WACANA SENI
Journal of Arts Discourse

The Simulation of Museum Interior Experiences Through 3D Visualisation: The Comparison Study on Visitor Perception

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Published online: 31 December 2025

To cite this article: Astrid Kusumowidagdo, Yusuf Ariyanto, and Christina Jeanette. 2025. "The Simulation of Museum Interior Experiences Through 3D Visualisation: The Comparison Study on Visitor Perception." *Wacana Seni Journal of Arts Discourse* 24(Supp. 1): 6–28. https://doi.org/10.21315/ws2025.24.s1.1

To link to this article: https://doi.org/10.21315/ws2025.24.s1.1

ABSTRACT

Enhancing the appreciation of museums among the younger generation is crucial for preserving cultural heritage, fostering education, and inspiring creativity. The interior experience at the Majapahit Information Centre Museum in Trowulan, Indonesia, plays a vital role in creating a welcoming and engaging atmosphere. This study aims to analyse the relationship between young visitors' perceptions and their experiences in museum interiors, with a focus on comparisons between contemporary and traditional environments that emphasise local values. By attracting and involving younger visitors, museums can convey knowledge and promote cultural heritage, thereby supporting efforts to preserve cultural heritage. The study utilised a quantitative approach through an experimental survey involving 75 respondents who evaluated 3D visualisations of two simulated museum settings: one contemporary and one traditional. Descriptive statistics were used to analyse factors contributing to satisfaction with the space, including orientation and navigation, spaciousness and display density, design and display style, lighting, and colour. Findings indicate that museum interiors with contemporary styles significantly influence cognitive responses, particularly in terms of design style and appearance. Conversely, traditional interior styles significantly impact cognitive responses related to lighting factors, as well as the spaciousness and density of display. These insights offer valuable implications for designing museum environments that resonate with younger audiences and can guide future research in this area.

Keywords: *3D simulation, museum interior design, visitor perception*

INTRODUCTION

Indonesian tourism is experiencing rapid growth, with one notable trend being cultural immersion. Encouraging museum visits, particularly among domestic tourists, serves as a valuable approach to fostering cultural engagement. To harness this potential, governments, tourism institutions, and local communities must collaborate to enhance museum-based tourism by improving facilities, increasing accessibility, and developing attractive programmes. Museums not only contribute to tourism but also play an essential role in cultural education, particularly for the younger generation.

However, interest in museums, particularly among the younger generation, is minimal (Binekasri 2023). Despite this, it is crucial to continue developing museums and ensuring their sustainability by regenerating a younger audience. Museums face challenges engaging younger audiences due to insufficient emphasis on visitor experiences, evolving entertainment references, and the need to adapt to digital trends. By rethinking strategies, adopting innovative approaches, and enhancing the overall museum experience, institutions can make museums more appealing and engaging to younger generations.

To combat the decline in youth interest in museums, institutions must consider factors such as aesthetics, ambience, and the overall visitor experience, particularly for millennials (Risnawati and Rahimah 2023; Binekasri 2023). Effective spatial navigation (Lazaridou and Psarra 2017) and the development of captivating, interactive museum environments tailored to the preferences and learning styles of younger audiences are essential. Additionally, leveraging user-generated content and social media to showcase visitor experiences can generate interest and attract a younger demographic (Vu et al. 2018).

As highlighted by Hyun et al. (2018) and Kim and Lee (2020), aesthetics and ambience are becoming crucial considerations for engaging the younger generation. This research examines how ambience can enhance engagement by comparing the design elements of contemporary and traditional styles. The Majapahit Information Centre, which houses collections from the ancient Majapahit Kingdom of Indonesia, serves as a case study with functions similar to those of a museum. Efforts to rejuvenate the Majapahit Information Centre aim to improve visitors' experiences, not only for tourism but also for educating local communities, particularly the younger generation.

This study addresses a critical gap in understanding the preferences of the younger generation regarding the preferred museum interior styles by conducting comparative studies and case objects in the Indonesian context. Specifically, it examines the perception of museum interior design elements as stimuli to enhance experiential engagement. By filling this void across these three domains, the research aims to provide significant insights into enhancing museum design. Furthermore, it explores digitally simulated museum designs that accurately reflect real world conditions, offering a comprehensive framework for future advancements in museum interior design.

Recent studies have focused on essential design elements in museums (Alshamaileh et al. 2019; Kim et al. 2020; El Sheikh 2020), design elements related to the younger generation (Cesário and Nisi 2023), design for inclusivity and disability in museums (Weisen 2008; Carrizosa et al. 2020), as well as the improvement of museums with IoT and digitalisation (Beavis et al. 2021; Lin et al. 2022; Li et al. 2023).

Based on the preceding, this research aims to understand the perceptions of young visitors regarding museum interiors and their cognitive responses to these environments. Key factors of cognitive response include orientation and navigation, spaciousness and display density, design and display style, lighting, and colour, all of which are examined in the context of comparing contemporary and traditional interior styles.

METHODS

This research is a quantitative investigation using an experimental survey. One of the key advantages of experimental survey research is its ability to provide researchers with a structured approach to data collection. By designing surveys that include specific questions or experimental manipulations, researchers can control variables and maintain consistency in data

collection. This control enables the systematic investigation of relationships among variables and the evaluation of causal effects. Moreover, experimental survey research enables researchers to collect data from large numbers of participants efficiently. This research combines experimental manipulations with survey instruments, enabling the researchers to explore nuanced aspects of human behaviour and perception. The minimum number of participants per treatment group is essential in experimental design. Adequate participant allocation to different experimental conditions is vital for detecting treatment effects and ensuring the internal validity of the study.

The total number of respondents is 75, all of whom can be categorised as younger visitors, specifically those belonging to Generation Z (Gen Z). This sample size has been carefully considered for the study. Based on the provided references, Scholl-Grissemann et al. (2022) highlighted the importance of having a sample size of a minimum of 30 participants per experimental condition as a rule of thumb in experimental consumer behaviour research. Additionally, Madinur et al. (2018) conducted a study in which they followed the rule of thumb of dividing 60 patients into two groups of 30 each for their research.

These 75 respondents will complete the same questionnaire after observing two museum interior conditions: a 3D visualisation featuring contemporary and traditional interior styles, as in Figures 1 and 2. The museum being the object of research is the Trowulan Information Centre. The Trowulan Information Centre, situated in East Java, Indonesia, is a significant site that displays relics from the Majapahit kingdom. The museum serves as a key hub for sharing information about the region's cultural heritage with both local and international visitors.

These are two conditions that outline the 3D rendering settings used to simulate the exhibition of Majapahit artefacts under two different museological ambiences. In the traditional setting, the artefacts were presented in a darker atmosphere typical of historical museums. Global

Figure 1 3D visualisation in a traditional style museum interior

Source: Author's collection

Figure 2 3D visualisation in a contemporary style museum interior

Source: Author's collection

illumination with a physically based indoor lighting simulation was applied at 50–150 lux, following the Commission Internationale de l'Éclairage (International Commission on Illumination and the Illuminating Engineering Society) guidelines for sensitive objects. A 60° field of view and rendering in Autodesk 3ds Max at 3,840 × 2,160 pixels with Arnold emphasised intimacy, authenticity, and shadow depth.

In the contemporary setting, the artefacts appeared in a brighter and more open ambience, reflecting modern gallery design. Lighting intensity was increased to 200–300 lux, consistent with standards for durable materials such as stone and metal, while a 75° field of view simulated open-plan spatial perception. Renderings in Autodesk 3ds Max with Corona emphasised spatial clarity, soft shadows, and surface precision, presenting the Majapahit art efacts with modern visual accessibility.

The first analysis utilises descriptive statistics. Descriptive statistics are crucial for comparing different groups or conditions within a study. This research makes two comparisons, namely, the assessment of traditional and contemporary environments. The importance of using statistical distributions for image classification emphasises the advantages of ensemble solutions in data analysis. This highlights how descriptive statistics can help identify patterns and make informed decisions based on data characteristics.

