information and characteristics of the museums used for the case studies.

Name of the Museum	City and Year	Museum Features
Suzhou Museum West Branch • International Hall. • Historical and Cultural Hall.	SuZhou 2021	Suzhou is a renowned tourist city in China. This museum won the 2022 National Top Ten Museum Exhibition Excellence Award; it interprets Suzhou's regional culture and heritage through various digital interpretation devices, and the thematic exhibition in the International Hall features popular digital interpretation technologies.
Shanghai Museum East Branch • Ancient Bronze Gallery. • Ancient Chinese Jade Gallery. • Chinese Numismatics Gallery. • Ancient Ceramics Gallery.	ShangHai 2024	The newly completed Shanghai Museum East Branch is dedicated to displaying ancient Chinese art and cultural heritage. Its promotional focus is on creating a "visitor-friendly" and "digitally intelligent" museum, which attract large numbers of residents, tourists, and culture enthusiasts of all age groups.
Chiangnan Watery Region Culture Museum of China • Basic Exhibition Hall.	HangZhou 2022	Chiangnan Watery Town's unique cultural and architectural heritage earned it the 2022 China Museum Top Ten Exhibition Excellence Recommendation Prize. The exhibition employs extensive digital media to interpret and display heritage and culture, and it has also been unanimously praised by the industry.

3.1.2. Scope of This Research

The research scope is defined from the perspective of museum exhibition spaces, encompassing both walkable and usable exhibition areas for visitors, as well as the engagement relationship between older visitors and digital interpretation and interactive exhibits.

The survey was conducted at three research museums every Wednesday and Saturday from January to February 2025.

3.2. Methods and Data Collection

In this research study, we employed a visitor-centric approach that integrated various methodologies to examine the engagement behaviours and experiences of older visitors at exhibitions. These methodologies encompass non-contact behavioural observation for comprehensive data collection, physical environment measurements using the 7UD checklists, semi-structured interviews based on the AHP, and visualisation plotting techniques for data analysis. This integrated approach, as depicted in Figure 3, ensured a comprehensive and in-depth understanding of elderly visitors' participation in interactions, preferences,

and feedback, accurately capturing the behavioural experiences and perspectives of various elderly visitor groups through structured surveys.

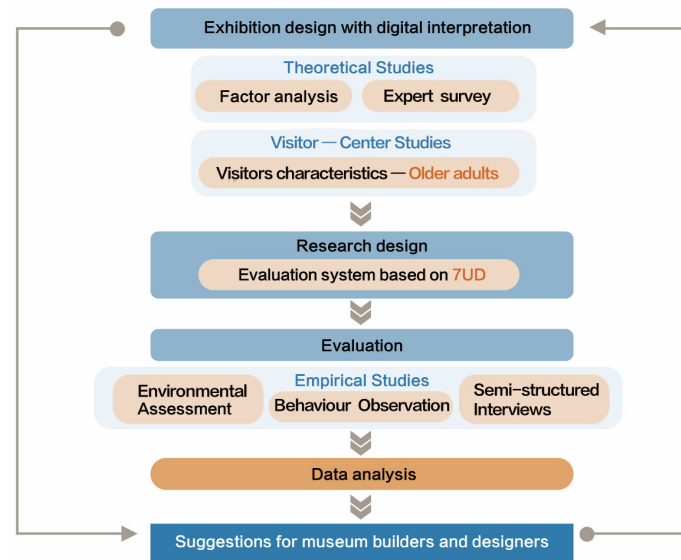


Figure 3. Structured surveys and process integration.

3.2.1. Analytic Hierarchy Process (AHP)

This section utilised the summarised indicators and factors influencing older visitors' engagement and experiences, employing the AHP methodology for scoring [35]. At this stage, expert opinions were utilised to organise, rank, and simplify the multi-level factors and indicators influencing elderly visitors' participation in digital interpretation and interaction, which were derived from the literature review. The objective was to provide research tools and survey directions for further visitor investigations, thereby enhancing the accuracy of this study by evaluating five museums and digital media experts on the importance of each factor. The factor analysis approach, which utilises professional expertise and experience in museum exhibitions and digital media interpretation, not only objectively determines the relative importance of factors influencing older visitors' engagement behaviours but also provides a comparison between expert perspectives and visitors' actual behavioural perceptions, offering more reliable reference principles for future planning and design [34].

3.2.2. Non-Contact Behavioural Observation Utilising the IAE Scale

The objective of observation research is to investigate whether and how older visitors engage with and interact with digital interpretation exhibits from an observer's perspective. Particular attention is paid to the intentions and behaviours of older visitors when engaging with digital interpretation exhibits. The key point of observation is that the subjects remain unaware of being observed, and the researchers do not interfere with the visitors' behaviours for any reason [39,49,90]. In this study, each exhibit was limited to a 15 min duration. The researcher, who is also the first author of this article, was responsible for observation and recording and documented the length of time visitors spent in front of the digital interpretation exhibits and their interactive behaviours during that period.

To measure the level of engagement of older visitors with digital interpretation, this study employed the IAE Scale during non-contact observation [80,87], as shown in Appendix A, Table A2. Through AP recording, quantitative data on attraction scores can be obtained as an indicator of older visitors' engagement. Additionally, a deeper understanding of the behavioural characteristics of older visitors can be gained by combining

verbal records with involvement-level records [49,91]. The older visitors, whose verbal communication and interaction were recorded, were informed of this study's purpose and signed an informed consent form.

3.2.3. Design Feature and Physical Environment Measurement by the 7UD Checklist

During the preliminary investigation, the researcher and first author of this article used Table 2 to document the design features of 88 digital exhibits from three museums and their physical environmental characteristics. These were subsequently utilised in this study for follow-up investigations, data statistics, and analysis. Furthermore, based on the UD checklist proposed by Ai (2025) [69], all digital exhibits were examined with the seven principles of UD. The focus was on the relationship between exhibit types or characteristics and visitor or participant behaviours, as well as the obstacles older visitors encounter when facing digital interpretation.

Table 2. Outline of the semi-structured interview.

Outline of Semi-Structured Interview	
NO.	Questions that may be posed to interviewees during the interview
1	Why did you come to the museum? Do you like museums?
2	Which digital exhibit attracted you? What was the reason it caught your attention?
3	What are your thoughts on the design of the digital exhibits? Did it meet your expectations?
4	Did you use the digital interactive device? How was your experience with the entire operation process?
5	What issues have you encountered while engaging in digital interpretation and interactions?
6	What issues do you encounter during the process of acquiring knowledge or information?
7	How do you find the exhibition environment?
8	Do you have any other terrible experiences?
9	What suggestions do you have for the digital exhibits in this museum?

3.2.4. Semi-Structured Interviews

The core of this research section aimed to further explore what precisely attracts and engages elderly visitors in digital interpretation and interaction through in-depth interviews. It concentrated on pinpointing what catches their eye in the exhibition setting and what influences them during their engagement with digital exhibitions. The researchers in this study randomly selected older visitors in the museum lobby and conducted interviews after obtaining informed consent. Older adults who were navigating without focusing on any exhibit information were excluded.

The interview outline was established based on the user experience questionnaire, encompassing “the first impressions of the digital exhibits”, “the interactive experience at the behavioural level of engagement”, and “gains from visit” [13,87]. Table 2 presents the questions that might be asked during the interview. The Laddering Technique was utilised throughout the interview process, where a sequence of “what” and “why” questions was used to understand the reasoning of older adults, progressively revealing reasoning at various levels of abstraction [35].

This study was reviewed and approved by the Institutional Review Board of Naresuan University, ensuring scientific and reasonable design, fairness, impartiality, voluntary informed consent from the participants, and the protection of their rights and privacy, with no conflicts of interest or ethical violations. Figure 4 shows the overall research process and methodology.

