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Effects of Interactive Experiences on Memory in a Virtual Museum

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Abstract

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Virtual Reality (VR) technology profoundly influences museums by facilitating artifact collection, preservation, and remote accessibility to traditional cultures. VR transcends physical constraints, enabling visitors to engage with exhibits across diverse locations. The effective utilization of content is crucial for constructing a virtual domain that evokes a positive impression and fosters memories. This experimental study aimed to scrutinize the influence of interactive and non-interactive content on visitors' memory, attractiveness, and slow-motion conditions while engaging with VR in museum environments. Simulated exhibition halls feature three rooms with interactive content, such as opening windows to view videos, manipulating and observing 3D models of exhibits, and pressing buttons to explore the relationships between exhibits. Additionally, the three rooms featured non-interactive content in experiments 1, while Experiment 2 comprised three rooms featuring interactive content with distinct features, alongside one room exhibiting non-interactive content. Experiment 3 involved six exhibition halls accommodating three varieties of slow-motion. Twenty-four participants observed all virtual museum content and assessed recognition memory, agency, and attractiveness using questionnaires. The experimental results, analyzed via average scores, reveal significantly higher memory scores for interactive content with no difference in perceived agency and attractiveness. Interactive content enhances memory

efficiency without

affecting the slow-motion agency and attractiveness perception, emphasizing its pivotal role in creating impactful visitor experiences.

key words Virtual reality, Virtual Museum, Memory, Attractiveness, Interactive contents, Non-interactive contents, slow-motion, agency

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Chapter 1

Introduction

Virtual reality (VR) technology offers users an immersive and interactive occurrence through the utilization of a headset and input devices, enabling them to engage with a computer-generated simulated environment [1], participate in realistic simulations [2], and enhance learning experiences [3]. The popularity of VR has experienced a notable upsurge in multiple domains, such as gaming [4], entertainment [5], education [6], healthcare [7], and tourism [8], leading to a significant enhancement of the overall user experience. The utilization of VR technology within the domain of museum tourism has attained extensive universality, primarily because of its capability to provide visitors with remote access to observe meticulously simulated contents of artifacts and art objects, offering a realistic experience that transcends geographical limitations, allowing access from any corner of the globe [9]. The design of content in virtual museum environments poses a notable challenge, as educational content must successfully capture visitor interest while simultaneously imparting substantial and comprehensive knowledge [10]. Virtual content is categorized into interactive and non-interactive types, with the former promoting user engagement through real-time interaction, whereas the latter lacks interactivity and mainly contains static information [11].

Several studies have provided valuable insights into the implementation of virtual reality (VR) applications within museum settings, employing either interactive or non-interactive content. Lugrin et al. [12] presented an innovative location-based Virtual Reality (VR) Museum designed for educational and cultural purposes. The

museum offered the unique feature of accommodating multiple users in a multi-zone environment, including captivating indoor and outdoor dinosaur exhibitions and showcasing exhibits with non-interactive content. Fu and Li [13] introduced an innovative framework for designing interactive content within virtual museums, incorporating various models, such as 3D, motion, geographic, and audio components. In addition, Li and Huang [14] investigated the design of interactive content in the Palace Museum using VR technology, with a specific emphasis on acquiring knowledge and enhancing cultural experiences. The findings demonstrated that virtual reality enhanced the understanding of artifacts, enabled immersive experiences, facilitated interactive learning, and promoted a shift from passive observation to active exploration among visitors. Furthermore, Sweetman et al. [15] investigated different presentation methods of content between the real and virtual realms. The findings showed that multisensory experiences, particularly those involving interactive virtual objects, significantly improve memory compared with conventional visitor experiences. Finally, Krokos et al. [16] compared the presentation approaches between VR technology and regular display screens using non-interactive content, revealing that VR technology utilizing non-interactive content enhances memory.

Furthermore, a sense of agency referred to the sense of initiating and controlling actions in order to influence events in the outside world in the Moore et al. [17] study. At the implicit level, a basic low-level feeling of being an agent is formed. This level was non-conceptual and did not involve explicit agency attributions. Rather, experiences of action are simply tagged as self-caused or not. Although this feeling of an agency may be ‘ conscious ’ , it is a pre-reflective state. Winkler et al. [18] study objective was to investigate the influences of latency (i.e., technical system response time), action modality (button press, voice command), and display modality (head-mounted display, monitor) on the sense of agency (SOA). Results showed that the SOA was weaker for

actions employing voice commands as opposed to button presses, except for the explicit SOA in the monitor condition. Higher latencies diminished the explicit, but not the implicit SOA.