The second analysis used multilinear regression. The benefits of using multilinear regression for visitor perception research in valuing virtual simulation and 3D modelling, experimental research as researches had done by Wu et al. (2022) that investigated how virtual experience influences bodily descriptions of artefacts, shedding light on the impact of virtual experiences

on perception and Llorca-Bofí and Vorländer (2021) that presented a detailed 3D architectural framework for sound perception research in virtual reality, focusing on visual and acoustic cues for comprehensive research.

The instrument in this research refers to Forrest (2015). The survey examines design style and display style factors as part of the cognitive responses to museum interior experiences. Design and display style possess indicators: design styles, vitrine design, interior walls, interior ceiling, interior accessories, and unity of design elements. At the same time, cognitive response has indicators, including sense stimulation, mystery, focus, effort engagement, choice, legibility and coherence, as well as exploration (Figure 3).

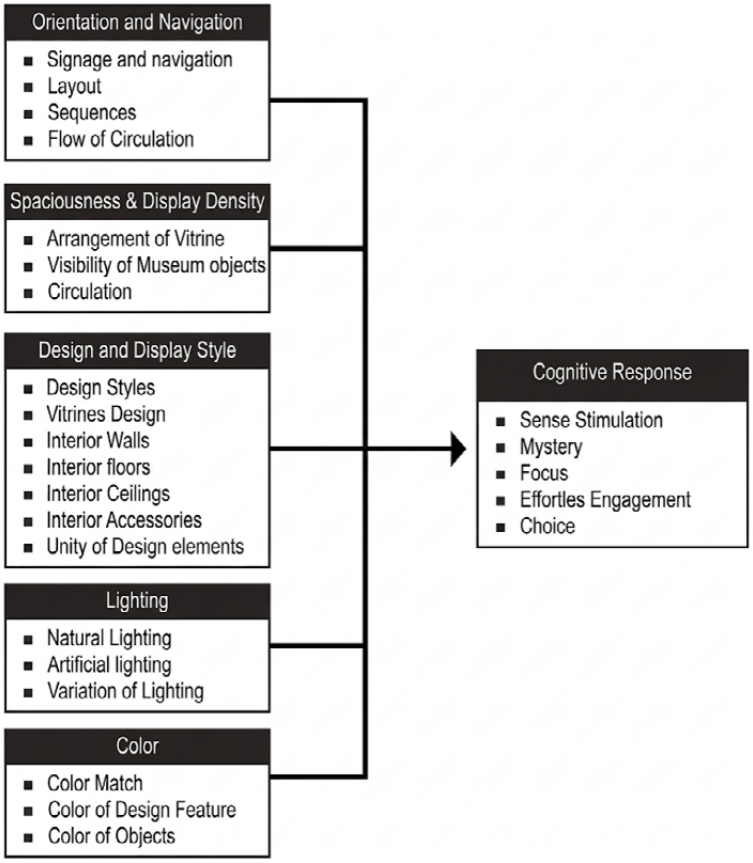

Figure 3 The relationship between variables

In this research, the effort to create 3D modelling is conducted using AutoCAD software alongside other 3D modelling applications, all of which have been technically mastered. This technical proficiency enables the creation of precise, detailed three-dimensional representations, thereby enhancing the overall quality and effectiveness of the design process. This process tries to create a close simulation of the real world. A pilot validation was carried out through a focus group involving architects and target user representatives (Table 1). The session aimed to evaluate the proposed framework by simulating both contemporary and traditional museum settings, ensuring its relevance and feasibility for real world application.

Table 1. The advisers of this project

No	Name	Role
1	Ms. Endah Budi Heryani	The Chairman of Balai Pelestarian Kebudayaan is a member of Technical Implementation Unit (UPT) in the field of cultural preservation under the Directorate General of Culture. He reports to the Director General of Culture
2	Ms. Rizky Susantinah	Museum expert, anthropologist
3	Ms. Sakuntala Verlista	Interior design expert
4	Ms. Feti Mayasari	Architecture expert

RESULTS

The discussion is organised into three main parts. The first part describes the characteristics of the respondents, which provide the study's background context. The second part discusses the questionnaire's validity and reliability, ensuring the robustness of the measurement tools. Finally, the third part presents the results of descriptive statistics and multiple linear regression analysis, highlighting the relationships among the studied variables.

Characteristics of Respondents

The characteristics of the respondents in this study encompass several aspects, providing a comprehensive background of the participants. These characteristics include the residential area, which indicates the geographical distribution of respondents, and age, which helps to understand the demographic profile of participants engaging with museum activities. In addition, respondents' hobbies are considered, as they may influence individual preferences and motivations for cultural or leisure activities.

Furthermore, the study examines respondents' physical visits to museums, highlighting the types of museums they have visited and the frequency of such visits. It also examines the purpose of visiting a museum, in both physical and virtual forms, to reveal whether the motivations are primarily educational, recreational, cultural enrichment, or social interaction. Specifically, the purpose of visiting a virtual museum is investigated, considering how digital platforms might attract audiences with different expectations compared to traditional museum settings.

Lastly, the frequency of museum visits is analysed across both physical and virtual museums to provide insights into participants' behavioural patterns and levels of engagement with museum experiences. Together, these characteristics offer an essential context for interpreting the subsequent analyses of validity, reliability, and regression.

First, from the questionnaire distributed, it was found that the respondents came from various residential areas in Surabaya. Of the 75 respondents, 10% came from North Surabaya, while 54% came from West Surabaya. A total of 17% came from East Surabaya, and 10% each came from Central and South Surabaya (Figure 4).

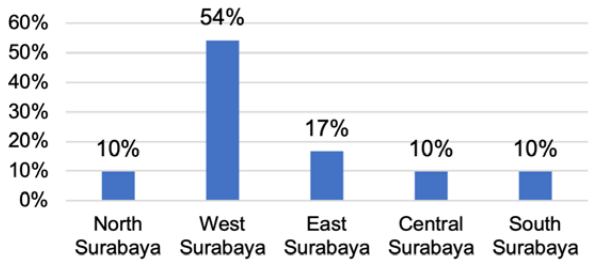

Figure 4 The respondents' origin

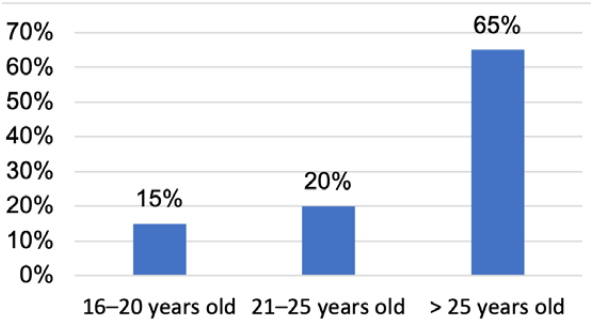

Figure 5 Respondents' age

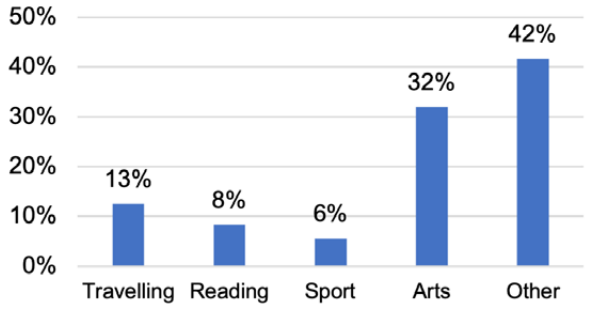

Figure 6 The respondents' hobbies

Most respondents were aged 16 to 19 years old, accounting for 65% of the total. The remaining 35% of respondents were aged 20 to 25 years old (Figure 5).

In Figure 6, the results of the distributed questionnaire revealed that 13% of respondents had a hobby of travelling, while 8% had a hobby of reading. It was also found that 6% of respondents enjoyed sports, and 32% had hobbies related to art. There were also 42% of respondents who had other hobbies.