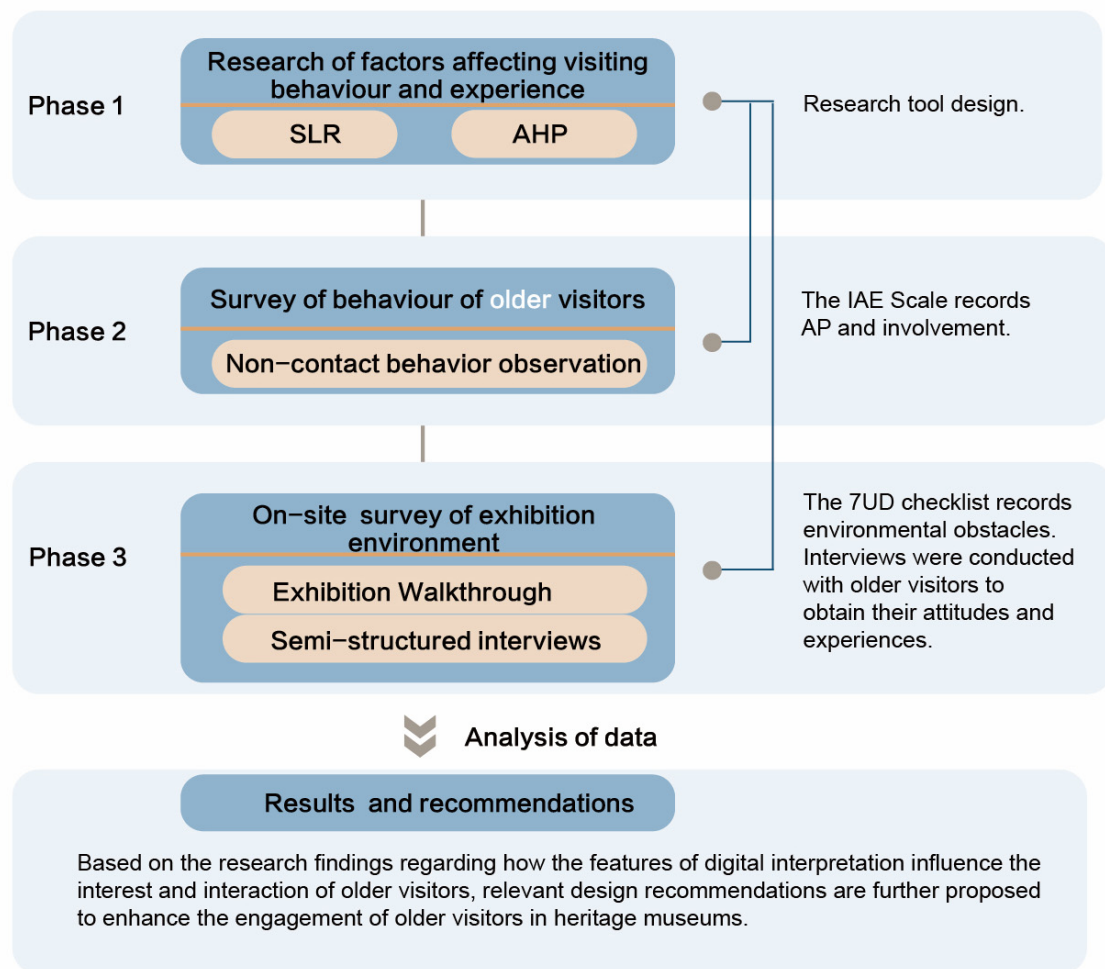


Figure 4. Research process and methods.

3.3. Population and Sample

3.3.1. Participants

The visitor research was divided into two parts. The first part involved non-contact behavioural observation using the IAE Scale, where the researcher recorded older visitors passing by each digital interpretation and interaction exhibit. Individuals who approached within half a meter of the exhibit were considered valid samples. These older visitors were distinguished by their appearance, posture, and communication status, with ages ranging from 55 to over 70 years old. This study defined visitors aged 60 and over as elderly visitors. However, acknowledging the variability in the development of physical characteristics, some visitors may exhibit signs of ageing but are not necessarily 60 years old; these individuals were also included in the observations. A total of 456 older adults participated in the data collection process (258 females and 198 males).

The second part consisted of post-visit interviews. A total of 38 older adults participated in the interviews following their visits, with 31 of these being valid samples. Their ages ranged from 60 to 72 years, including 20 females and 11 males, and they had fully toured the target exhibition hall, forming impressions and opinions about the digital interpretation.

3.3.2. Experts

Three experts from relevant fields were invited to participate in this study, including a professor specialising in museum exhibition design research, an associate professor in digi-

tal media interaction and intelligent technology, and a senior research fellow at a museum. The results are presented using random codes A to C to protect each expert's perspectives.

Three experts participated in this research for the first time to evaluate the importance of factors related to museum digital interpretation that affect the engagement and experience of older visitors. The experts conducted an AHP (Analytic Hierarchy Process) scoring of the elements using a questionnaire. The second expert evaluation aimed to assist researchers in identifying museum design features and in assessing and reviewing the results of the 7UD checklist evaluation.

4. Results

A series of data was collected through expert evaluation and three museum studies. During the data analysis phase, descriptive analysis, correlation analysis, and comparative studies were employed to present and interpret the results of each section.

4.1. Factors Affecting the Interest and Engagement of Older Visitors

This section utilised Excel software, Microsoft 365 version, to calculate and analyse the questionnaire responses provided by three experts, conducting consistency tests for each questionnaire. Two questionnaires were not accepted, and three questionnaires were deemed valid ($CR < 0.1$) and suitable for further analysis [36]. The objective of the AHP is to identify the primary factors affecting elderly visitors' participation and experience, as well as their relative importance.

In the first-level analysis, the most significant factor is "design features", with an average weight of 0.4278. The second is "Visitor Features", with an average weight of 0.3168. Lastly, "environmental features" have an average weight of 0.2552.

In the second-level analysis, all three experts concurred with the elements and indicators proposed in this study, without any objections. Under the dimension of "design features" the order of importance is as follows: A2—Visual Materials, A1—Exhibit Configuration, and A3—Content Framework. Expert C holds a differing stance, believing the order of importance to be A3—Content Framework > A2—Visual Materials > A1—Exhibit Configuration. Under the "Visitor Characteristics" dimension, the importance levels of each factor are as follows: C3—Personality Traits, C2—Behavioural Preferences, and C1—Behavioural Characteristics. Under the "environmental features" dimension, the order of importance is as follows: Spatial and Device Scale, Layout and Path, Atmosphere and Lighting. The opinions of the three experts differ significantly. The factors and their respective weights at each level are illustrated in Figure 5.

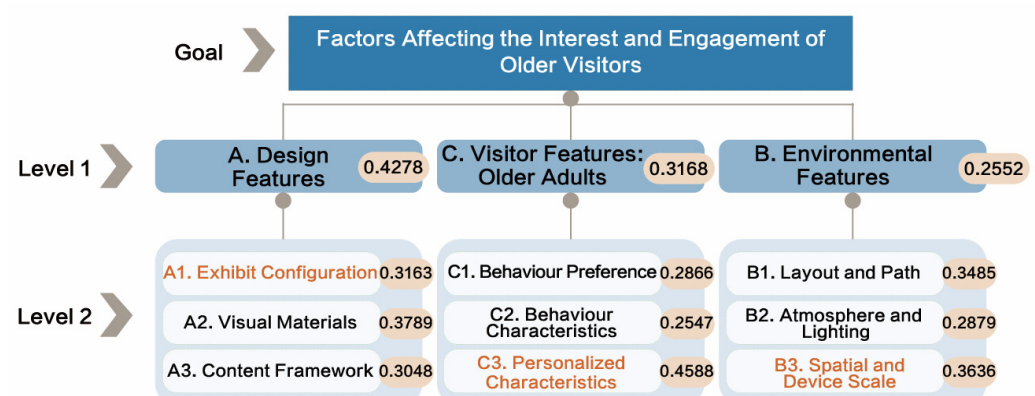


Figure 5. The factors and weights at every 2 levels.

4.2. Analysis of Design Features of Digital Interpretation Exhibit

This study adopted the classification of interactive exhibit forms summarised by Lu (2018) [81] and the classification of digital exhibits used by Lo (2023) [80]. Combining the current application of new technologies in museum exhibitions, the digital interpretation exhibits in the three museums were categorised into “Viewing-Based Type”, “Trigger Viewing Type”, “Interactive Display Type”, “Interactive Gaming Type”, and “Immersive Spaces Type”. Table 3 presents the technical characteristics of each type of digital interpretation technology.

Table 3. The classification and technical characteristics of each type of digital exhibit.

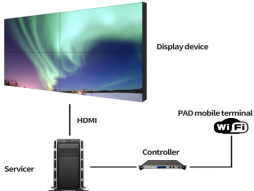
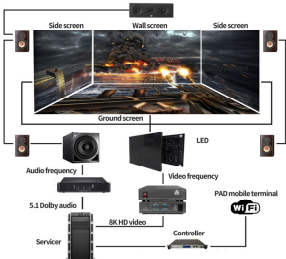
No.	Type	Description	
		Topological Relationship Diagram	Example of a Photo from the Exhibition
1	Viewing-Based Type	Present the objects and content to the visitors through multimedia formats, such as audio or video. The exhibits automatically play and demonstrate without requiring any visitor interaction, with no option to control the playback progress [80]. 	
2	Trigger Viewing Type	The exhibit is activated and triggered by visitors, with its dynamic process pre-set, and the visitors' actions do not affect the progression of the display [80]. 	
3	Interactive Display Type	An interactive system designed utilising machinery, electrical power, and related technologies, where the visitors can interact with designed programs through a computer screen and also with the exhibit, responding differently based on the operator's input, with mutual feedback between the two [29,88]. 	

Table 3. *Cont.*

No.	Type	Description	
		Topological Relationship Diagram	Example of a Photo from the Exhibition
4	Interactive Gaming Type	By applying gaming concepts, elements, or mechanics to interactive exhibits, visitors engage with various forms of participatory displays, such as gaming programs, artistic creations, competitive games, and physically interactive games, allowing participants to acquire knowledge through gameplay [39,72,80].	
			
