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Design Innovation and User Experience of Sensory Interactive Experience in Museum Exhibition Space

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Abstract. This research examines the influence of multi-sensory experiences on visitor engagement within museums in the United Kingdom, with particular emphasis on the roles of physical design elements, technological integration, and sensory stimuli. Utilizing a comprehensive literature review, along with observational studies and surveys across 12 specialized museums, this study identifies critical factors that enhance visitor interaction and satisfaction. The findings reveal that the incorporation of interactive and multi-sensory elements, such as augmented reality and tactile exhibits, significantly augments visitor engagement. This study highlights the evolving function of museums as dynamic educational platforms that amalgamate entertainment and learning. It underscores the imperative for future museum designs to adapt to the digital era and cater to the diverse expectations of visitors. The results suggest that a strategic integration of sensory experiences can transform museums into more inclusive and immersive environments, thereby enriching the educational and cultural experiences of their audiences.

Keywords. Multi-sensory experience, museum experience, exhibition design, behaviour, digital era

1. Introduction

Museums hold a distinguished place in society as repositories of cultural, historical, and scientific artifacts, serving as vital educational institutions and spaces for public engagement. With the advent of the digital age, the traditional roles of museums—collecting, preserving, researching, and exhibiting materials—are undergoing significant transformation [1]. The challenge for modern museums is to adapt to these changes while continuing to offer enriching educational experiences that blend entertainment with learning.

Multi-sensory experiences have emerged as a crucial element in enhancing visitor engagement and satisfaction in museums. These experiences involve the integration of various sensory stimuli—visual, auditory, tactile, and olfactory—within the exhibition space. Research indicates that elements such as interactive exhibits, augmented reality (AR), and virtual reality (VR) significantly boost visitor interaction and satisfaction [2].

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Additionally, the physical layout, lighting, soundscapes, and even the ambient temperature of museum spaces contribute to the overall visitor experience [3]. Designing effective museum spaces thus requires a multifaceted approach that goes beyond interactivity. It involves creating environments that are inclusive and immersive, catering to diverse visitor expectations and learning styles. Scholars like emphasize the importance of considering the communicative dynamics between humans and exhibitions, noting that interaction is an effective way to attract and engage visitors across different types of museums, including art, history, and cultural institutions [4].

This study aims to explore the impact of multi-sensory experiences on visitor engagement in UK museums. By examining various design strategies and technological integrations, this research seeks to identify key factors that enhance visitor interaction and satisfaction. Through a comprehensive review of literature, observational studies, and surveys conducted in specialized museums, this study will provide insights into how museums can evolve to meet the changing needs of their audiences in the digital era. The ultimate goal is to demonstrate that thoughtful integration of sensory experiences can transform museums into more dynamic, inclusive, and educational spaces, enriching the cultural and learning experiences of their visitors.

2. Literature Review

2.1. Museum Exhibition as a Function of the Museum

Museums are crucial educational institutions that contribute to sustainable human and social development by reflecting culture, art, and education [5]. They serve as educational supplements to formal schooling and as open education platforms where visitors engage based on personal interests [4]. Beyond collecting and conserving, museums enrich knowledge and attract diverse audiences through interactive and technological enhancements [6].. Examples include the National Museum of Australia's digital artifact interaction, the Museum of Islamic Art in Qatar's hands-on exploration spaces, and the Smithsonian American Art Museum's use of augmented reality [7]. These initiatives illustrate the shift towards more engaging and participatory museum experiences.

2.2. Museum Classification and Field Visits

Over time, the diversity of museums has given rise to different ideas and social roles, and new perceptions of museums have emerged. Museums are sometimes categorized on the basis of their source of funding (e.g., state, municipal, private), but this does not clarify the types of museums. In the study of museum functions, general and specialized museums have different purposes [8].**.** In the study of museum functions, general and specialised museums have different purposes. They can be categorised into five basic types (Table 1) : natural history and natural science, science and technology, history, art and general[9].

Table 1. Two ways to classify the museum

Two ways to classify the museum	Typology
Classified by content	A. Art museums, B. Historical museums, C. Anthropological museums, D. Natural history museums, E. Technological museums, F. Commercial museums.
Classified by purpose	A. National museums, B. Local, provincial or city museums, C. College and school museums, D. Professional or class museums, E. Museums or cabinets for special research owned by societies or individuals.