Of the 75 respondents, it was found that they had various purposes for visiting museums. This aligns with the survey results, which showed that 35% and 14% of respondents stated that they visited museums to explore ancient artefacts and to avoid stress. It was found that 26% of respondents visited museums out of curiosity, while 15% and 10% visited museums to accompany family or friends and for attractions and novelty, respectively (Figure 7).

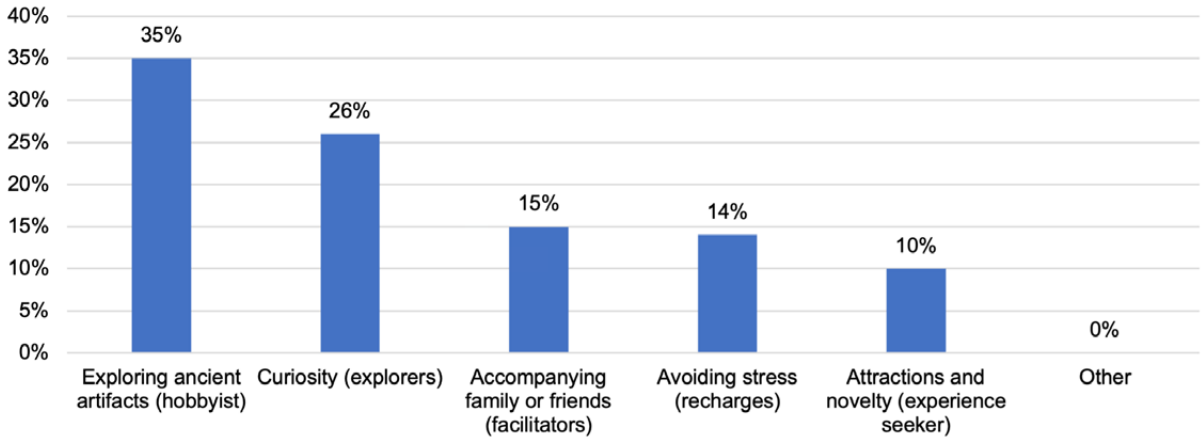

Figure 7 The purpose of museum visit

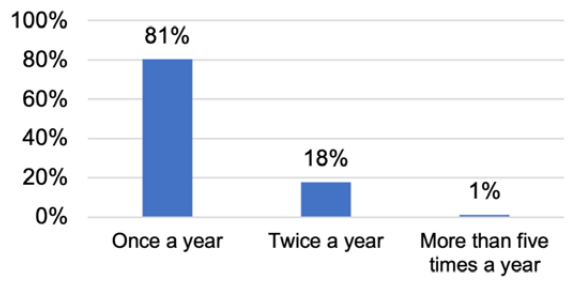

Figure 8 Frequency of museum visits

As seen in Figure 8, the frequency of museum visits varied among respondents. Of the 72 respondents, 81% visited a museum once a year. Another 18% visited a museum twice a year. Only 1% visited a museum more than five times a year.

As shown in Figure 9, respondents visited museums at different locations. It was found that 46% of respondents visited museums located within the city. Then, 22% of respondents visited museums outside the city. A total of 29% and 3% of respondents visited domestic museums and museums abroad, respectively.

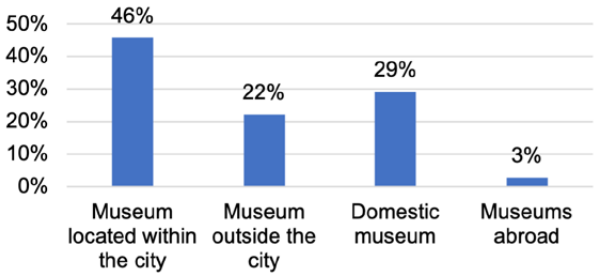

Figure 9 The Location of the museum visited by the respondents.

Accordingly, the respondent profile is deemed highly appropriate, as the majority consist of young men and women who represent the primary subjects of this study, with a predominant interest in the arts and prior experience visiting local museum sites.

Result of Validity Test

The questionnaire testing was carried out on an initial sample of 30 respondents to evaluate the clarity, reliability, and validity of the research instrument. This pilot test was conducted to ensure that the respondents could properly understand each question and indicator and were capable of measuring the intended variables. The variables included in the questionnaire consist of several latent constructs, each represented by multiple indicators related to aspects such as design style and display, lighting, pleasantness, and cognitive responses. The data obtained from these 30 respondents provided the basis for preliminary analysis, including validity and reliability testing, to confirm whether the instrument meets the required statistical standards. The results of this initial test indicate that the questionnaire items are suitable for further data collection in the main study.

In this study, instrument validity testing was conducted using Confirmatory Factor Analysis (CFA). CFA was applied to verify whether the indicators accurately reflect the latent constructs based on theory. Unlike Exploratory Factor Analysis (EFA), CFA focuses on confirming the theoretical model with empirical data. Convergent validity is assessed through outer loadings and Average Variance Extracted (AVE), while discriminant validity is tested using cross-loadings. This combined approach ensures the instrument is valid in measuring intended constructs and distinguishing among them.

Results of Convergent Validity Testing

In Table 2, the results of the convergent validity test indicate that all indicators in the model have outer loading values above 0.70, except for a few indicators under the construct Design Style and Display (X3.5 = 0.661; X3.7 = 0.670). Nevertheless, since these values remain within the acceptable tolerance threshold of ≥ 0.60, the indicators can be retained. Moreover, all indicators are significant with *t*-statistics > 1.96 and $P < 0.05$, confirming their validity in reflecting their respective latent constructs. The AVE values for all constructs also meet the required criterion of ≥ 0.50, ranging from 0.618 to 0.879. This demonstrates that each construct explains more than 50% of the variance of its indicators, thereby confirming that the model satisfies the convergent validity requirement.

Table 2 The results of the convergent validity test

No	Question	Validity test			
		Outer loading	t-statistic	P-value	AVE
1	X1.1 ← Orientation and navigation	0.898	24.925	0.000	0.728
2	X1.2 ← Orientation and navigation	0.841	13.033	0.000	
3	X1.3 ← Orientation and navigation	0.842	18.194	0.000	
4	X1.4 ← Orientation and navigation	0.832	12.266	0.000	
5	X2.1 ← Spaciousness and display density	0.905	29.062	0.000	0.827
6	X2.2 ← Spaciousness and display density	0.861	11.842	0.000	
7	X2.3 ← Spaciousness and display density	0.959	73.465	0.000	
8	X3.1 ← Design style and display	0.724	7.482	0.000	0.618
9	X3.2 ← Design style and display	0.809	10.072	0.000	
10	X3.3 ← Design style and display	0.876	24.846	0.000	
11	X3.4 ← Design style and display	0.788	5.507	0.000	
12	X3.5 ← Design style and display	0.661	4.052	0.000	
13	X3.6 ← Design style and display	0.929	41.326	0.000	
14	X3.7 ← Design style and display	0.670	5.794	0.000	
15	X3.8 ← Design style and display	0.795	11.505	0.000	
16	X4.1 ← Lighting	0.924	26.835	0.000	0.879
17	X4.2 ← Lighting	0.927	22.192	0.000	
18	X4.3 ← Lighting	0.962	46.275	0.000	
19	X5.1 ← Colour	0.898	18.536	0.000	0.833
20	X5.2 ← Colour	0.949	48.347	0.000	
21	X5.3 ← Colour	0.890	14.961	0.000	
22	X6.1 ← Pleasantness	0.896	22.368	0.000	0.804
23	X6.2 ← Pleasantness	0.901	17.006	0.000	
24	X6.3 ← Pleasantness	0.839	12.355	0.000	
25	X6.4 ← Pleasantness	0.942	48.803	0.000	
26	X6.5 ← Pleasantness	0.901	19.019	0.000	
27	X7.1 ← Cognitive responses	0.802	15.520	0.000	0.714
28	X7.2 ← Cognitive responses	0.864	19.075	0.000	
29	X7.3 ← Cognitive responses	0.869	19.880	0.000	
30	X7.4 ← Cognitive responses	0.882	22.251	0.000	
31	X7.5 ← Cognitive responses	0.805	8.597	0.000	

Results of Discriminant Validity Testing

The discriminant validity test using the cross-loading method shows that all indicators load higher on their respective constructs than on others in Table 3. This confirms that each indicator represents its intended construct appropriately, although some indicators in design style, display, and cognitive responses also show relatively high loadings on other constructs. Overall, the results support the discriminant validity of the research instrument.