5	Immersive Spaces Type	The information is aggregated into a complete spatial context, where interactive installations integrate emerging technologies with sensory experiences, aiming not only to provide visual experiences but also to deepen the audience's multisensory engagement through technology [51,72].	
			

A total of 88 sets of digital interpretation exhibit design and environmental features were documented across three museums, with the collected data imported into SPSS Statistics 27.0.1 for recoding and statistical analysis. Under the indicator A11—Digital Interpretation Format, 51 items were classified as the Viewing-Based Type (58%), 2 items as the Trigger Viewing Type (2.3%), 27 items as the Interactive Display Type (30.7%), 6 items as the Interactive Gaming Type (6.8%), and 2 items as the Immersive Spaces Type (2.3%). The statistical results indicate that traditional viewing-based digital interpretation continues to be the predominant form in newly built Chinese museums.

Based on the importance ranking of each factor, the researcher further selected the statistical results of the second-level factors, including A1—Exhibit Configuration and A2—Visual Materials, as well as the third-level indicators, including A12—Main Media Equipment, A13—Sensory Forms, A14—Number of Participants, A21—Clear Signage and Explanation Systems, A22—Distinct Themes, A23—Visual Style, and A25—Narrative Types for Visualisation.

The analysis results depicted in Figure 6 indicate that at indicator A12, the primary forms of digital equipment are touchscreens, indicators, and projections. Considering that the selected permanent exhibition halls are comprehensive history-themed rather than specialised interactive or children's exhibition halls, the implementation of new technological approaches is limited. Virtual reality technologies, such as XR and VR, which are frequently mentioned in the literature, were not observed. The Chiangnan Watery Region Culture Museum houses a digital interpretation exhibit that utilises virtual imaging,

but it is currently out of order. At the Shanghai Museum East Branch, new materials have been introduced as the medium, such as projecting visual interpretations of objects directly onto the glass of showcases, replacing traditional wall-mounted televisions. The purpose of digital interpretation in comprehensive heritage tourism museums is to provide detailed and engaging explanations of historical knowledge and heritage culture, rather than interactive experiences. Indicator A14 refers to interactive display devices, which are generally intended for single-user operation. There are, however, a few exceptions in the form of multi-touch screens. In contrast, viewing-oriented exhibits can accommodate 3–5 simultaneous viewers at once. Only the viewing space allows for groups.

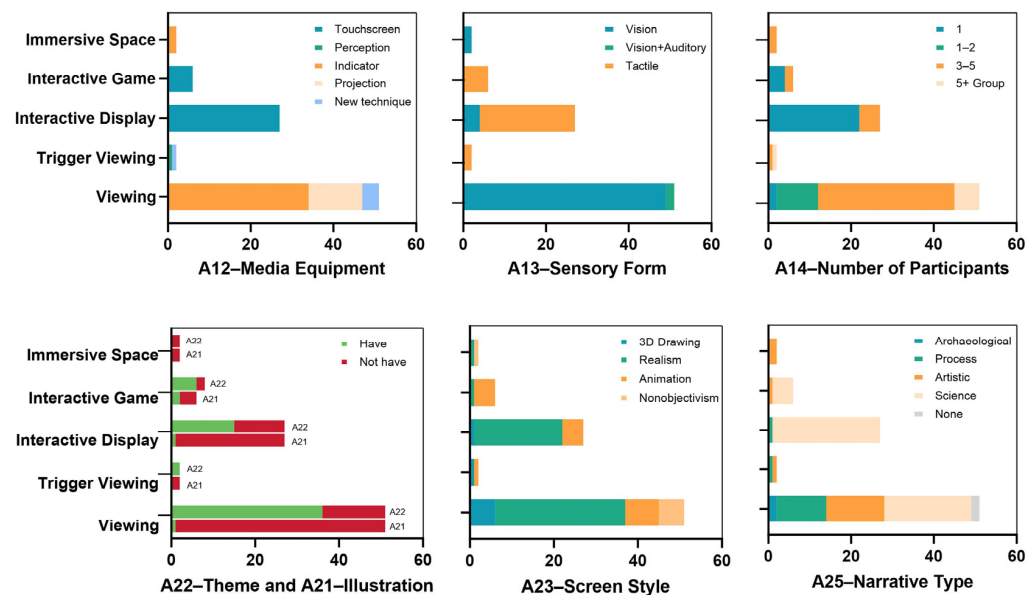


Figure 6. Statistical analysis results of the main design features of digital interpretation exhibits.

The results indicate that the digital exhibits in the three museums predominantly feature science popularisation and documentary content with realistic visual styles. The methods of process narration and artistic aesthetic narration are also widely applied. However, regrettably, the cases surveyed during this research did not reflect the narrative related to historical reappearance and scene restoration. This narrative type has been proven effective in enhancing visitor experience and can fully leverage the advantages of digital interpretation technologies [4,75].

Further examination of the physical characteristics of digital exhibits in the three museums revealed varying degrees of neglect toward elderly visitors. At the Suzhou Museum West, the forms of digital media exhibits include audiovisual spaces, interactive inquiries and games, as well as artistic installations. These exhibits feature distinct artistic styles but lack relevant informational descriptions. Elderly visitors tend to pause and observe viewing-based exhibits, while their participation in other types of exhibits is relatively low. The Chiangan Water Town Museum features 42 digital media installations, with exhibit types primarily focused on interactive displays and viewing. However, because of the specialised and difficult-to-understand content, elderly visitors exhibit relatively low engagement with the extensive digital media offerings. The Shanghai Museum East is committed to building a “visitor-friendly museum,” with digital interpretation emphasising “process.” For instance, the use of 3d modelling technology enables three-dimensional displays of heritage, presenting them in a more life-oriented manner that encourages elderly visitors to linger and observe. However, the narrow spatial scale, crowded environment, and lack of leisure seating for prolonged viewing pose obstacles to participation for most elderly individuals. Additionally, some slightly complex interactive display methods, such as

operating screens, are also somewhat challenging for the elderly. In the subsequent sections, we will explore in depth the design and environmental features of digital interpretation exhibits that are particularly appealing to older visitors.

4.3. Analysing Behavioural Observation and Attraction Power (AP) of Digital Interpretation

In this phase of this study, we observed what caught the attention of the older visitors during their visits; interestingly, it was the features of the exhibits that piqued the interest of these older visitors. We recorded AP data from 456 older visitors across seven exhibitions in three museums, comprising 196 males and 260 females. Their primary visitation patterns included companionship visits, such as those with couples or other older adults, in groups of 3–4 people, with a smaller proportion (0.88%) being accompanied by their children. Furthermore, 2.19% of the older visitors were accompanied by children. In the records from the last several days, only one elderly individual with mobility issues (using a wheelchair) visited, accompanied by their children. The rest were all healthy, independently mobile older adults.

We imported the recorded results into SPSS Statistics 27.0.1 and calculated the attractiveness score for each exhibit. The results, displayed in Table 4, indicate that only three older visitors were recorded with a score of 3, which accounted for 0.66% of the total, suggesting that almost no older visitors successfully participated in digital interactions or fully watched the digital interpretations. A total of 52 older adults were recorded with a score of 2, indicating that only 11.28% of the older visitors were attracted to the digital interpretation exhibits and willing to engage in interactions or view them. In total, 82 elderly were recorded as scoring 1 point, representing 17.79% of the older adults who were attracted to the digital exhibits but did not stay to view or participate. Overall, 70.28% of the older visitors paid no attention to the digital interpretation exhibits at all. When passing by the digital exhibits, they chose to ignore them. In terms of engagement with digital exhibits, only 2.39% of the older visitors displayed behaviours such as focused attention, interaction, and photography.

Table 4. Statistics of demographic characteristics and IAE Scale recording.

AP Score	Female	Male	Total	%
0	181	141	322	70.61%
1	43	38	81	17.76%
2	31	19	50	10.96%
3	3	0	3	0.66%
Total	258	198	456	
+1	11	4	115	3.29%
Mean	0.48	0.40	0.45	

We further conducted cross-tabulation statistical descriptions in SPSS Statistics 27.0.1 and examined the influence of various factors and indicators on the AP and engagement of the older visitors using chi-square tests. According to the statistical results, out of the 88 digital interpretation exhibits, only 1 managed to achieve an AP score of 2 points. This exhibit featured an ancient character image reconstructed using virtual imaging technology within a restoration setting, accompanied by narration in a local dialect without detailed explanatory knowledge. Overall, 88.6% of the exhibits were deemed unappealing to the elderly visitors, with an AP score ranging from 0 to 1 point; those scoring 0 points made up 47.7% of the total. Only 10.2% of the exhibits managed to capture the attention of the elderly visitors; however, they failed to engage them in staying and interacting. We plotted

the AP score proportion chart based on the important factors and indicators derived from the AHP results. As illustrated in Figure 7, indicators A11—Exhibit Format ($p = 0.447 > 0.05$) and A23—Screen Visual Styles ($p = 0.213 > 0.05$) had no significant impact on the attention of older visitors. On the contrary, indicators A12—Main Media Equipment, A13—Sensory Form, and A25—Narrative Type significantly influenced the attention and attractiveness to the older visitors.