Overall, these studies have contributed to the understanding of design considerations and the educational impact of VR environment settings, and several studies have concentrated on examining the correlation between the real and virtual worlds by employing interactive or non-interactive content to compare the advantages associated with each of them. Nevertheless, the identification effect of memory and attractiveness on both interactive and non-interactive content presents a challenging research gap that demands immediate attention to design valuable content for virtual environments, with the goal of offering visitors an optimal and immersive experience while examining the influence of agency within interactive content in virtual museums, specifically considering the interplay between memory and attractiveness.

This study investigated the effect of interactive and non-interactive content on the recognition memory, agency, and perceived attractiveness of visitors within a virtual museum environment using VR technology. The museum exhibition halls were simulated, encompassing three rooms that showcased interactive content, such as the ability to open windows for video viewing, manipulate and observe 3D models of exhibits, and utilize buttons to view exhibit information. Additionally, three rooms contained non-interactive content. The experimental design comprised two separate experiments. The primary experiment was dedicated to assessing memory and the attractiveness of participants using interactive and non-interactive content. The question format of the questionnaire was conducted to determine the relationship between interactive content and non-verbal and verbal information. The secondary experiment specifically targeted the same objectives but encompassed the comprehensive utilization of each feature inherent to interactive content, compressing the presence of

video accessibility, the ability to manipulate 3D models, and the inclusion of a button for accessing information content. Twenty-four participants actively observed all virtual museums in all experiments, subsequently evaluated their recognition memory using 30 questions in a four-choice format, and investigated their perceived attractiveness using one question with a multiple-answer format. The third experiment explored about relationship of agency with memory and attractiveness. Twenty-four participants actively observed all six exhibition halls with interactive content with different levels of slow-motion and did the three questionnaires including agency, memory, and attractive questionnaires. The average scores of the interactive and non-interactive content questionnaires were analyzed to evaluate the influence on memory, agency and attractiveness.

Chapter 2

Experimental design

In order to assess the influence of the effectiveness of interactive and non-interactive content in terms of memory and attractiveness within the specific context of a virtual museum necessitates the deliberate employment of specialized tools and a meticulously designed experimental framework, as outlined below.

2.1 Development tools

The video game industry offers a significant role within the VR domain, as VR content is fashioned through game development tools [19]. Unity is a widely adopted game development tool that offers dedicated support for creating VR experiences, which includes streamlined integration with StreamVR, enabling the direct creation and rendering of VR media into VR Head-Mounted Displays (HMDs) [20]. This research employs the Unity game engine to generate and visually present all museum contents, while the utilization of HTC VIVE facilitates the integration of HMDs and controllers.

2.2 Participants

Seventy-two who was Japanese and international participants from a Kochi University of Technology were divided into 24 for each experiment (Male = 15, Female = 9, Male = 13, Female = 11, and Male = 16, Female = 8) who lacked experience in Thai cuisine. The average age of the participants was 21.4 (SD = 1.94). Participants

were invited to wear head-mounted displays (HTC VIVE) and hold the controller with their dominant hand to engage in virtual museum observation.

2.3 Interactive and non-interactive contents

The selection of a content theme plays a pivotal role in ensuring the correction rate of these experimental results. Thereby, the theme of Thai cuisine was selected, considering that all participants possessed limited familiarity with Thai culture. The virtual museum effectively showcases the content of Thai cuisine through the classification into six exhibition halls based on geographical regions of Thailand, including Central, West, South, East, North, and North-East [21]. Each exhibition hall features a combination of interactive and non-interactive content, specifically curated to suit the unique characteristics and culinary traditions of the respective region.