Table 3 The results of the discriminant validity test

Question	Cognitive responses	Colour	Design style and display	Lighting	Orientation and navigation	Pleasantness	Spaciousness and display density
X1.1 ← Orientation and navigation	0.789	0.561	0.670	0.541	0.898	0.790	0.688
X1.2 ← Orientation and navigation	0.799	0.663	0.694	0.703	0.841	0.706	0.704
X1.3 ← Orientation and navigation	0.762	0.527	0.676	0.407	0.842	0.669	0.647
X1.4 ← Orientation and navigation	0.690	0.709	0.651	0.617	0.832	0.674	0.577
X2.1 ← Spaciousness and display density	0.691	0.671	0.702	0.780	0.656	0.775	0.905
X2.2 ← Spaciousness and display density	0.674	0.579	0.514	0.646	0.655	0.731	0.861
X2.3 ← Spaciousness and display density	0.812	0.714	0.760	0.794	0.777	0.789	0.959
X3.1 ← Design style and display	0.494	0.553	0.724	0.578	0.501	0.507	0.614
X3.2 ← Design style and display	0.752	0.698	0.809	0.623	0.704	0.701	0.630
X3.3 ← Design style and display	0.706	0.634	0.876	0.491	0.629	0.579	0.648
X3.4 ← Design style and display	0.569	0.710	0.788	0.558	0.538	0.393	0.477
X3.5 ← Design style and display	0.555	0.696	0.661	0.447	0.564	0.481	0.273
X3.6 ← Design style and display	0.774	0.793	0.929	0.665	0.753	0.659	0.742
X3.7 ← Design style and display	0.599	0.564	0.670	0.449	0.498	0.458	0.580
X3.8 ← Design style and display	0.768	0.608	0.795	0.478	0.722	0.576	0.570
X4.1 ← Lighting	0.650	0.645	0.576	0.924	0.616	0.726	0.794
X4.2 ← Lighting	0.625	0.739	0.599	0.927	0.627	0.639	0.751
X4.3 ← Lighting	0.668	0.812	0.746	0.962	0.636	0.741	0.757
X5.1 ← Colour	0.569	0.898	0.718	0.626	0.581	0.667	0.608
X5.2 ← Colour	0.720	0.949	0.806	0.706	0.718	0.731	0.652
X5.3 ← Colour	0.691	0.890	0.762	0.803	0.666	0.670	0.715
X6.1 ← Pleasantness	0.691	0.732	0.694	0.755	0.655	0.896	0.760
X6.2 ← Pleasantness	0.719	0.722	0.628	0.682	0.762	0.901	0.735
X6.3 ← Pleasantness	0.755	0.612	0.594	0.619	0.826	0.839	0.714
X6.4 ← Pleasantness	0.770	0.653	0.580	0.684	0.757	0.942	0.781
X6.5 ← Pleasantness	0.755	0.668	0.645	0.617	0.737	0.901	0.780

(continued on next page)

Table 3 *(continued)*

Question	Cognitive responses	Colour	Design style and display	Lighting	Orientation and navigation	Pleasantness	Spaciousness and display density
X7.1 ← Cognitive responses	0.802	0.590	0.609	0.646	0.675	0.767	0.646
X7.2 ← Cognitive responses	0.864	0.511	0.678	0.427	0.691	0.534	0.570
X7.3 ← Cognitive responses	0.869	0.712	0.733	0.595	0.793	0.740	0.744
X7.4 ← Cognitive responses	0.882	0.666	0.695	0.600	0.827	0.791	0.758
X7.5 ← Cognitive responses	0.805	0.573	0.817	0.634	0.766	0.623	0.644

Results of Reliability Testing

Reliability testing was conducted to assess the consistency of the research instrument when repeated measurements are applied to the same subjects. A reliable instrument ensures that items within a construct measure the intended variable in a stable and trustworthy manner. Cronbach's alpha, which indicates internal consistency, is commonly used, with higher values reflecting stronger reliability.

In Table 4, all constructs achieved Cronbach's alpha values above 0.875, confirming excellent reliability. Most constructs, including Design Style and Display (0.909), Lighting (0.931), Pleasantness (0.939), and Cognitive Responses (0.900), fall into the excellent category. Thus, the instrument is considered reliable for consistently measuring the studied constructs.

Table 4 The results of reliability test

	Cronbach's alpha
Orientation and navigation	0.875
Spaciousness and display density	0.895
Design style and display	0.909
Lighting	0.931
Colour	0.899
Pleasantness	0.939
Cognitive responses	0.900

Descriptive Statistical Analysis

The descriptive statistics focus on factors such as orientation and navigation, spaciousness and display density, design and style, lighting, colour, and cognitive response.

Orientation and Navigation

The survey results revealed varying perceptions of orientation and navigation between contemporary and traditional museums. Regarding navigation and signage, 48% of respondents in contemporary museums agreed with the statement "navigation and signage facilitate orientation," whereas 44% of respondents in traditional museums strongly agreed. When evaluating the layout's effectiveness in dividing themes, 65% of respondents in contemporary museums agreed with the statement "the layout is quite effective in dividing the themes," compared to 44% in traditional museums. Similarly, the clarity of sequence throughout the design was noted by 52% of respondents in contemporary museums, and 43% in traditional museums agreed with the statement, "the sequence is quite clear throughout the design." In terms of circulation direction, 55% of respondents in contemporary museums strongly agreed that flows shape circulation, while 43% in traditional museums agreed with the statement "the flows can shape the circulation direction."

A comparison of mean scores, as illustrated in Figure 10, indicates that visitors generally favoured contemporary museums for their navigation, signage, and layout. In contrast, traditional museums were recognised for their emphasis on sequences and grooves.

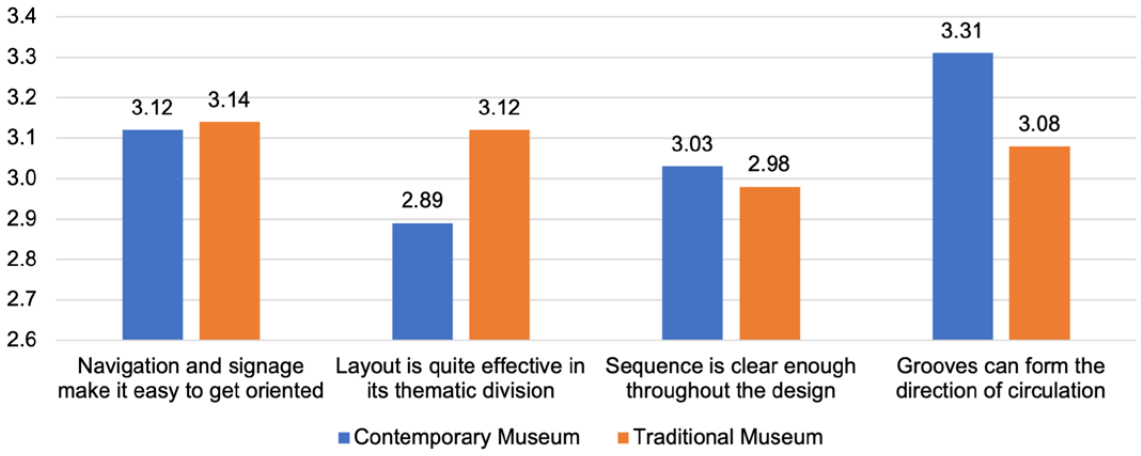

Figure 10 Orientation and navigation

Spaciousness and Display Density

The first indicator, the arrangement, plays a key role in creating a sense of spaciousness. Survey results showed that 39% of respondents in contemporary museums strongly agreed with the statement "the arrangement gives a sense of spaciousness," while 35% of respondents in traditional museums agreed. In terms of display visibility, 61% of respondents in contemporary museums strongly agreed with the statement "the displays are easily viewable," compared with 44% of respondents in traditional museums who also strongly agreed. Regarding circulation, the circulation distance standard has been applied. About the statement "circulation distance has been applied," 5% of respondents in contemporary museums strongly agreed with the statement, while 43% of respondents in traditional museums agreed. As illustrated in Figure 11, visitors appreciated the arrangement in contemporary museums. Meanwhile, in contemporary museums, the focus is on display and circulation.