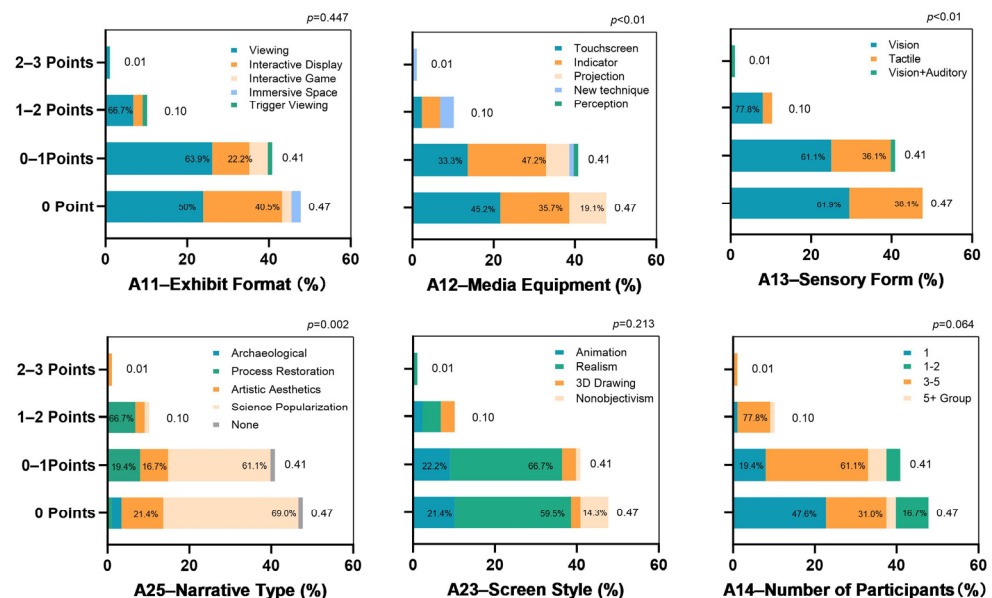


Figure 7. Statistical analysis results of the AP in the main factors and indicators.

Simple new technologies, larger-scale displays, narrative content that reproduces processes, and digital interpretation devices that require no operation are more likely to attract older visitors to stay. Based on the results of our behavioural observations and involvement records, the older female visitors were more inclined to engage in digital interpretation and interactions during visits and generate more verbal communication. Among the elderly visitor couples, the female participants often left prematurely because their male companions urged them to, failing to fully engage in the digital interpretation experience. Following this, the older visitors accompanying children would pause to watch a digital interpretation during the waiting process. Older adults were willing to engage in digital interactions when guided by their adult children during visits. Those who toured alone were predominantly male and tended to pay more attention to digital exhibits that offered clear, knowledge-based interpretations.

4.4. Analysis of Environmental Features and UD Evaluation Results

The findings of this section are divided into three parts: (1) whether the various factors and indicators align with UD principles; (2) the correlation between UD scores and AP; and (3) the correlation between the constraints and barriers faced by older visitors during their visits and UD, with a focus on environmental features.

4.4.1. Analysis of UD Compliance Status for Digital Interpretation Exhibits

The inspection results of the 7UD checklist evaluation of 88 sets of digital interpretation exhibits were imported into SPSS Statistics 27.0.1 for recoding. The results were then combined with the AP scores and indicator data regarding factors that influence engagement among older visitors. Ultimately, the UD scores and corresponding levels for each digital interpretation exhibit were obtained.

The interpretation of scores and grades is as follows: 0 to 1 points correspond to the “Failed” grade, indicating non-compliance with UD; 1 to 2 points correspond to the “Poor” grade, meaning almost non-compliance with UD; 2 to 3 points correspond to the “Fair” grade, indicating basic compliance with UD; 3 to 4 points correspond to the “Good” grade, representing compliance with UD; and 4 to 5 points correspond to the “Excellent” grade, indicating that the exhibit demonstrates good compliance with the seven principles of UD. In this study, “Good” and “Excellent” are considered grades that digitally interpret compliance with the principles of UD.

The results indicate that among all digital interpretation exhibits, UD1 demonstrated relatively good compliance, with 94.3% of the digital interpretations meeting the UD1 standards. However, UD2, UD3, and UD5 exhibited compliance rates below 50%, at 29.6%, 43.2%, and 45.5%, respectively. Only 16 exhibits (18.18% of the total) met all seven universal design principles, whereas 3 exhibits (3.40%) did not meet any of them. As shown in Figure 8, the digital interpretation across the three museums generally adheres to the UD principles, scoring between “Fair” and “Good,” indicating significant room for improvement.

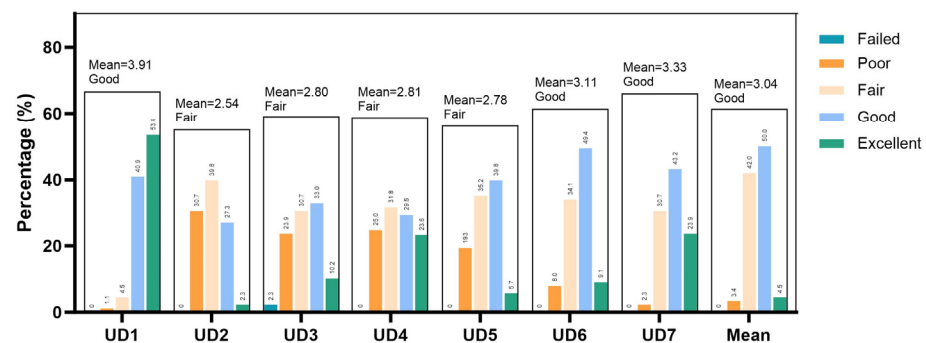


Figure 8. Statistical results of digital interpretation exhibit UD scores and grades.

4.4.2. Analysis of the Correlation Between AP and UD Scores

Upon analysing the UD evaluation results, we discovered that digital exhibits with lower UD score grades corresponded to lower AP and involvement. For instance, exhibits with all UD indicators at the Failed and Poor grades received an AP score of 0. However, not all low UD scores equate to low AP. This implies that the seven principles of UD can be employed to identify the reasons behind low AP, and specific UD metrics are instrumental in determining whether older visitors are attracted to digital interpretations. Thus, we conducted a correlation analysis between the UD scores and AP scores to investigate the mechanisms by which UD enhances engagement among older museum visitors. Utilising SPSS Statistics 27.0.1, we performed correlation tests on 456 sets of AP data and UD score data, uncovering significant correlations ($p < 0.001$) between the compliance grades of UD and AP. Further linear regression analysis revealed that none of the seven principles of UD individually had a significant impact on AP. Only when all seven principles acted in concert did they demonstrate a significant effect ($p < 0.01$). Please refer to Appendix A, Tables A3 and A4 for details.

In essence, the AP and involvement of digital interpretation exhibits for older visitors can be improved by adhering to UD. However, the behavioural traits of the sampled older visitors did not indicate a preference for any specific aspect of the seven principles of UD. A failure to meet any one of the 7UD might result in older visitors shunning digital interpretation and interactions. Nonetheless, the findings from behavioural observations tentatively suggest that non-adherence to UD3 and UD6 is more likely to deter older

visitors from engaging with digital interpretation exhibits. Further analysis is required to confirm this.

4.4.3. Comparative Analysis of Visiting Barriers for Older Visitors and UD

A comparative analysis was conducted to examine the environmental features of digital interpretation and universal design (UD), aiming to identify existing barriers and limitations for older visitors in the current digital interpretation and interaction. The issues identified across the 88 sets of exhibits and their corresponding obstacles for the elderly are summarised as follows. (1) UD1: The positioning of digital exhibits often presents challenges for older visitors, such as being placed in cramped corners or dimly lit spaces. The physical demands of interaction are excessive, requiring actions like raising arms, bending over, or tilting the head back to view content—movements that do not align with the physical characteristics of older adults. (2) UD2: Digital exhibits impact surrounding exhibits, leading to mutual interference. The convergence of crowds viewing digital exhibits and those observing nearby displays results in congestion, causing elderly visitors to frequently avoid these crowded areas. Some exhibits are situated away from the main visitor circulation route, with older visitors often favouring a single, direct touring path. (3) UD3: The absence of clear visual cues or a defined content theme can deter older visitors from entering, as they may perceive the device as irrelevant to the exhibition. Interactive digital exhibits that require operations such as clicking to query or triggering playback might cause older visitors, without younger companions, to hesitate in approaching. (4) UD4: Whether in a professional or artistic context, aesthetics that are disconnected from daily life struggle to forge meaningful bonds with the exhibits, leading to elderly visitors passing by without pausing or engaging. Digital interpretation devices that lack clear operational instructions or guided tours might capture the interest of elderly visitors, but they may not encourage active participation. (5) UD5: The glare from high-tech and multimedia can make older visitors feel insecure, leading them to avoid approaching. Additionally, the cramped and dimly lit viewing space at the entrance may cause older visitors to feel uncertain and insecure, further deterring them from approaching. (6) UD6: Audiovisual equipment can attract older visitors; however, the absence of resting seats makes it challenging for them to stay and watch. Additionally, the design of the seats may not accommodate the physical needs of the elderly, such as providing cushions. Videos that require looking up or down excessively consume physical energy and diminish older visitors' interest. (7) UD7: Interactions that are unsuitable for the physical characteristics of older visitors include overly small interactive screens requiring precise operations or simple drag-and-drop and screen zooming functions that prove exceptionally challenging for older adults. Indeed, digital exhibits featuring small screens that necessitate personal interaction often go unnoticed by the elderly, who neither pause to engage nor watch others operate them.