2.3. Visitor Interaction

In the museum experience model shown in Figure 1 the museum visitor's experience comprises three parts: physical context, social content, and personal context [4]. The figure suggests that every visitor (i) brings their own personal and social contexts, (ii) Is differently affected by the physical context, and (iii) Makes different choices, such as which aspect of the context to focus on.

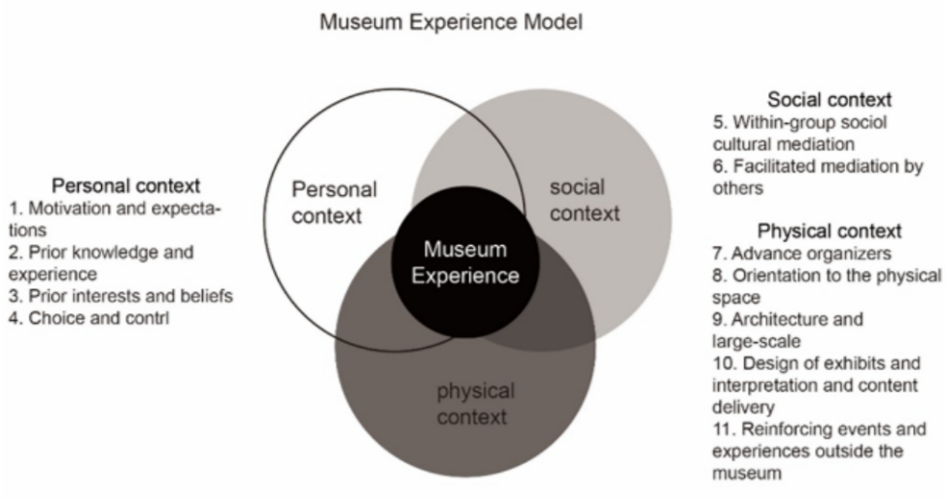

Figure 1. Museum experience model (Falk and Dierking, 2013)

Researchers found that visitor-exhibit interaction tends to be passive, with perceived value being crucial in shaping visitors' evaluations of exhibitions and museums [11]. Enhancing perceived value involves providing services and interactions that evoke positive impressions and emotions, ultimately leading to a fulfilling visitor experience. Visitors actively engage with exhibits, selecting items to interact with and exploring them thoroughly [11]. Even when unaware of the content, visitors expect to engage with tags, videos, and audio materials leading to further interpretation and discussion with companions [4].

2.4. Multi-Sensory Interaction Experience in Museum/Exhibition

The museum experience involves both cognitive processes and sensory engagement., cognition in user experience, including observation, participation, and enjoyment [13]. Some advocate tactile experiences to enhance comprehension and memory of artworks, and peers suggest that multi-sensory learning can enhance memory [14].

In exhibitions, visitors process information through their experiences, influenced by cognitive biases like the availability heuristic and framing effect [15]. Scientists have discovered the intersection between multisensory experiences and museum experiences and suggest opportunities for enhanced learning [16]. Museums increasingly adopt multi-sensory approaches to cater to diverse visitor needs, aiming to deepen understanding and appreciation of art objects.

3. Methodology and Procedure

For methodology there were 4 progresses in this study to achieve the research objectives: literature review, observation, survey, and analysis. Firstly, based on the literature review, we found a strong correlation between human sensory experience in museum spaces and visitor behaviour. Next, following the literature review, an attempt was made to observe the different types of museums from a bystander's perspective. Then, a questionnaire from a pilot study was used to find out how people thought and felt about a particular exhibition.

3.1. Observation of 12 Specialised Museums with Exhibitions

According to the Museums Association, the UK is home to around 2,500 museums, of which nearly 1,800 are accredited to nationally recognised management and service standards (e.g. Table 2, data collated from the authors, official website provides museum names only).