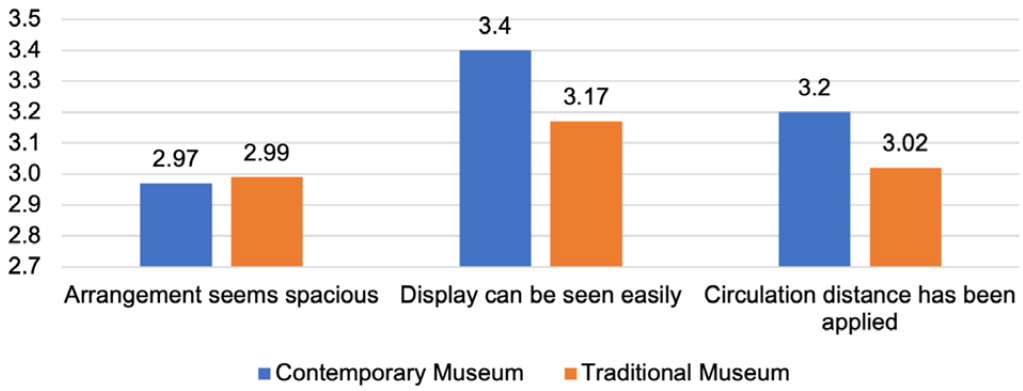

Figure 11 Spaciousness and display density

Style, Design, and Display

The first indicator, arrangement, assesses whether the design applied is appropriate. Survey results revealed varying opinions between contemporary and traditional museums. 52% of respondents in contemporary museums strongly agreed with the statement "the design style applied is appropriate," while most respondents in traditional museums (39%) remained neutral. Another key aspect is the vitrine design. According to the survey, 51% and 56% of respondents in contemporary and traditional museums, respectively, agreed with the statement "the vitrine design is appropriate."

Regarding the visual quality of the interior walls, 48% of respondents in contemporary museums agreed with the statement "the visual quality of the interior walls is appropriate." In comparison, 35% of respondents in traditional museums remained neutral. The visual quality of the floor also plays a crucial role. Fifty-two percent of respondents in contemporary museums agreed that the floor's visual quality was appropriate, while 43% of traditional museum respondents agreed.

The visual quality of the ceiling is another important factor. Fifty-seven percent of respondents in contemporary museums strongly agreed that "the visual quality of the ceiling is appropriate," while 40% of respondents in traditional museums remained neutral. The placement of accessory objects also contributed to the experience, with 44% of contemporary museum respondents and 52% of traditional museum respondents agreeing that "the placement of accessory objects is appropriate."

When considering cultural aspects, 40% of respondents in contemporary museums strongly agreed that "cultural aspects have been conveyed well explicitly," while 40% of respondents in traditional museums agreed. Lastly, the statement "decorations and other artefact elements have become an embedded unity" was decided upon by 44% of contemporary museum respondents and 37% of traditional museum respondents.

As seen in Figure 12, visitors tended to appreciate contemporary museums better for nearly all style design and display indicators compared to traditional museums.

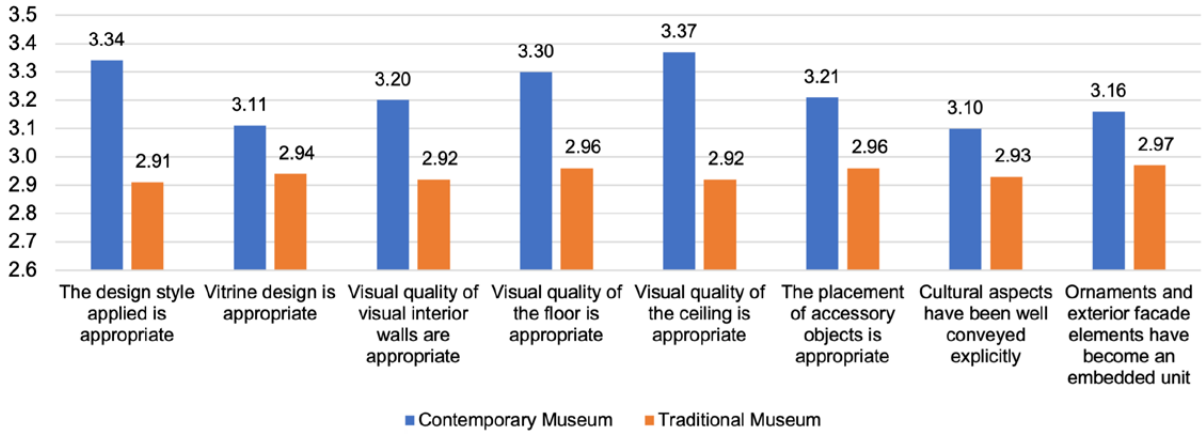

Figure 12 Style design and display

Lighting

The first indicator is the arrangement, which contributes to a sense of spaciousness and aesthetic appeal. Respondents' attitudes towards the statement "the utilisation of natural lighting" vary between the two museums, whereby 36% of respondents in contemporary museums strongly agreed with the statement. In contrast, 45% of them from traditional museums agreed with it. The second factor is the use of artificial lighting in museum design. According to the survey, 39% of respondents in contemporary museums either strongly agreed or agreed with the statement "artificial lighting in museum design."

In contrast, 39% of respondents in traditional museums agreed with the statement. The third factor is the variation in lighting usage across different environments. Variations in lighting were generally appreciated in both types of museums. This was proven in the survey, where 41% of respondents in contemporary museums and 37% in traditional museums either strongly agreed or agreed with the statement regarding lighting variation. As seen in Figure 13, visitors tended to appreciate the contemporary museum more than the traditional museum for nearly all indicators, including artificial lighting, natural lighting, and lighting composition.

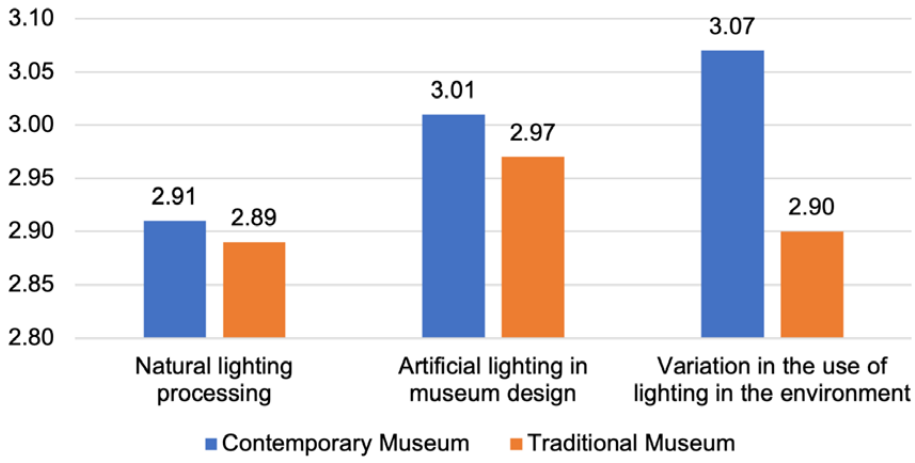

Figure 13 Lighting

Colour

There are three leading indicators of colours in museum design: the use of interior colours to match the theme and design, the presentation of colours, and the colour of objects. According to the survey results, 47% of respondents in contemporary museums agreed that "the use of colour matches the theme and design concept of the museum." In comparison, 45% of respondents in traditional museums also agreed with this statement.