These environmental issues have caused older visitors to lose interest in digital interpretation and interactions. In addition, when they can only watch others operate the devices, they are unable to participate, leading them to give up.

4.5. Analysis of Interview Results with Older Visitors

To further explore the factors that can influence the engagement behaviours and visiting experiences of older visitors in real exhibition scenarios, we randomly selected older visitors near the exit of a target exhibition hall in the museum lobbies for in-depth interviews. Through this phase of this research, we not only gained a deeper understanding of what older visitors observed at the exhibition site but also learned about their level of engagement and their further desires.

We conducted on-site random interviews with a total of 38 older visitors, among whom 5 exhibited implicit resistance during the interviews. Although they were aware of this study's content and the confidentiality agreement and consented to participate, their responses were limited to statements such as "I think it's fine" and "I have no opinion, I'm just looking around." Subsequently, their further interviews were abandoned. Additionally, responses from two older adults that were unrelated to the question, such as "I'm not educated, I don't understand what this means," were also excluded. Of the remaining 31 older adult participants, 3 visited alone, 6 were accompanied by their adult children, 10 were couples, 3 brought a preschool child, and 9 visited with friends. Among these, 8 were out-of-town tourists, and 23 were residents. We organised the interview records, extracted keywords, and summarised viewpoints from the three dimensions as stated below.

4.5.1. Motivation and the First Impressions of the Digital Media

The questions about visitation motives centred on inquiries such as "Do you often visit museums?" and "What brings you to this museum?" Of the older adult respondents, 58.06% answered "leisure and relaxation, casual stroll"; 12.01% were "museum enthusiasts," and 29.03% responded "specially visiting museums during travel." This suggests that a substantial number of older visitors to museums are of the professional type. Many retirees exhibit a great enthusiasm for visiting museums.

By posing questions such as "Did you notice the digital media exhibits?", "Do you like digital media?", and "Are you willing to participate in digital interactions?", we obtained data on older visitors' acceptance of digital interpretation and their visceral responses during museum visits. The general attitudes of the older visitors towards various types were as follows: 83.87% believed it was fine, with keywords including "interesting format," "interesting content," "simple operation," "helpful for visiting," and "knowledge expansion." Four older adults explicitly expressed dissatisfaction with digital media interpretation, mainly due to "unprofessional content, poor production quality, and lack of interest." An older adult stated that he would not pay special attention to digital media and was indifferent to its quality. Furthermore, 19.6% of the participants indicated that, in comparison to digital interpretations, they were more focused on physical objects.

4.5.2. The Interactive Experience at the Behavioural Level of Engagement

The questions in this part revolved around "Have you watched or participated in digital exhibits?", "What difficulties have you encountered in operation?", and "Were you aware this was interactive?" Upon analysing the interview data, we uncovered an intriguing phenomenon: while 83.87% of the elderly stated that "digital media is fine," their reasons were somewhat ambiguous. However, when discussing obstacles or suggestions related to its use, these participants became highly enthusiastic. The keywords were "no explanation, don't know how to operate," "content unrelated to the exhibition," "too many people," and "not suitable for me." Some elderly individuals also stated that "These are for young people to play with; it has nothing to do with me, so I won't actively participate."

Most elderly visitors for leisure purposes stated, "We're getting old and don't understand how these things work. We just look at what we can comprehend and won't bother studying how it operates." Conversely, seniors with higher education and those who frequently visit museums commented, "I find the operation very simple. I'm over 60, yet I don't experience any difficulty whatsoever."

4.5.3. Gains from Visit

The questions at the gains level concentrated on "Do you believe digital media assisted your visit?", "Do you think digital media improved your visiting experience?", "Do you

enjoy multimedia?”, and “What type of multimedia do you prefer?” This dimension of questions elicited a variety of responses, with no significant difference in the number of participants. Some older adults believed that “digital media is excellent, as its innovative formats help me better understand exhibition content,” while others stated that “I don’t pay much attention to digital media—if I come across something viewable, I’ll take a look, and if it’s interesting, I’ll watch longer, just to pass the time.” Additionally, some elderly visitors expressed the view that “digital media is fine, but I only want to see cultural relics—that’s what I came for.”

Some older adults voluntarily mentioned digital exhibits that left a deep impression on them. Several points particularly drew our attention: (1) Procedural interpretation entails observing the production process of physical objects and delving into the historical narratives that accompany them. (2) Content or imagery related to daily life can evoke memories of past experiences. (3) The exhibit has a clear and eye-catching theme, with content that is closely related to the exhibition’s theme. (4) The exhibit provides an environment that is spacious, comfortable, and safe, free from crowding.

The interview surveys, structured around questionnaires, allowed us to gain an in-depth understanding of the content that interests older visitors and the barriers they face during their visits. Similarly, through their descriptions, we also identified the need for further efforts to enhance the recognisability and readability of digitally interpreted exhibition items. Moreover, museum creators must endeavour to involve elderly visitors in digital interpretation and, crucially, communicate clear, engaging, and informative content to aid their understanding of the exhibition. Figure 9 depicts the frequency count of keywords derived from the interviews. These high-frequency words reflect the characteristics and needs of the older participants in this survey. Although most of the older adults found the digital interpretation and interactive exhibits to be favourable, some of the older adults expressed unwillingness to engage with digital exhibits, believing these digital exhibits were not designed for them. The female visitors showed greater willingness to participate in digital exhibits, while the primary purpose of elderly visitors in museums was leisure and relaxation. The outcomes of the high-frequency characteristic word analysis, based on semi-structured interviews, are detailed in Appendix A, Table A4.



Figure 9. Frequency count of keywords collected from the interviews.

4.6. Comparative Analysis: Three Museums

The digital interpretation across the three museums highlights their unique characteristics. The Suzhou Museum West Branch’s digital interpretation focuses on aesthetic experiences and popular science narratives, primarily presented in viewing formats. The identified issues encompass dim lighting and environmental conditions that hinder read-

ability and lead to visual discomfort. Additionally, the interview responses often mentioned difficulties in understanding exhibit content, which seemed unrelated to the exhibition. These issues underscore that digital interpretations that do not adhere to the UD4, UD5, and UD6 principles are more prone to impede the participation of elderly visitors.

The Chiangnan Watery Region Culture Museum's digital interpretation aims to introduce and popularise heritage culture and knowledge, primarily through interactive displays and viewing-based exhibits, with varying degrees of non-compliance with the UD1-UD7 principles. The primary issues and obstacles involve digital exhibits that are excessively dense and have homogeneous formats, which can cause older visitors to lose interest. Additionally, the attraction of digital exhibits can lead to overcrowding, resulting in disorientation and spatial confusion among older visitors. Most critically, the interpretation format lacks relevant explanations and engaging titles, prompting older visitors to prefer more appealing physical exhibits.

The digital interpretation at the Shanghai Museum East Branch emphasises the process of reconstructing and interpreting history and heritage, primarily through the forms of exhibit viewing, interactive displays, and interactive games. The compliance status with UD (universal design) at this museum is the best among the three museums, particularly because of the clear and explicit digital interpretation explanations and thematic content, which attract elderly visitors to stay and participate. However, UD5 and UD6 present significant issues, including traffic congestion due to the location of video playback and a lack of appropriate viewing space, which causes considerable physical exertion for older visitors.