Table 2. Statistics on the category of museums in the United Kingdom

Category of museum	Percentage of total
Local Museum	39.3%
General Museum	9.2%
Art Gallery	15.7%
Military Museum	6.8%
Transport Museum	4.8%
Country Museum	3.6%
Maritime Museum	3.0%
Natural History Museum	1.6%
Aviation Museum	2.7%
Industrial Museum	9.6%
Science Museum	2.0%
Sport Museum	1.6%
Other	0.2%

Academics are increasingly turning to platforms such as TripAdvisor to understand the museum experience by analyzing visitor reviews [17]. Based on TripAdvisor rankings and reviews, we selected 12 museums, prioritizing smaller, niche institutions over popular ones. These include the Design Museum, the Saatchi Gallery and the Serpentine Gallery.

The geographical analysis (Figure 2) draws on sources such as Historic UK to understand the distribution of museums across the UK, focusing on quantitative statistics for London and the distribution of museums in other cities.

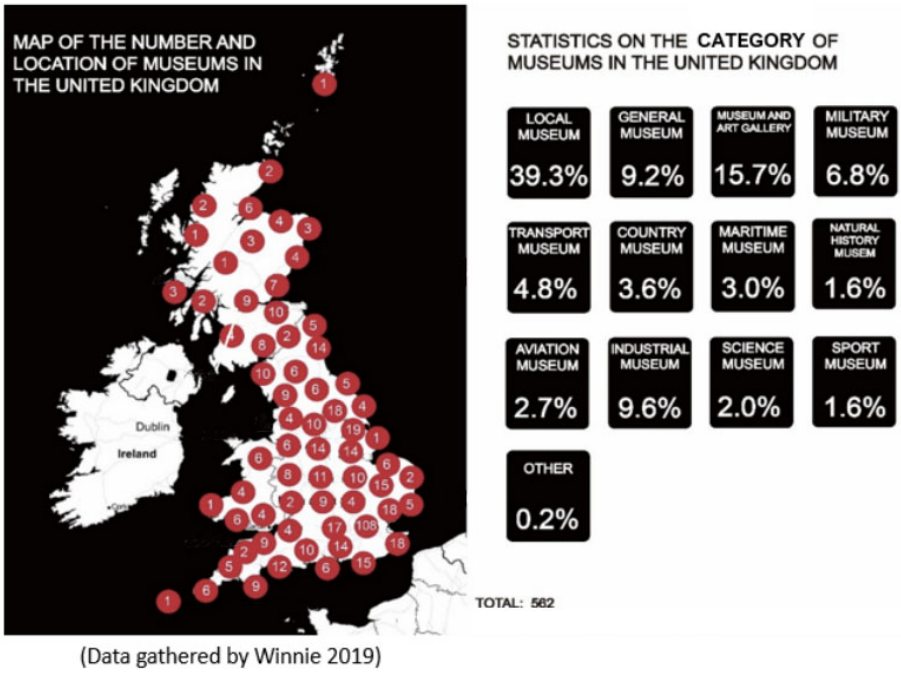

Figure 2. Location of museums and category in the United Kingdom

3.2. Multi-Sensory Transformation in 12 Museums

Research on the potential influence of sensory engagement on museum visitors included a look at how displays at 12 different museums communicate with visitors (see Table 3). In most cases, visitors are approached in a more conventional manner through exhibits. There is a broad variety of visual sensory communication options available to visitors to museums, including text guides, media engagement and publications. Virtual reality (VR) is one of the tools that some of them use. These sensory encounters are not as frequent and are confined to the sort of show. Finally, only the twelfth exhibition, "BIG FOOD," displays the interplay between the senses of smell and taste. This is because the exhibition is centred on food.

Table 3. A classification of museums using the multi-sensory transform

Museum	**Sense Type**				
	Visual	**Auditory**	**Haptic**	**Olfactory**	**Gustatory**
1. Design Museum	Text guide Lighting Interaction Media interaction	Audio guide Video display	Commercial model	None	None
2. Saatchi Gallery	Interaction VR Booklet	Audio guide Video display	Installation art(interact)	None	None
3. Serpentine Gallery	Video display Screen	Audio guide Video display	None	None	None
4. White Cube	Text guide	Video display	None	None	None