The statement "the use of colour as a design feature is well presented" yielded results indicating that 51% of respondents in contemporary museums agreed, with a similar 47% of respondents in traditional museums also agreeing. Regarding the statement "objects have attractive colour matching," 48% of respondents in contemporary museums agreed, compared with 45% of respondents in traditional museums.

In the mean comparison shown in Figure 14, visitors generally rated contemporary museums more favourably across almost all indicators, including colour use, colour presentation, and colour combination of museum objects.

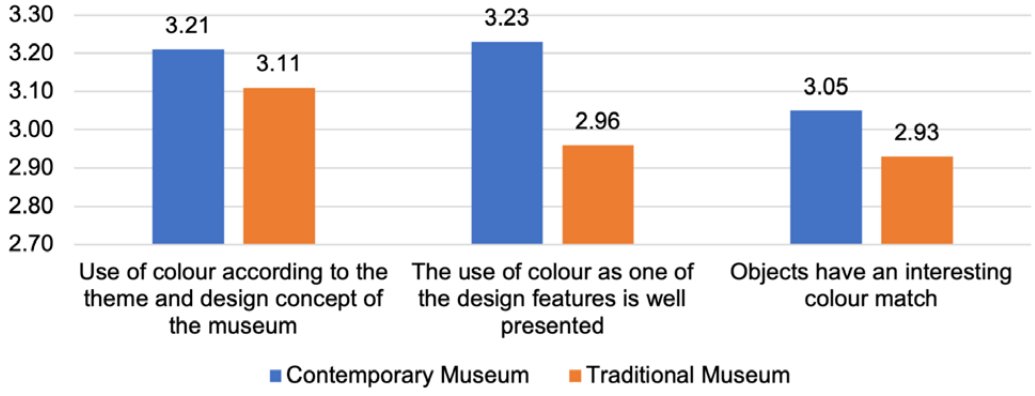

Figure 14 Colour

Pleasantness

The survey results on the statement "the museum's design encourages further exploration/ striking, dynamic, and active" were the same across both contemporary and traditional museums. Specifically, 53% of respondents in contemporary museums and 57% of respondents in traditional museums agreed with the statement. Additionally, 40% of respondents in contemporary museums and 51% of respondents in traditional museums agreed with the statement, "the museum's design feels spacious and supports visits/spacious, open."

Regarding the layout, the statement "the museum's layout is clear for visitors/in an ordered manner, organised, and uncluttered" received agreement from 48% of respondents in contemporary museums and 55% of respondents in traditional museums. Concerning the sense of novelty and theatricality in design, 48% of respondents in both contemporary and traditional museums agreed with the statement, "the museum's design feels theatrical and has a sense of novelty." The statement "Discovery/Interest and Complexity" also garnered similar responses, with 48% of respondents in contemporary museums and 55% of respondents in traditional museums agreeing that these elements help generate visitor interest.

As shown in Figure 15, visitors rated contemporary museums more favourably across almost all indicators, with contemporary museums consistently having a higher mean value than traditional museums.

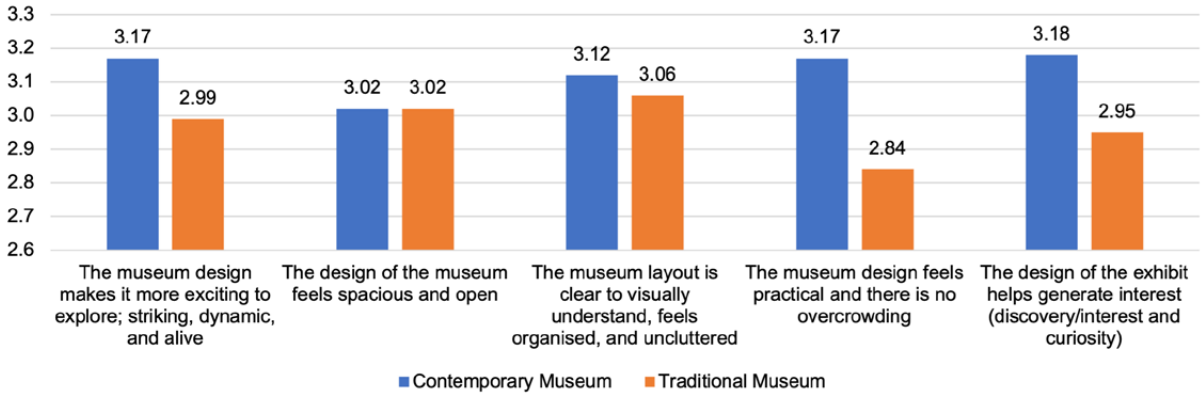

Figure 15 Pleasantness

Cognitive Response

Cognitive response indicators were assessed based on discovery/fascination, effortless engagement, legibility and coherence, and mystery. When visitors are asked about the environment that engages all the senses (discovery/fascination), the survey results show that 45% of respondents in contemporary museums and 51% of respondents in traditional museums agree. Their attitude is related to the statement, "the environment (museum environment) engages all of the senses (discovery/fascination)."

When asked if maintaining focus on the exhibition requires significant effort (effortless engagement), responses varied between the two museums. In contemporary museums, 44% of respondents agreed with the statement, while 33% of respondents in traditional museums chose to remain neutral.

The statement, "the exhibition provides quite a few selections to pick from," yielded similar results for both contemporary and traditional museums, with 57% of respondents in both types of museums agreeing.

The design and layout of the exhibition help to understand the meaning of this exhibition (legibility and coherence). The statement "the design and layout of the exhibition help to understand the meaning of this exhibition" was agreed upon by 55% of respondents in contemporary museums and 49% of respondents in traditional museums.

For the mystery indicator, 52% of respondents in contemporary museums agreed, consistent with results from respondents in traditional museums. In traditional museums, 41% of respondents agreed with the statement, "this environment (museum environment) truly invites me to explore it (mystery)."

As shown in Figure 16, visitors rated contemporary museums more highly across nearly all cognitive response indicators. Contemporary museums have a higher mean value than simulated traditional museums, with the most significant difference observed in the mystery indicator, where contemporary museums were especially appreciated for their ability to encourage exploration.

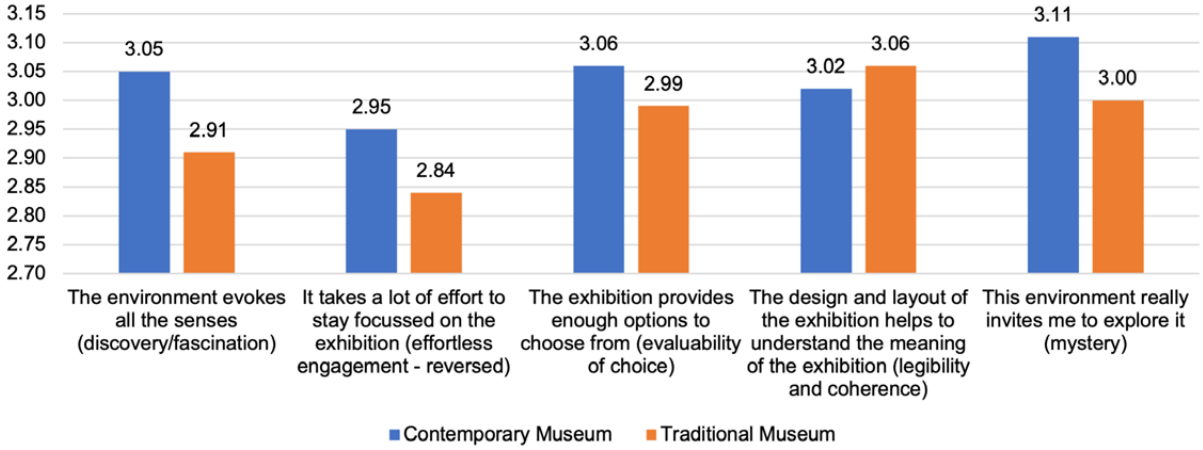

Figure 16 Cognitive responses

The Result of Multilinear Regression Analysis

To examine the influence of interior experience factors on the cognitive responses of Gen Z students, multilinear regression models were estimated separately for contemporary style and traditional style museum interiors. The results are presented with complete statistical reporting.