The types of older visitors to the three museums are influenced by regional characteristics, also exhibiting distinct needs and features. The older visitors to the Suzhou Museum West Branch, comprising both residents and out-of-town tourists, were primarily leisure-oriented, with purposes ranging from daily recreation to tourism. However, attitudes towards digital interpretation were polarised. The professional older visitors believed that greater attention should be paid to the exhibition content, arguing that the digital interpretation in this museum is overly entertaining and lacks meaning. Conversely, visitors who were there for leisure tended to be more satisfied with the digital interpretation, as digital devices do not impede their museum experience in any way. The older visitors in the interviewed sample at the Chiangnan Watery Region Culture Museum were all residents who stated that "the museum has a pleasant environment with air conditioning and cultural offerings, making it an excellent place for leisure." Among the older visitors to this museum, almost none exhibited interest in digital interpretation ($AP \leq 1$). Behavioural observations and interviews revealed that they preferred to seek out physical exhibits for viewing, as their unfamiliarity with digital media led them to overlook them. During the interview process, more obstacles were encountered than at the other two museums, with most of the older adults expressing no opinion on digital media. The Shanghai Museum had the highest number of professional older visitors compared to the other two museums, with its visitors comprising locals, out-of-town tourists, and museum enthusiasts. Our interviews revealed that the professional or highly educated older visitors were more inclined to participate in digital interpretation and interactions, providing highly positive feedback. This contrasts sharply with the professional older visitors interviewed at the Suzhou Museum West Branch.

5. Discussion

5.1. Discussion of the Evaluation System

The case studies and comparative research findings presented above all demonstrate the multiple benefits of employing diverse approaches in assessing older visitors. The

assessments conducted strictly by established procedures are rigorous and detailed, with the results demonstrating consistency across the three surveyed museums while also being capable of pinpointing specific issues. The integration of qualitative and quantitative data methods offers a rich and detailed understanding of digital interpretation and exhibitions. Moreover, the comparative analysis method ensures that the evaluation results act as supportive evidence for understanding, rather than presenting findings in isolation.

- (1) A satisfaction-based questionnaire survey aims to capture visitors' attitudes and needs; however, the results are heavily reliant on participants' responses [37], making it challenging to ascertain the actual behavioural reactions of older visitors when they encounter digital interpretation in museum settings. It is widely acknowledged that behavioural observation methods rely heavily on the subjective records of investigators. Consequently, standardised testing will enhance the reliability of a study [80]. In this evaluation system, rigorous scales are employed not only for behavioural observation but also for documenting design features and environmental features. Previous semantic analysis methods in research have largely depended on visitors' linguistic proficiency and cognitive patterns [35]. However, the target demographic of this study—older adults—appears unsuitable for such an approach because of declines in cognitive abilities and physical perception. Thus, the Analytic Hierarchy Process (AHP), based on expert evaluation, was utilised to develop the scale and evaluation indicators for this study. Through a systematic literature review and a rigorous expert evaluation, potential biases of the researchers were minimised to the greatest extent possible.
- (2) Current evaluation practices are often influenced by a positivity bias in outcomes, where visitors report what museums wish to hear [92]. This became evident during our interview process. When asked about their impressions of digital media, the participants uniformly responded positively, expressing satisfaction. However, as conversations deepened, they became more willing to articulate the obstacles encountered during their visits and share more authentic perspectives.
- (3) The environment assessment, which incorporates universal design principles, offers a method for creating behavioural experiences for older visitors, with simultaneous attention to both physical and psychological environmental factors. It connects the concepts of exhibition designers with the behavioural responses and experiences of older visitors. This evaluation enables builders to identify which museum exhibition resources and efforts significantly impact elderly tourists and allows them to propose improvement suggestions based on these findings.

5.2. Discussion of Limitations

Initially, this evaluation was carried out in three newly constructed and popular cultural heritage museums in China. Despite the consistent outcomes from these museums, variations in themes and exhibition content necessitate differences in the design of digital media compared to those in science popularisation museums, science and technology museums, and thematic museums. Consequently, when applying this evaluation system to other types of museums, each case must be analysed individually. Secondly, regarding the target population, this evaluation system was constructed based on factors such as the behavioural characteristics, needs, and motivations of older adults. As a result, when applying this method to studies involving various types of visitors, it is necessary to make improvements and adjustments. Thirdly, because we used the non-contact observation method, some errors were inevitable when visually determining the age of older participants. Moreover, during the interviews, the older adults frequently demonstrated a reluctance to answer questions about their educational background and cultural factors,

leading to uncertainties in cognitive statistics. Future work should consider how this study can more accurately measure the impact of elderly visitors' cognitive characteristics on their engagement behaviours.

5.3. Discussion of the Evaluation Results

This study is divided into two parts to explore and analyse the factors influencing the visiting behaviours and experiences of elderly visitors in museum exhibition environments. Specifically, during the initial phase of constructing the evaluation system, we conducted a systematic literature review (SLR) and utilised the Analytic Hierarchy Process (AHP) method. The collaborative effort with three experts resulted in the identification of eight major categories of factors and twenty-five detailed indicators that influence older visitors' engagement in digital interpretation. Within this evaluation, we took into account not only design factors but also environmental factors associated with the digital interpretation devices and the factors of older visitors' features. The results of the AHP analysis indicate that at the first level, A—Design Factor ($W = 0.4278$), A1—Visual Materials ($W = 0.3789$), and A2—Exhibit Configuration ($W = 0.3163$) were identified as the primary factors influencing older visitors' engagement. This was followed by C3—Personalised Features ($W = 0.4588$) and C1—Behavioural Preferences ($W = 0.2866$), under factor C—Visitor Features ($W = 0.3168$) and then B3—Spatial Configuration and Exhibit Scale ($W = 0.3636$), as well as B1—Layout and Visiting Path ($W = 0.3485$), under factor B—Environmental Factor ($W = 0.2552$). This slightly differs from previous research findings. Wu (2012) proposed that among all factors, environmental and visitor factors served as the primary influences [29]. Thus, the authors continue to hypothesise that the behavioural factors influencing elderly visitors can be categorised into three main areas: “design factors,” “visitor factors,” and “environmental factors,” albeit with different methods for evaluation and verification.

The second phase of this study focused on the implementation of the evaluation system. We validated various design and environmental factors using AP and involvement. The findings suggested that digital exhibits with high attractiveness possess the following characteristics: novel visual forms and media devices (A12), clear themes (A22), process and historical reconstructions in interpretation (A25), larger display scales (B34), low information load (A31), non-complex content (A32), spacious and comfortable environments (B31), and exhibit placement along primary visiting path (B12). Notably, digital interpretations of space, particularly those in a cinema-style format, are more appealing to elderly visitors.

Correlation testing between AP and the design factors revealed that neither the type of digital interpretation (A11) nor the screen visual style (A23) had a significant impact on the interest of older visitors. According to the attention model theory, visitors seek exhibits that capture their attention while requiring minimal effort for maximum gain during browsing [64]. Elderly museum visitors prioritise reducing cognitive load and pursuing meaningful experiences over mere knowledge acquisition [11], showing distinct behavioural differences from learning-oriented cultural tourists [58]. This phenomenon may be closely linked to the motivational patterns and environmental perception characteristics of older adults. Consequently, we further investigated the limitations of digital interpretation for older visitors in museum exhibition environments and proposed corresponding solutions.

Upon conducting a comparative analysis of the UD evaluation results and the AP assessment findings, it was revealed that among the three museums, digital exhibits with lower 7UD compliance levels, indicating more issues in environmental measurement, corresponded to lower AP scores. Based on specific interview outcomes, we identified environmental characteristics that deter elderly visitors from engaging with digital inter-

pretation exhibits. The primary shortcomings of UD1 were evident in staircases, dimly lit environments, and exhibits designed for children, which were considered unsuitable for older visitors. Deficiencies in UD2 were reflected in inappropriately positioned digital exhibits, causing crowd congestion and leading older visitors to avoid these areas. The inadequacies of UD3 stemmed from the fact that digital interpretation exhibits were challenging for older visitors to locate or recognise functionally. The shortcomings of UD4 stemmed from a lack of clear and coherent themes, resulting in content confusion and perceptions of irrelevance to the exhibition. UD5 issues revolved around older visitors avoiding exhibits with high-tech features or dim lighting because of perceived safety hazards. UD6 deficiencies were observed in the absence of rest seating or improperly positioned digital interpretation displays, causing excessive physical strain for older visitors. The shortcomings of UD7 included small displays and poorly lit environments, which did not cater to the physical needs of elderly visitors. These identified problems and barriers collectively discourage elderly visitors from actively engaging in digital interpretation during their museum visits.

In previous studies, visitors' motivations have been considered the primary factor in determining their engagement with museums and satisfaction with exhibitions [39,70]. In this research, we also observed the randomness and unpredictability in the behavioural responses of older adults during their visits. To put it simply, digital interpretation exhibits that successfully capture the attention of older visitors generally satisfy the seven principles of UD well. However, digital exhibits that meet these seven principles of UD do not necessarily attract older visitors' attention, as this is the result of multiple interacting factors. This influence mechanism is complex and variable. Therefore, we believe that the reason for this phenomenon is rooted in the unique physical and psychological traits of older adults; motivation and inner needs are key factors in determining whether they are attracted to digital exhibits and engage with them. Conducting in-depth interviews with older visitors post-visit was both important and essential for this study. The results confirmed that the motivation of elderly museum visitors significantly differs from that of other adult visitors: leisure and cultural immersion are their primary motivations, with an increased demand for comfortable environments and concise exhibition information, while their need for acquiring new knowledge and entertainment is diminishing [15,43].