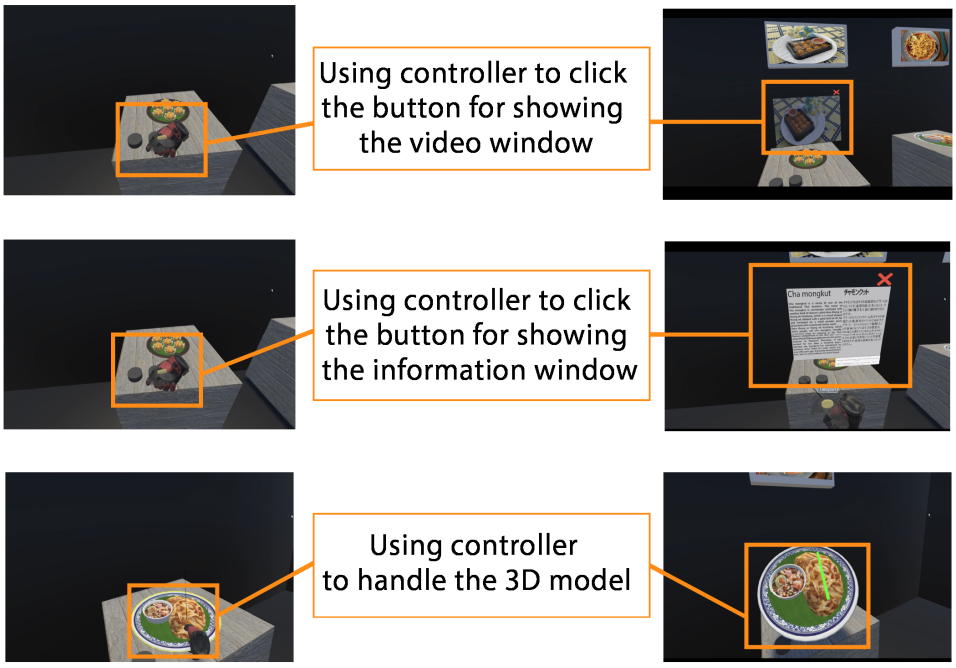

Fig. 2.1 The virtual museum incorporates all features of interactive content.

2.3 Interactive and non-interactive contents

The design of interactive content emphasizes user engagement by prioritizing real-time interaction. The interactive content possesses three distinct features encompassing: 1) allowing participants to activate the information display by pressing a designated button, 2) enabling participants to play the video by a designated button, and 3) facilitating participants to manipulate and examine 3D objects by physically holding them in their hands. Figure 2.1 illustrates the interactive content pertaining to cuisine within the Central region of Thailand. The participant was obligated to press a button in order to activate the popup window, which displays detailed information about the food by respective region. Similarly, another button press was required to activate a separate popup window to play a video. Alternatively, the participant is provided with the choice to physically hold and visually explore the 3D object representation of the dish in their hands.