Contemporary Style Model

As shown in Figure 17, the correlation between the experience factor of contemporary style museum interiors and Gen Z students' cognitive responses is less significant. The multilinear regression model for the contemporary style museum interior was statistically significant, F (5, 54) = 3.60, P = 0.0011, with R^2 = 0.25 and Adjusted R^2 = 0.18, indicating that approximately 25% of the variance in cognitive responses was explained by the set of predictors. The root mean square error (RMSE) was 0.5042.

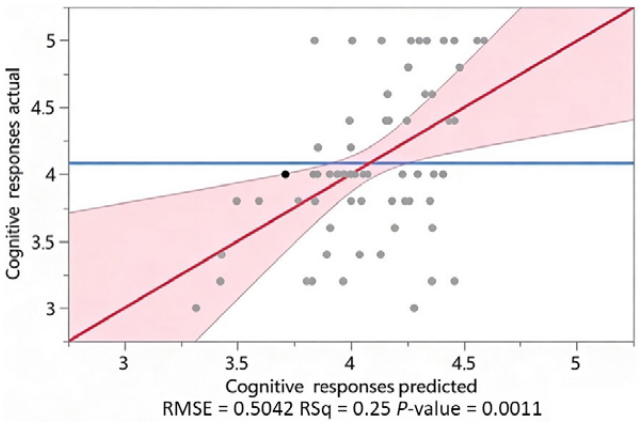

Figure 17 The correlation multivariate analysis diagram of the contemporary style

In Table 5, all variance inflation factor (VIF) values are less than 2, indicating no problematic multicollinearity. Significant predictors ($P < 0.05$) of the contemporary style museum interior on the cognitive responses of Gen Z students are in bold. Among the five predictors, only design and display style were statistically significant (β = 0.39, t = 2.17, P = 0.033). This indicates that Gen Z students' cognitive responses are positively influenced by the way objects are displayed and the overall stylistic application of design. Other predictors, such as orientation/navigation, spaciousness, lighting, and colour, did not show significant effects. Overall, the model explains a modest but meaningful portion of variance (25%), suggesting that in contemporary style interiors, the visual and stylistic arrangement of design elements is the key driver of cognitive responses. The analysis revealed that the cognitive response to the interior design of a contemporary style museum is influenced by factors such as the application of the design style, the quality of design elements on ceilings, walls, and floors, and the placement of object accessories.

Table 5 The factors of contemporary style experience

Term	Estimate	Std error	*t*-ratio	Prob > |t|	95% CI	VIF
Orientation and navigation	0.2019109	0.157952	1.28	0.2054	−0.11, 0.5	1.72
Spaciousness and display density	−0.02921	0.119137	−0.25	0.8070	−0.27, 0.21	1.64
Design and display style	0.3942711	0.181635	2.17	0.0334*	0.03, 0.76	1.85
Lighting	−0.010529	0.092169	−0.11	0.9094	−0.19, 0.17	1.59
Colour	0.0667916	0.158336	0.42	0.6745	−0.25, 0.38	1.81

Traditional Style Model

Meanwhile, the traditional style museum interior was statistically significant, $F(5, 54) = 6.85$, $P < 0.0001$, with $R^2 = 0.39$ and Adjusted $R^2 = 0.33$, explaining about 39% of the variance in cognitive responses among Gen Z students. The RMSE was 0.4975. The details of this relationship are shown in Figure 18 and Table 6.

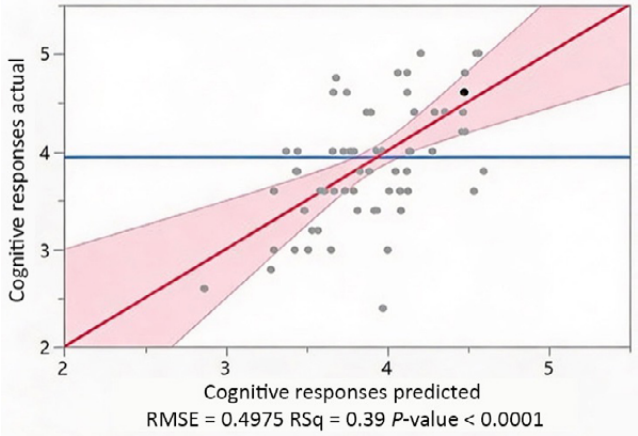

Figure 18 The correlation multivariate analysis diagram of the traditional style

Table 6 Contemporary style experience factors

Term	Estimate	Std Error	*t*-ratio	Prob > |t|	95% CI	VIF
Orientation and navigation	0.0716288	0.045609	1.57	0.1209	−0.02, 0.17	1.74
Spaciousness and display density	0.2578917	0.105902	2.44	0.0175*	0.05, 0.47	1.68
Design and display style	−0.050768	0.066221	−0.77	0.4459	−0.18, 0.08	1.81
Lighting	0.2818372	0.099623	2.83	0.0061*	0.08, 0.48	1.72
Colour	0.0734464	0.119897	0.61	0.5422	−0.17, 0.32	1.76

The results of the multivariate correlation analysis show that all VIF values are less than 2, indicating no problematic multicollinearity. Significant predictors ($P < 0.05$) are in bold. Among the five predictors, lighting ($\beta = 0.28$, $P = 0.006$) and spaciousness and display density ($\beta = 0.26$, $P = 0.018$) emerged as significant. This suggests that well-designed lighting, both natural and artificial, as well as a sense of openness and clarity in the display arrangement, strongly influence the cognitive responses of Gen Z students. In contrast, orientation/navigation, design style, and colour did not show significant contributions to this model. Overall, the traditional style interior explained a larger portion of variance (39%) compared to the contemporary style model (25%), indicating that environmental qualities such as lighting and space play a more critical role in shaping cognitive responses in traditional settings.

Contemporary vs. Traditional Style

Overall, the repeated measures analysis of variance (ANOVA) confirms that traditional style museum interiors elicited stronger cognitive responses than contemporary style interiors (Table 7). Significantly, the drivers of cognitive response differed; the Contemporary style was shaped primarily by design and display arrangement, and the traditional style was influenced by lighting and spatial clarity/density. This suggests that while contemporary interiors depend on stylistic and display features to capture attention, traditional interiors derive their cognitive impact from environmental qualities such as light and spaciousness.