5. Bank of England	Text guide Route map Video guide	Video display	Touchable replica model Scene design Digital screen	None	None
6. London Transport Museum	Text guide Booklet Video guide	Video display	Touchable replica model Scene design Digital screen	None	None
7. V&A Childhood	Text guide	None	Scene design	None	None
8. Body world (Exhibition)	Text guide Lighting Interaction Media interaction	Audio guide Video display	Touchable replica model Scene design Digital screen	None	None
9. The Fan Museum	Text guide	Audio guide	None	None	None
10.The Sherlock Holmes Museum	Scene design	None	Scene design	None	None
11.Big Food (Exhibition)	Video	Video display	Touchable replica model Scene design Digital screen	Smelling	Food tasty experiment
12. The Founding Museum	Lighting Video display Screen	Audio guide Music auditory	Scene design	None	None

3.3. Participants

A total of 16 persons participated in the observation, 9 postgraduates and 6 PhDs. In terms of age group, 3 (17.65%) were in the age group of 18-24 years, 11 (64.71%) were in the age group of 25-34 years, 1 (5.88%) was in the age group of 35-44 years and 2 (11.76%) were in the age group of 45-54 years. The participants were from design, manufacturing, engineers and other industries. Culturally, they came from a variety of countries including China, France, Thailand, USA, Mexico and UK. Although the 16 participants in this pilot study represented a small group of people, they provided a comprehensive evaluation of the content and experience of the exhibition from a variety of perspectives.

3.4. Questionnaire Design

We listed a series of questionnaires for the possible concerns of the participants to facilitate our analysis at a later stage, the questionnaires are listed below:

Table 4. Questionnaire design

Questions	Answer Selection
Part 1: Questions about exhibition experiences	
Q1: Do you often visit exhibition or museum?	Yes. Sometimes. No.
Q2: Who do you visit the museum with (Multiple options)	Alone; A partner/ friend; Your family; Your school/college/A tour-group; Other(s).
Q3: What type of exhibition/museum is most attractive to you	Art/design; Historical;;Science; Geology; Other (s).
Q4: Thinking about the last exhibition you attended. How did you feel about it?	Extremely good/Moderately good/Slightly good/Neither good nor bad/Slightly bad/Moderately bad/Extremely bad.
Q5: Do you remember the contents of this exhibition?	Definitely yes/Probably yes /Might or might not /Probably not/Definitely not.

Q6: How long has it been since the last time you visited an exhibition/museum?	_____.
Q7: In the recent exhibition that you visited, to what extent did the content interest you?	Not at all 1 2 3 4 5 6 7 8 9 10Extremely
Q8: What makes an object interesting to you?	A. The way it looks (eg. Colour, shape, size, etc.). B. Personal interest in that type of object C. Having seen it before D. It looks very curious and wanting to know what it is E. Others_____.
Q9: What aspects are you more important when you visit an exhibition/museum?	F. Arrangement of objects G. Arrangement of space H. The quality of objects on display I. Length of information content available J. Ability to interact with objects K. Interact with knowledgeable staff L. Environment (e.g. light, space design, etc.) M. Others_____.
Q10: Which style of guide method will you prefer / which was the most successful way to stimulate your interest in the exhibit? (Multiple options)	Booklet/ Touching the exhibit/ Audio equipment/ Smelling the exhibit if necessary/ Tasting the exhibit if necessary/ Communicate with stuff/commentator/ Workshop/ courses
Q11: Did the exhibition provide you with new/updated knowledge? For example, a new understanding of objects or culture.	Definitely yes /Probably yes /Might or might not /Probably not /Definitely not.
Q12: Do you think that the way you interact when you visit the exhibition will help you	Definitely yes /Probably yes /Might or might not /Probably not /Definitely not.
Part 2 General questions	
Q1: What is your gender?	Male /Female/ No want to say
Q2: Age range	Under 16/ 16-24/ 25-34/ 35-44/ 45-54/ 55 or older
Q3: What is your occupation/ job title?	
Q4: Which of these describes your personal salary last year?	
Q5: How can you get the exhibition/museum information?	Social media/ Website/ Advertisement/ Family/ friend/ Other

4. Discussion

Based on each question in the questionnaire, we conducted a sequential analysis of the 11 qualitative questions collected. These questions were divided into 5 aspects to analyse, e.g., personal preferences, the impression of the exhibition, the evaluation from participants, classifying participant's behaviours and interactive effect.