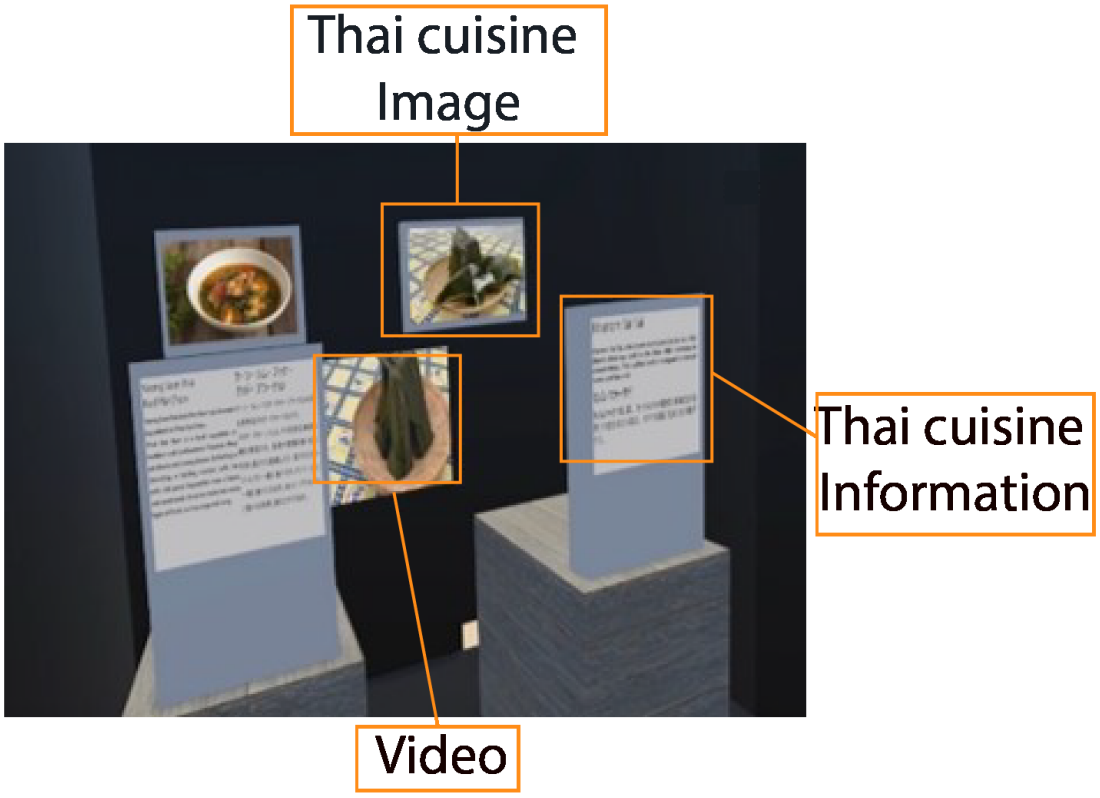

Fig. 2.2 The exhibition showcases the exhibit information with non-interactive content.

The non-interactive content is specifically designed to present food and dessert exhibits without any user engagement. Figure 2.2 illustrates the non-interactive content pertaining to cuisine information within the West region of Thailand. The participant possessed solely the capability to observe the pre-established static image, video, and information passively.

2.4 Experiment 1

This experiment aimed to evaluate the comparative effectiveness of both interactive and non-interactive content on memory and attractiveness. Notably, each exhibition hall that incorporates interactive content encompasses all three features mentioned previously. The virtual museums were designed with four distinct groups, each of which consisted of six exhibition halls, each showing only one interactive or non-interactive content, and each hall was connected to the other, as illustrated in Figure 2.3. In order to achieve precise results in this experiment, each group systematically switched positions between different content types and exhibition halls, as illustrated in Figure 2.4.

Fig. 2.3 Top view of virtual museum group 1 consisting of six connected exhibition halls based on Thai regions.

Group 1		Group 2		Group 3		Group 4	
Feature	**Exhibition hall**	**Feature**	**Exhibition hall**	**Feature**	**Exhibition hall**	**Feature**	**Exhibition hall**
Interactive	Central	Non-interactive	Central	Non-interactive	West	Interactive	West
Non-interactive	West	Interactive	West	Interactive	Central	Non-interactive	Central
Interactive	South	Non-interactive	South	Non-interactive	East	Interactive	East
Non-interactive	East	Interactive	East	Interactive	South	Non-interactive	South
Interactive	North	Non-interactive	North	Non-interactive	North-East	Interactive	North-East
Non-interactive	North-East	Interactive	North-East	Interactive	North	Non-interactive	North

Fig. 2.4 The layout of six exhibition halls based on Thai regions and contents in the virtual museum by experimental groups for Experiment 1.

Twenty-four participants were invited to engage in the exploration of the virtual museum. Subsequently, all participants were systematically classified into four distinct groups according to the virtual museum groups. Each participant was required to wear a VR HMD and firmly grasp the controller using their dominant hand, as illustrated in Figure 2.5. Each museum group was assigned to each participant to explore the halls precisely within a designated time of 42 min, allowing approximately 7 min for each exhibition hall.

Two questionnaires were meticulously developed and prepared for all participants subsequent to their comprehensive museum exploration. The first questionnaire assessed the participants' recognition memory. The questionnaires encompassed information pertaining to Thai cuisine showcased within the explored museum, comprising 30 questions divided into five questions allocated for each exhibition hall. A four-choice format was employed within the question by incorporating illustrated and

non-illustrated versions of the example pictures.

Fig. 2.5 The participants utilized head-mounted displays (HMDs) and held the controller with their dominant hand to engage in virtual museum observation.

The second questionnaire was used to evaluate the participants' perceived attractiveness. The questionnaire comprised one question specifically related to the favorite Thai cuisine of the participants observed within the explored museum. Each participant was given only one question with twenty-four multiple choices covering the number of Thai cuisine exhibits, accompanied by an image and a concise description for each answer item, allowing them to select multiple answer options.