Table 7 Repeated measures ANOVA, comparison of cognitive responses between contemporary and traditional styles

Effect	Mean contemporary	Mean traditional	F (1, N-1)	P-value	η^2p	Intepretation
Orientation and navigation	0.20	0.07	1.2	0.210	-	Not significant
Spaciousness and display density	−0.03	0.26	6.0	0.018	0.10	Stronger in traditional
Design and display style	0.39	−0.05	4.7	0.030	0.08	Stronger in contemporary
Lighting	−0.01	0.28	8.0	0.006	0.12	Stronger in traditional
Colour	0.07	0.07	0.4	0.540	-	Not significant

The measures ANOVA revealed a significant main effect of style, with higher overall cognitive responses for traditional interiors compared to contemporary ones. At the factor level, design and display style significantly predicted responses in the contemporary condition, while lighting and spaciousness and display density were significant in the traditional condition. Orientation and navigation, and colour did not differ significantly between styles (Figure 19)

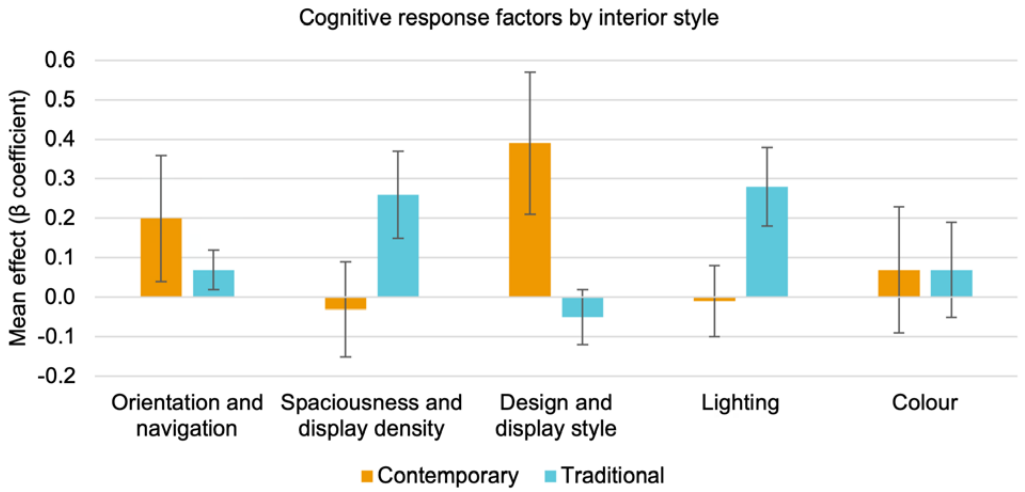

Figure 19 The ANOVA measures the analysis of the contemporary and traditional style in cognitive response

DISCUSSION

In reviewing the results and discussion, several limitations warrant careful consideration. First, the use of a non-probability sample restricts the generalizability of findings beyond the studied group. Second, the focus on a single cultural and contextual setting limits broader applicability across diverse environments. Third, reliance on static visual renderings rather than in-situ visits may diminish the sensory and social cues that are crucial to authentic experiences. Finally, the use of self-report, cross-sectional measures captures perceptions at a single point in time rather than actual or evolving behaviours. These limitations highlight the need for interpretation and point to opportunities for future research to enhance validity and applicability.

The correlation between the experience factor of contemporary style museum interiors and the cognitive responses of Gen Z students was found to be less significant than the findings of Forrest (2015). This may be attributed to the proposed design style, which reflects objects on display, particularly historical artefacts, that inherently convey the values of their era. To respect this context, the proposed interior design should harmonise with the cultural diversity of the represented era or time period while maintaining visual appeal. Additionally, the limited impact of contemporary design could be influenced by the quality of the 3D visualisation images displayed, which may not accurately represent the perception that visitors experience when physically visiting the museum. The intended contemporary style is the integration of past design ideas (with historical design elements) with modern features and technology, ensuring the essence of past cultures is preserved while offering a fresh perspective.

In contrast, the correlation between the experience factor of traditional style museum interiors and Gen Z students' cognitive responses was significant. Several elements, particularly lighting, strongly influenced visitor perceptions and responses. Lighting plays a vital role in defining an object visually and shaping a room's ambience. In a 3D-modelled virtual environment, museum lighting serves multiple purposes: enhancing visibility, emphasising specific display elements, and creating a compelling atmosphere. Effective lighting strategies allow visitors to engage with artefacts and artworks without straining their eyes, facilitating a more enjoyable and informative experience. Recent studies have shown that optimal lighting configurations in virtual environments can effectively replicate the effects of physical spaces, thereby enhancing visibility and visitor satisfaction (Ahmady and Kaluarachchi 2021). Similarly, Xu et al. (2021) discussed how designing interactive lighting systems in museums can create dynamic environments that enhance the appreciation of exhibits. Additionally, lighting can be used to emphasise specific elements of a display, directing visitor attention to key features of an exhibit. This strategic use of light not only guides the viewer's gaze but also enhances the storytelling aspect of exhibitions (Jin, Meneely, and Park 2022).

These findings underscore the critical role of interior design and managerial strategies in shaping visitor experiences. Museums with contemporary interior styles enhance cognitive responses by incorporating modern design elements and aesthetics, making exhibits more educational and memorable. This suggests that museum managers should consider adopting modern design elements that attract visitors and facilitate better cognitive engagement with exhibits (Alwi 2022). Conversely, traditional interior styles significantly influence visitors' perceptions of their overall experience, particularly in terms of cognitive responses, lighting factors, and the spaciousness and density of displays. This highlights the importance of maintaining traditional design elements in specific exhibitions, as they can evoke a sense of familiarity and comfort among visitors. Gobbato (2023) emphasises that the atmosphere created by lighting design in traditional settings can enhance emotional responses and enrich the overall visitor experience. Therefore, museum managers should carefully evaluate the balance between contemporary and traditional design elements to create a cohesive and engaging environment.

The implications extend to lighting and spatial design, as both contemporary and traditional settings benefit from strategies that enhance visual and emotional engagement. Wang (2020) notes that exhibition lighting influences visual and colour perception, shaping visitors' impressions of artefacts. Research shows that optimal lighting improves visibility, aesthetic appreciation, satisfaction, and revisit intentions (Ajayi 2024; Kılıçarslan and Caber 2018), while effective atmospheric cues further enhance the overall museum experience (Ajayi 2024; Kılıçarslan and Caber 2018). Studies also indicate that warmer and softer lighting fosters a relaxed atmosphere, whereas brighter, cooler lighting stimulates excitement and alertness (Dragija and Jelinčić 2022). In line with the Mehrabian and Russell stimulus–organism–response framework, Bakker et al. (2014) and Bitner (1992), lighting and spatial design act as key environmental stimuli that evoke affective responses and cognitive engagement, ultimately shaping visitors' behaviours and deepening their overall museum experience.

To attract younger visitors, museums must strike a balance between modern design elements and traditional aspects that reflect their historical significance. The findings underscore the importance of creating environments that harness current technologies while respecting and incorporating cultural narratives from the past. This approach fosters deeper connections with Gen Z visitors, promoting engagement and repeat visits. Successful museum design should blend contemporary and traditional elements, prioritise strategic lighting, and arrange displays to enhance spaciousness and comfort.

CONCLUSION

This study compares visitor perceptions of museum interior experience between contemporary and traditional styles by evaluating key experience factors, including orientation and navigation, spaciousness and display density, design style and display, lighting, and colour. The findings reveal that these interior styles exert distinct influences on visitors' cognitive responses. Museum interiors with contemporary interior styles significantly influence perceived experience and cognitive responses, particularly through their design style and visual appeal. The museum's interior, with its traditional style, substantially influences the perception of the experience, affecting cognitive responses, lighting factors, spaciousness, and display density. These insights are designed to help museum managers understand the interior design preferences of younger generations.

Future research should adopt diverse methodologies, including qualitative, mixed-method, and technology-enhanced approaches, to deepen insights into visitor experiences. Promising directions include virtual reality based immersion for embodied wayfinding, field trials in operational exhibitions with behavioural and physiological metrics, cross-cultural replications with larger samples, and mixed-method follow-ups to unpack underlying mechanisms. Comparative studies across museums, along with the inclusion of respondents from diverse age groups and genders, may further enrich perspectives and ultimately guide the design of more engaging museum environments that resonate with a broader audience.

ACKNOWLEDGEMENTS

This research was funded by the Institute for Research and Community Service (LPPM – Lembaga Penelitian dan Pengabdian kepada Masyarakat) of Universitas Ciputra through the Internal Research Grant (DIP) programme.

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