As one interviewee remarked, "I visit the museum to view ancient artefacts I've never encountered before" when asked if it is more appealing to view physical exhibits than to stare at screens. However, older visitors might also perceive, because of psychological cognition and bias, that these digital interpretations are not intended for them but rather tailored for younger visitors. The high-frequency words in Figure 9 reveal the polarised attitudes of older visitors towards digital interpretation and interaction: "Digital interpretation is great—I don't want to participate"; "Content interpretation is insufficient—Hard-to-understand content"; and "Interesting and novel format—Not interested, not suitable for me." This also underscores how older visitors, on the one hand, yearn to experience new things, yet, on the other hand, resist unfamiliar content.

Our research findings suggest that the design and environmental features of digital interpretation can be improved through the application of universal design (UD) principles, thereby better meeting the physiological and psychological needs of older visitors. Table 5 outlines specific improvement recommendations based on UD, emphasising content, guidance, and age-friendly design for digital interpretation. It is important to note that this study suggests enhancing digital environments to better suit older visitors by applying UD principles. The aim is to accommodate individuals of all physical abilities, rather than creating digital exhibits solely for the elderly. This approach aligns with the principles

of inclusive design and is the purpose behind the introduction of the seven universal design principles.

Table 5. Suggestions for improvement based on seven principles of UD.

Suggestions for Digital Exhibit Design and Improvement Based on Seven Principles of UD		
Phenomenon 1: Older visitors were not attracted when approaching the digital interpretation.		
Problem analysis	- Older visitors cannot recognise the purpose and function of digital exhibits, considering them irrelevant to the exhibition. - The digital exhibit location deviates from the main content line. - Small scale, low recognition.	
With UD	Not UD2; not UD3; not UD7	
Suggestions: - If possible, position digital exhibits along the main exhibition path, ensuring they are visible and easy to locate. When considering older visitors, digital interpretation should not be placed in cramped corners. - The visual presentation of digital exhibits should create a striking contrast with the surrounding environment to enhance their appeal. - Colour contrast in specific digital regions. - Create aesthetically pleasing and easily comprehensible logos and pictograms to aid in the recognition of the functions of digital exhibits. - Set appropriate partitions and dividers for screening. Independent exhibits are more effective at capturing visitors’ attention, particularly that of the elderly. - Considering the needs of various types of visitors, it is advisable to install displays of different sizes whenever possible. For instance, larger displays that align with the general public’s cognition, along with attractive headline descriptions, should be provided. Moreover, alternative avenues for interpretation and inquiry should be provided for professional visitors. - Clear directional signs or maps should be placed in areas prone to confusion—maps suitable for the elderly.		
Phenomenon 2: Older visitors noticed the digital interpretation but did not stay.		
Problem analysis	- Within the same exhibition, digital interpretation with similar content and visual materials loses its appeal. - The digital exhibit lacks a clear theme and is deemed as difficult-to-understand content. - The style of visual materials is judged to be exclusive to young people or children. - The environment being too dark or crowded is considered unsafe. - Located on a secondary route, requiring additional walking to reach. - Location is difficult to access.	
With UD	Not UD1; not UD2; not UD3; not UD4; not UD5; not UD6	
Suggestions: - Use various communication methods to enable visitors to understand the content from different perspectives, avoiding repetitive content and narrative form and addressing the elderly’s need for concise and intuitive information. - A clear theme should be established for the digital interpretation exhibit, closely connected with the main content of the exhibition. This ensures that visitors with varying abilities can understand the forthcoming content. The theme should be clear and succinct. - Signage should be eye-catching and prominent to accommodate visitors of all types and cultural backgrounds. - Digital exhibits should have a visual identity and guidance that resonates with the psychological characteristics of different visitor types while steering clear of overly entertainment-focused or childishly styled guidance. - The digital display environment should have appropriate lighting, taking into account the visual characteristics of elderly audiences. Overly dim spatial conditions should not be created merely for atmospheric purposes. - The surrounding environment of digital equipment should be safeguarded against potential hazards, such as dark environments, protruding obstacles, and narrow passages. - Digital interpretation exhibits should be placed along the main route, but not at traffic nodes, to prevent congestion. - Digital exhibits should be established in relatively independent spaces or locations to prevent interference with surrounding exhibits. - Digital exhibits should be located in a manner that is accessible to all, avoiding obstacles such as steps, narrow bridges, sunken areas, or other features that could impede the access of elderly or disabled individuals.		
Phenomenon 3: Older visitors noticed the digital interpretation but only made brief stops.		
Problem analysis	- The content load is too heavy, making it difficult to capture important information. - The content is complex and considered overly specialised, requiring mental effort. - The content is simple and deemed meaningless. - The content requires interactive operation and is considered unrelated to oneself. - Glare, noise, and other uncomfortable physical environments.	
With UD	Not UD3; not UD4; not UD6; not UD7	
Suggestions: - The content framework for digital interpretation organises information by importance, with presentation methods requiring intuitiveness and conciseness. - Establish a content framework that aligns with the cognitive levels of visitors from various age groups, avoiding excessive difficulty or oversimplification. Incorporate culture and knowledge that is more closely related to daily life, rather than emphasising specialisation. - Adopting a content framework that progresses from foundational to advanced levels can meet the needs of visitors with diverse professional backgrounds. - Sufficient space should be maintained between exhibits, such as the spacing between digital media and physical exhibits or explanatory information. Avoid information overload and an excessive cognitive burden. - Equip digital interactive exhibits with concise, visual operation instructions. Guide older visitors, as these are designed specifically for them. - Establish dedicated guidance instructions for older visitors near digital exhibits, indicating that these are interactive digital displays they can engage with. - Provide a suitable and comfortable viewing/experience space for non-operating users. - The media space should utilise glare-free spatial decorative materials.		
Phenomenon 4: Older visitors engage with digital exhibits, but do not involve or complete the full visit.		
Problems analysis	- The duration is lengthy, and the lack of rest seating leads to excessive physical exertion. - Prolonged exposure to unsuitable lighting conditions leads to visual fatigue. - Requires maintaining a highly physically demanding posture for extended periods, such as looking upward or bending over. - The content fails to meet expectations; for instance, instead of providing background interpretations, it merely offers displays of physical exhibits.	
With UD	Not UD4; not UD5; not UD6	
Suggestions: - Comfortable operating, interaction time should not be too long. - Provide temporary seating for visitors, which should consist of chairs designed to accommodate the physical characteristics of elderly visitors. - Digital media exhibits require appropriate lighting and an environment conducive to easy identification and reading. - Digital devices should be placed within the normal line of sight, not positioned above display cabinets, on the floor, or on lower tabletops. - Considering the operational characteristics of visitors with different physical attributes, such as older visitors with reduced dexterity, the need for precise operations should be minimised. - The narrative structure of digital interpretation should eschew repetitive introductions of physical exhibits, as procedural, three-dimensional, and storytelling interpretations are more appealing to elderly visitors. Examples include procedural explanations and illustrations that restore historical scenes through scene reconstruction. - Adopt a visual interpretation approach to present engaging and entertaining content within an appropriate duration, ensuring to avoid excessive cognitive load to maintain attention.		

6. Conclusions

To explore the relationship between digital interpretation and museum engagement among older adults, we developed an evaluation system tailored to the psychological characteristics of older adults, based on the Analytic Hierarchy Process, and implemented this evaluation in three museums. In this evaluation, we documented the design and environmental features of 88 sets of digital interpretation and interaction exhibits and observed and measured the interactive behaviours of 456 older visitors. The results indicate that existing digital media exhibits have relatively low appeal to older adults. While seniors are willing to engage with digital interpretation and interaction, and acknowledge that digital

interactions enhance their experiences, adopting new technologies proves somewhat challenging for them. This difficulty partly arises from psychological unfamiliarity and certain physiological limitations, such as dizziness caused by immersive cinema experiences.

The preliminary results suggest that the visual materials used in digital interpretation and the content framework, as well as the scale characteristics and spatial configuration of exhibits, have a significant impact on the engagement of older visitors. Moreover, we verified that several features—novel communication mediums and equipment, operation-free devices, clearly presented themes, and process recreation narratives, closely tied to daily life—can significantly enhance older visitors' attention and level of involvement. Particularly, digital exhibits that are larger in scale and have more spacious layouts are more likely to attract engagement from older visitors.

Our research further indicates that most digital exhibits do not adhere to the UD principles, particularly in aspects of Flexibility in Use (UD2), Simple and Intuitive Use (UD3), Low Physical Effort (UD6), and Size and Space for Approach and Use (UD7), and do not sufficiently cater to the needs of older adults. These issues can be addressed by implementing the seven principles of universal design to minimise limitations and barriers, thereby enhancing digital engagement for older visitors.