2.5 Experiment 2

The purpose of this experiment aligns with the objectives outlined in Experiment 1, with a specific focus on the individual features of the interactive content. The virtual museums were meticulously designed to encompass four distinct groups, with each group comprising four exhibition halls. Among these halls, three showcased interactive content featuring various features, whereas one hall exclusively presented non-interactive content. In order to achieve the correction rate results in this experiment, each group systematically switched positions between different content types, features of interactive content, and exhibition halls, as illustrated in Figure 2.6.

Feature		Group 1	Group 2	Group 3	Group 4
		Exhibition hall			
Interactive Content	Video	North-East	West	Central	South
	3D Model	West	Central	South	North-East
	Button	South	North-East	West	Central
Non-interactive content		Central	South	North-East	West

Fig. 2.6 The layout of exhibition halls and contents in the virtual museum by experimental groups for Experiment 2.

2.6 Experiment 3

This experiment proposed the impact of agency on memory across varying slow-motion speeds in virtual museum environments. Six distinct groups of virtual museums were carefully crafted, each comprising six exhibition halls. These exhibition halls were stratified into three slow-motion levels—no slow, medium slow, and high slow —for interacting with museum content, as illustrated in Figure 2.7.

Group/Room	Room 1 and 2	Room 3 and 4	Room 5 and 6
A	No slow	Medium slow	High slow
B	No slow	High slow	Medium slow
C	Medium slow	No slow	High slow
D	Medium slow	High slow	No slow
E	High slow	No slow	Medium slow
F	High slow	Medium slow	No slow

Fig. 2.7 The layout of exhibition halls and contents in the virtual museum by experimental groups for Experiment 3.

Twenty-four participants were selected to explore the virtual museum over a designated period of 42 minutes, allowing approximately 7 minutes for each exhibition hall, mirroring the setup of experiment 1. The sequence of exhibition halls was randomized across participant groups.

Three questionnaires were meticulously designed and administered to all participants. The initial questionnaire gauged participants' sense of agency during museum exploration. The questionnaires covered aspects such as agency, ownership, presence, and entertainment, utilizing a scale ranging from 1 (strongly disagree) to 7 (strongly agree). The second and third questionnaires focused on memory and attractiveness, mirroring the structure of experiment 1.

Chapter 3

Results

3.1 Experiment 1

The assessment process of the results was executed subsequent to the conclusion of all experiments. Statistical methodologies were used to determine the influence of interactive and non-interactive content on memory by concentrating on both experimental results. Figure 3.1 depicted the chart of the average comparison between interactive and non-interactive content obtained from the response scores of the memory questionnaires in Experiment 1. Consequently, when presented with interactive content (Avg = 0.51, SD = 0.11), the average scores of correct answer rate obtained from a questionnaire pertaining to Thai cuisine exhibited a higher magnitude than the non-interactive content (Avg = 0.42, SD = 0.12) with the standard error value of 0.02 for interactive content and 0.02 for non-interactive content. The examination was performed using a t-test (t (23) = 3.12, p = 0.002, Cohen's d = 0.69), indicating statistical significance and providing evidence that both interactive and non-interactive content demonstrated substantial differences.