According to the collection of questions in charts (see Table 5), the majority of respondents indicated that they preferred art, design and history museums or exhibitions, although they were not used to visiting them (and some did not visit them at all).

Table 5. Statistics on individual questions in the questionnaire

Question	Selection
What is your gender?	Female 50% Male 50%
What is your age group?	A. Under B.18-24 C.25-34 D.35-44 E.45-54 17.65% 64.71% 5.88% 11.76%
Do you often visit exhibition or museum?	A. Yes B. Not always C. No 50%% 43.75% 6.25%
Are you visit exhibition or museum with?	A. Along B. With a partner/friend C. With your family D. with your school/college E. With a tour-group F. Other(s) 25% 37.5% 21.88% 9.38% 3.125% 3.125%
What type of exhibition/museum is most attractive to you?	A. Art/Design B. Historical C. Science D. Special E. Geology F. Other 30.23% 34.38% 31.25% 15.63% 12.5%
Do you prefer an exhibition or not?	A. More interaction B. Less interaction C. no interaction 87.6% 12.5% 6.25%

Many aspects will affect the reasons why people do not visit museums. At the personal level, individual interest, attitudes, and motivations encourage a person to visit the museum. At the social level, the result shows that most of the participants prefer to visit the exhibition with friends and family (Table 6). In fact, that a medium exhibition space can bring people closer, and information can be shared better. For those who like to visit the exhibition, they can get abundant feelings through personal experience than the information brought to them by the artifacts itself.

Table 6. Participants experience comments

Participant No.	Experience Comment
No.1	Very disappointing event, lacking any real innovation or impact in relation to exhibitors and the products that they displayed. Very few inspirational exhibitors, unclear as to what was being displayed and promoted.'
No.3	'It was such a maze, really confusing. I didn't visit a lot of exhibitions but if know for sure that they could have optimised the organisation and the arrangement. Besides that, it was quite interesting to see all the stand with so many items and things displayed.'
NO.12	'The way they display the exhibition was good. Besides that, the majority of the project that presented an engineering component was not well design. Some of them were not event tested to see the proper functionality and just focus on the apparent.'

The analysis of participants' comments on exhibition design reveals several key considerations. Social interaction, involving close communication between visitors, designers, and products, is essential for understanding exhibits. However, spatial design confusion can hinder concentration and thought. Traditional methods fall short in meeting public demands for exhibition space design; user experience and interaction are crucial for core competitiveness [18]. Exhibition design should satisfy visual, customer, designer, and audience requirements, with design factors shaping customer experiences. Effective interactions, such as through space design or environmental factors, enhance visitor experience and content retention [19]. Participants emphasized the importance of space, products, interaction, communication, and educational value while noting areas for improvement like unclear information, insufficient interaction, excessive text, lack of attraction, innovation, and chaotic layout.

From the responses of questionnaire Q8 and Q9 (Table 4), the behaviour of participants who went to the New Designer exhibition could be divided into three types:

1. Self-thinking - After reading through the text, individuals combine the perception of the real object with the physical experience of the object to ask professional questions. Then they continue to observe.
2. Communication - They prefer to communicate directly by spoken language, but this general approach may not impress them.
3. Observation -They prefer to explore and solve problems while observing objects.

Questionnaire feedback suggests that three processes can enhance visitors' memory, depending on individual preferences. Eight visitors preferred detailed observation and tactile interaction, while five favoured asking questions while holding objects (Table 7). All 13 shared a desire for tactile engagement. User experience and interaction are crucial in design, with 13 respondents affirming that increased interaction would deepen their experience and aid recall (Table 8), though others were uncertain. The impact of interaction varies, necessitating careful consideration of essential versus problematic interactions.