This research contributes to the inclusive design of museum exhibitions and digital interpretation, demonstrating the potential benefits of applying principles of universal design. Our findings guide the design of exhibitions and digital interpretation in cultural tourism museums, thereby enhancing the role of museums in addressing population ageing and promoting active ageing. Moreover, museum exhibition designers and builders should consider the visual presentation of digital interpretation exhibits, the effectiveness of information interpretation, and the environmental impact of digital exhibits and devices, rather than merely focusing on the types and technologies of digital interpretation. This plays a crucial role in capturing the attention of older adults and influencing their engagement and experience. As some talkative older individuals expressed, the digital exhibits feel too distant, not intended for our viewing.

Through a rigorous and systematic evaluation system, this study identifies the barriers that older adults encounter in visiting museums. It also explores the root causes of these issues. The findings offer theoretical and practical evidence regarding the impact of digital interpretation on older visitors, guiding future development. Additionally, the discussion explores the benefits of these approaches for museum practitioners and the broader literature.

While older adults may not be the primary visitors to museums, they, like children, are demographic groups that deserve special care and attention within public services. By refining the form and content of digital design to better cater to the needs of all visitors, thereby bringing the elderly a sense of joy or fulfilment that goes beyond merely passing the time, we can encapsulate the essence of an inclusive museum, creating an optimal exhibition environment for everyone. The seven principles of universal design aim to ensure that all visitors, regardless of their abilities, have the right to access museums and engage with digital interpretation and interactive exhibits.

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Data Availability Statement: The review materials and sample data are presented in Appendix A. The data presented in this study is available on request from the corresponding author.

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Abbreviations

The following abbreviations are used in this manuscript:

UD	universal design
7UD	seven principles of universal design
SLR	systematic literature review
AHP	Analytic Hierarchy Process
AP	attraction power
UX	user experience
WHO	World Health Organisation

Appendix A

Appendix A.1. The Factors Affecting Visitors' Interest and Participation Behaviour

Table A1. The factors and details affecting visitors' interest and participation behaviour from literature review.

The Factors and Details Affecting Visitors' Interest and Participation Behaviour
A11—Digital interaction form: 1. Viewing type; 2. Trigger Viewing Type; 3. Interactive Display Type; 4. Interactive Gaming Type; 5. Immersive Spaces Type. [29,39,52,72,80]
A12—Main media equipment: 1. Touchscreen or multi-touch screen; 2. intelligent sensing; 3. display; 4. projection; 5. new technologies, including VR, XR, or 3d mapping, etc., new technique. [18,19,73,74]
A13—Sensory participation format: 1. Visual; 2. visual + auditory; 3. tactile; 4. other senses or multisensory. [18,51,75,80,85]
A14—Number of people the digital exhibit can accommodate simultaneously: 1. One person; 2. 1–2 people operating or viewing; 3. 3–5 people simultaneously operating or viewing; 4. group. [8,80,87,88]
A21—Explicit signage or explanation systems. [34,79,83]
A22—Explicit and theme of the exhibit. [35,75]
A23—Visual styles presented: 1. Realistic style; 2. cartoon or animation style; 3. 3d drawing style; 4. abstract art style. [35,72,85]
A24—1. Contrast colour; 2. harmonising with surrounding colours. [65,81,82,87]
A31—Information load: 1. High; 2. moderate; 3. low. [11,34,82]
A32—Complexity of information: 1. Complex and difficult information; 2. concise and easy information. [11,34,46]
A32—Narrative type: 1. Archaeological documentation; 2. process interpretation and reappearance; 3. historical reappearance (including historical scenes, historical stories, architecture, etc.); 4. science popularisation; 5. artistic appreciation; 6. static image playback, non-narrative. [4,72,74]
B11—Layout: 1. Fixed single flow path; 2. flexible flow path; 3. located in complex multi-corridor flow paths. [29,34,46]
B12—Exhibit layout location: 1. Located along the main exhibition route; 2. situated on special exhibition routes; 3. positioned on secondary exhibition routes. [16,29,34]
B21—Dedicated lighting, projection, and other atmospheric elements. [18,51,64]
B22—Create a sound atmosphere. [51,53,65]
B31—Independent space. [30,34,47]
B32—There are partitions/separate desks/walls. [29,46,64]
B33—Configuration: 1. Large-scale media installations; 2. artistic installations; 3. comprehensive scenes; 4. independent digital device. [46,64–66]
B34—Does not possess independent attributes: 1. Large indicator; 2. small indicator. [46,64–66]
C11—Demographic characteristics. [4,8]
C12—Motivation and purposes. [4,8,36]
C13—Purposes of museum visiting. [4,8,36]
C23—Number and characteristics of visitors (alone or in a pair/group). [8,80]
C22—Out-of-town visitors or local visitors. [4,36]
C23 The identity characteristics of visitors, such as parent–child families, students, couples, experts, etc. [8,36,80]
C31—Cognitive characteristics, such as cultural background. [8,85]
C32—Number of museum visits/year. [8,11]
C33—Visitors' physical characteristics and restrictions. [11]

Appendix A.2. Research Tool

Table A2. The sample of the IAE Scale.

Digital Media Attractiveness Record for Old Age Visitors							
Museum:					Date:		
Location:					Page:		
* Record declaration:							
F: Female; M: Male; D: People with disabilities							
Behavioural characteristics: whether it is a person, or two old people together, or with adult children, or with a preschool child							
Item		Record time					
NO.	Visitor Types				Score		Protocol
	F	M	D	Behavioural characteristics	Based	Add	
e.g.	✓			Alone	2	1	An older man took photos.
1.							
2.							
3.							
4.							
5.							

* Code of points: [0] Ignore. [1] Atten. [2] Engage. [3] Successful Engage. [+1] Involvement moment.

Appendix A.3. Research Results

Table A3. Correlation analysis results between AP and UD.

	UD1	UD2	UD3	UD4	UD5	UD6	UD7	Mean
AP	0.224 **	0.246 ***	0.279 ***	0.231 ***	0.158 ***	0.251 ***	0.145 **	0.308 ***
+1	0.096 *	0.147 **	0.151 ***	0.158 ***	−0.018	0.121 **	0.03	0.141 **
Total	0.218 ***	0.248 ***	0.279 ***	0.238 ***	0.135 **	0.247 ***	0.134 **	0.302 ***
	456	456	456	456	456	456	456	456

*** At the 0.001 level (two-tailed), the correlation is significant. ** At the 0.01 level (two-tailed), the correlation is significant. * At the 0.05 level (two-tailed), the correlation is significant.

Table A4. Regression analysis results on the seven principles of UD indicators.

	β	SE	Beta	t	p	95.0% Confidence Interval		Tolerance	VIF
	−0.7	0.262		−2.674	0.008	−1.214	−0.186		
UD1	0.031	0.082	0.026	0.383	0.702	−0.13	0.192	0.448	2.234
UD2	0.053	0.088	0.047	0.608	0.543	−0.119	0.226	0.34	2.941
UD3	0.154	0.064	0.19	2.422	0.016	0.029	0.279	0.324	3.084
UD4	−0.014	0.054	−0.018	−0.251	0.802	−0.12	0.093	0.378	2.645
UD5	0.062	0.053	0.061	1.172	0.242	−0.042	0.166	0.729	1.372
UD6	0.128	0.059	0.128	2.189	0.029	0.013	0.243	0.589	1.697
UD7	−0.028	0.058	−0.028	−0.486	0.627	−0.142	0.086	0.612	1.634

The dependent variable is AP (total).

Table A5. The results of the high-frequency characteristic word analysis.

Category	Feature Words/Phrases	Frequency	Remarks/Examples
Feature words	Favourable	17	Thought digital media was good/fine
	Diversified forms	10	Positive evaluation of digital interpretation
	Unwilling	9	Digital devices are complicated or uninteresting
	Environment	7	Complain about dim lighting, crowded space, confusing routes, etc.
	Simple content	6	Criticism of the lack of depth in multimedia content
	Novelty	5	Digital media are novel and interesting
	Video playback	5	Specific forms, such as video playback
	Safe	5	Emphasise a safe and unblocked space
	Vivid content	5	Positive comments, such as “vivid picture”
	Physical objects	4	Focus on physical objects
	Needs of the elderly	4	Mention of elderly maladaptation problems, such as dizziness
	Unclear illustration	4	Interactive devices lack guidance
	Irrelevant content	3	Criticism of digital content is irrelevant to the exhibition
	Children	3	Controversy over interactive design for children
	Overlook	3	Not paying attention to digital interpretation
	Not interested	3	Not interested in digital interpretation
	Not for me	3	Not suitable for the elderly
Gender	Female	20	The respondents were mainly female (64.52%)
	Male	11	The proportion of respondents who are male was 35.48%
Forms of visits	Couple	10	Common forms of tourists (such as couples travelling, friends group leisure)
	Group	9	
	Companionship	6	The family visit form is mostly used for residents
	With kids	3	Take preschool children on a tour
	Visit alone	3	Common among professional visitors
Motivation	Leisure and relaxation	15	Core needs are frequently mentioned by local tourists
	Cultural tourism	7	Core motivation of non-local tourists
	Learning	3	Mentioned by professional visitors

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