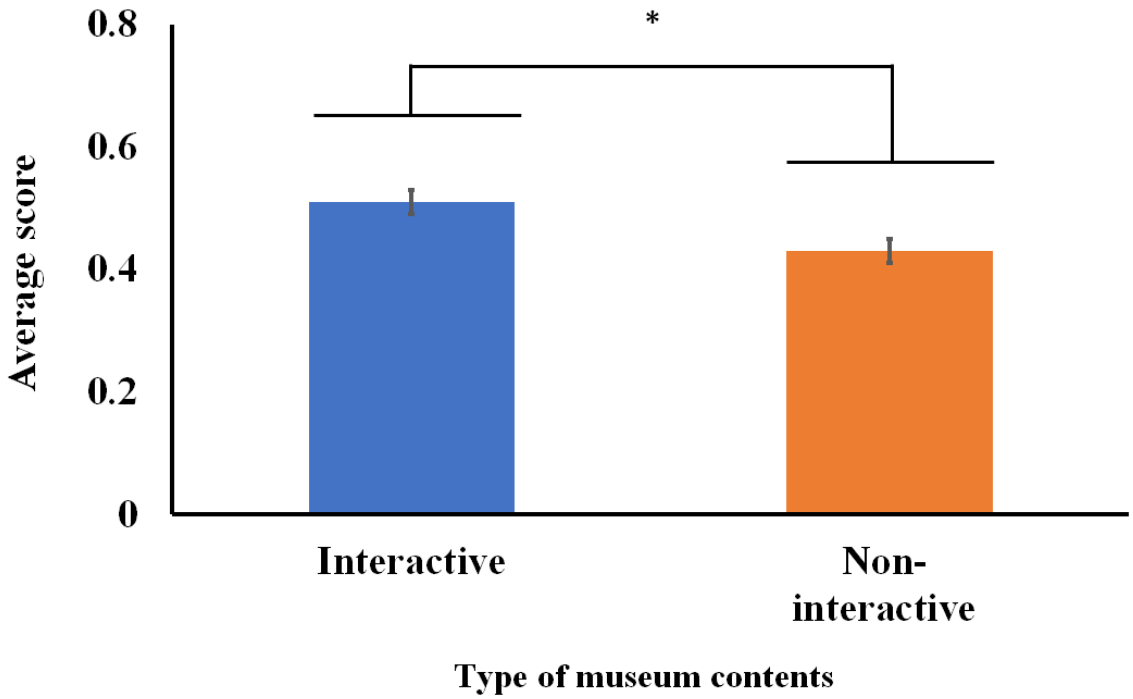

Fig. 3.1 The average of interactive and non-interactive content by memory questionnaire score in Experiment 1 with a standard error.

The format of the questions provided substantial statistical information, facilitating a correction rate examination of the relationship between interactive and non-interactive content. Figure 3.2 presented a graph of the average comparison between interactive and non-interactive content, with a focus on the question format, comprising questions with and without pictures. The data for this analysis were derived from the response scores of the memory questionnaires used in Experiment 1. Accordingly, the average score of correction rate, derived from questionnaires that incorporated pictures within the questions, exhibited values of 0.55 (SD = 0.17) and 0.34 (SD = 0.18) for interactive and non-interactive content with the standard error value of 0.03 for interactive content and 0.03 for non-interactive content. For questionnaires without pictures, the average scores of correction rate were 0.47 (SD = 0.15) and 0.50 (SD = 0.14) for interactive and non-interactive content with the standard error value of 0.03 for interactive content

and 0.03 for non-interactive content, respectively. The repeated measures of two-way analysis of variance were conducted for interactive contents and question formats. The main effect of interactive content, which consists of interactive and non-interactive content, was significant results (F (1, 23) = 11.66, p = 0.0024, η^2_G = 0.077). The main effect of the question format with picture and non-picture was not significant (F (1, 23) = 1.84, p = 0.19, η^2_G = 0.015). The interaction effect was significant (F (1, 23) = 9.13, p = 0.0061, η^2_G = 0.11). Furthermore, the simple main effect test was performed in order to elucidate the interaction relationship. The simple main effect of question format with picture and no-picture in interactive content was not significant (F (1, 23) = 0.22, p = 0.65, η^2_G = 0.0051), whereas in non-interactive was significant with (F (1, 23) = 10.07, p = 0.0042, η^2_G = 0.18). In addition, the simple main effect of interactive contents utilized with the picture question format was significant (F (1, 23) = 18.36, p = 0. 0003, η^2_G = 0.2553), while, the non-picture question format was not significant F (1, 23) = 2.45, p = 0. 13, η^2_G = 0.051).