Table 7. Questionnaire feedback analysis 1

Interesting comment	Participants
Being able to look at details of the objects	8
Communicate with designers	3
Being able to ask questions about the objects whilst holding them	5
Being able to compare a range of objects	1

Table 8. Questionnaire feedback analysis 2

Precious options	Participants NO.	Interesting comment
Being able to look at details of the objects	1	Need to understand the details of the materials and objects to see if it is relevant or related to project requirements. Physical object enables a tangible physical representation and therefore it is easier to understand its relevance.
	2	the more details give the more background knowledge, learning the other perspective could create the new innovation.
	4	When you look at the details and understand the organization of these details, you can understand all aspects of the overall design.
	13	I like staring at things to see all the details and understand why it is like that, what's the meaning. After that, if I still need more information I will ask someone
	14	The item that I can touch or play with, can give more impressions! When I played with it, I feel so fun! Some of the products, they only have a poster on the wall, or the products can not touch, so I just pass them to looked at others
Communicate with designers	11	Human contact with the creator of the object. Knowing that I could have asked all the questions that I wanted and the most suitable person to give me an answer was the creator itself.
	12	In order to understand some project, it needed some in deep explanation.
Being able to ask questions about the objects whilst holding them	9	was not really able to understand their work in one go. While looking at what they have made I have lot of questions, to confirm my thought about their work.
	4	When you look at the details and understand the organization of these details, you can understand all aspects of the overall design.
	16	It made me to understand more the product and the inspiration for doing it.
	10	Because when you are able to interact with the objects it is easier to understand what is the purpose of it, and see how it works.

5. Result

In our study, through triangulation analysis of exhibitions and audiences (Figure 3), we considered display objectives, audience engagement, educational aspects, and space quality. Exhibitions are evaluated not just on design, but also on their development, function, impact, and innovation, raising questions for visitors about future trends. User experience is enhanced through interaction and discussion, fostering memorable and innovative experiences. Some participants were confused by the spatial layout requirements, finding overly chaotic layouts disruptive to focus and thought.

Survey results (Table 9) highlighted the importance of spatial comfort, which significantly impacts visitors' psychological well-being. Effective display design and interaction facilitate better information retention and engagement [20]. Emotional spaces can deepen short-term memories into long-term ones, creating unforgettable experiences [21].

The quality of space profoundly affects our physical and emotional experiences. Emotions are conveyed through various forms of human communication [22]. Our perception of the environment is influenced by sensory stimuli, which can evoke desired behaviors and emotions [23].Movement within spaces can evoke emotions such as awe [24].. Participant feedback on spatial layout varied, reflecting both negative and positive emotional responses.

Qualitative research revealed the challenge of detailed classification due to the richness and diversity of language. To address this, we proposed a second, more structured questionnaire with fixed options to streamline data analysis. Confidential questions on income and occupation were included to differentiate views based on social class and education level, reflecting the museum's diverse audience.

In conclusion, the study showed that exhibition design and spatial layout significantly impact visitor experience, highlighting the need for further quantitative research to better understand and optimize exhibition experiences.

Table 9. A summary of visitors' major concerns in this pilot study

Audience concern in these 4 factors	
Objectives	1. Innovation ideas
	2. Future trend
	3. Quality attraction
	4. The value behind the items
Experience	1. Clear method to deliver the information
	2. Communication/ interaction
	3. Information transmission is not clear
Space	1. Arrangement
	2. Space function
	3. Route
Education	1. Knowledge acquisition
	2. Inspiration
	3. Educational significance behind the display

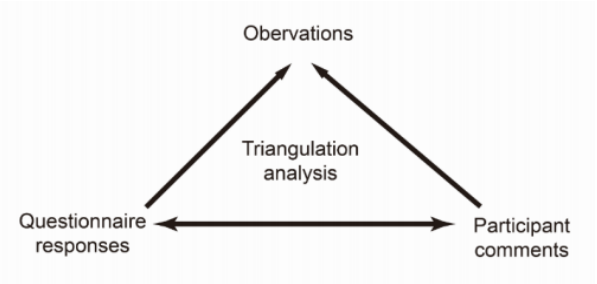

Figure 3. The triangulation analysis of three methods.

6. Limitation and Future Work

This pilot study was conducted by 17 participants, which is not fully representative of the experiences and thoughts of visitors. Therefore, in the second questionnaire, we considered requiring more participants to participate in order to obtain comprehensive information. The questionnaire was sent by email and the recipient was asked to forward it to friends and family. We ended up collecting as many as 2,000 responses for the next round of data analysis.

In our future work, we will still focus on analysing multisensory interactions in exhibition spaces. Future research will use this study as a basis for further in-depth studies of visitors' long-term and short-term memory in exhibition viewing, and in-depth explorations of the results of memory transformation of knowledge.

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