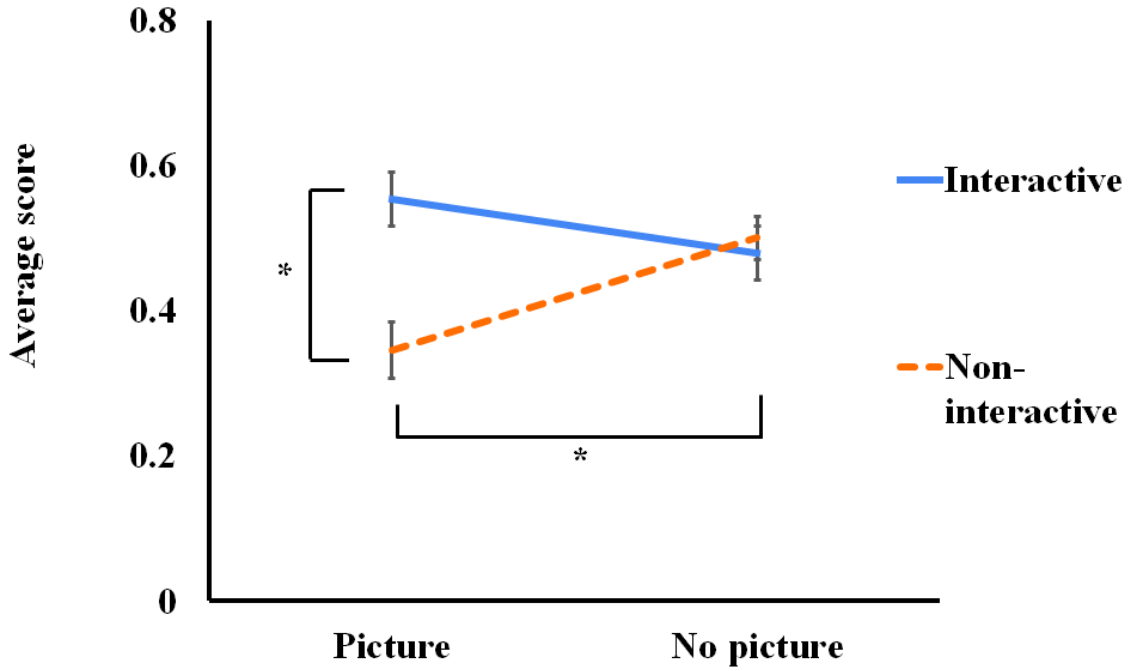

Fig. 3.2 The average of interactive and non-interactive contents evaluated by the type of question of memory questionnaire in Experiment 1 with a standard error.

3.2 Experiment 2

The interactive content encompassed three crucial features, and the comparison of each feature holds significant importance. Figure 3.3 presented a graph of the average comparison between all of the interactive and non-interactive content features obtained from the response scores of the memory questionnaires in Experiment 2. Consequently, the average scores of correction rate responses obtained from questionnaires concerning Thai cuisine, which incorporated all features of interactive content, including the ability to view a video, manipulate a 3D model, and access additional information windows by pressing a button, demonstrated values of 0.58 (SD= 0.28), 0.55 (SD = 0.24), and 0.61 (SD = 0.26) with the standard error value of 0.06, 0.05, 0.05, and 0.06, respectively while non-interactive content yielded a score of 0.57 (SD = 0.26). However, statistical analysis revealed no significant differences among these measurements with ANOVA ($F(3, 23) = 0.26$, $p = 0.85$, $\eta^2_G = 0.0126$).

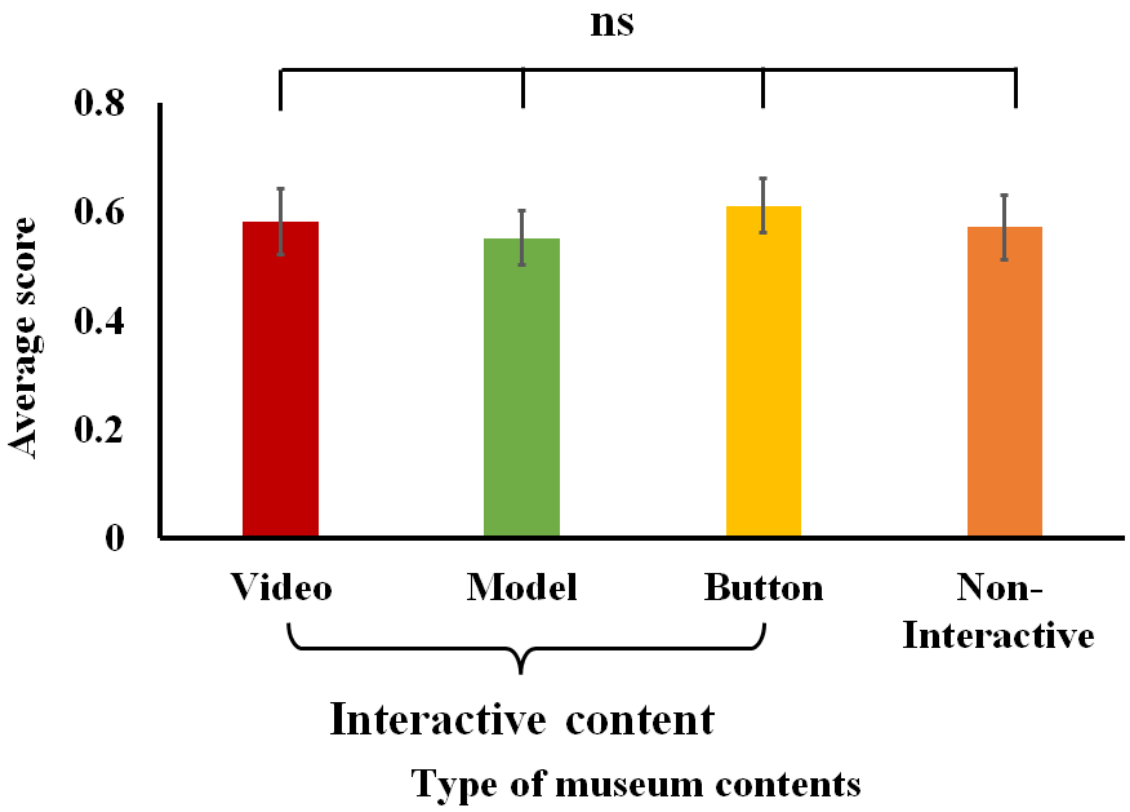

Fig. 3.3 The average scores of all features within the interactive and non-interactive content were calculated using the memory questionnaire in Experiment 2 with a standard error.

3.3 Experiment 3

Figures 3.4 (A) to (C) and Figure 3.5 (A) to (C) depict the scores derived from the agency questionnaire and the memory questionnaires utilized in Experiment 3.

The agency questionnaire comprised four inquiries, addressing the sense of agency, ownership, presence, and entertainment. The average score for the sense of agency, assessed on a scale from 1 (strongly disagree) to 7 (strongly agree), exhibited values of 5.58 (SD = 1.10), 5.50 (SD = 1.14), and 5.42 (SD = 1.58) across slow-motion levels—no slow, medium slow, and high slow with the standard error value of 0.07, 0.06, and 0.07—in Figure 3.4 (A). The conducted repeated measures ANOVA for agency scores did not yield significance among these measurements (F (2, 23) = 0.19, p = 0.82, η^2_G = 0.008).

Regarding the sense of ownership, the average scores were 4.91 (SD = 1.66), 4.66 (SD = 1.60), and 4.66 (SD = 1.65) with the standard error value of 0.05, 0.05, and 0.05 for slow-motion levels—no slow, medium slow, and high slow—in Figure 3.4 (B). The ANOVA results indicated no significance (F (2, 23) = 0.45, p = 0.64, $\eta^2_G = 0.019$).

The presence average scores from the agency questionnaire were 5.58 (SD = 1.17), 5.33 (SD = 1.27), and 5.29 (SD = 1.26) with the standard error value of 0.04, 0.06, and 0.06 for slow-motion levels—no slow, medium slow, and high slow—in Figure 3.4 (C). ANOVA analysis revealed no significant differences (F (2, 23) = 1.46, p = 0.24, η^2_G = 0.060).

The average scores for the sense of entertainment were 5.95 (SD = 1.16), 5.91 (SD = 1.06), and 5.79 (SD = 1.35) with the standard error value of 0.05, 0.04, and 0.05 across slow-motion levels—no slow, medium slow, and high slow—in Figure 3.5 (A). The ANOVA results did not reach significance (F (2, 23) = 0.58, p = 0.56, η^2_G = 0.025).

3.3 Experiment 3

Summarizing all agency questionnaire scores, the average scores were 5.51 (SD = 0.92), 5.35 (SD = 1.02), and 5.29 (SD = 0.81) with the standard error value of 0.03, 0.04, and 0.003 for slow-motion levels—no slow, medium slow, and high slow—in Figure 3.5 (B). ANOVA analysis indicated no significant differences (F (2, 23) = 1.45, p = 0.24, $\eta^2_G = 0.059$).

Lastly, the memory score results from Experiment 3 indicated average scores of 5.96 (SD = 0.27), 5.84 (SD = 0.23), and 5.76 (SD = 0.23) with the standard error value of 0.05, 0.04, and 0.04 across slow-motion levels—no slow, medium slow, and high slow —in Figure 3.5 (C). The repeated measures ANOVA conducted for memory scores did not reveal significance among these measurements (F (2, 23) = 0.10, p = 0.90, $\eta^2_G = 0.004$).

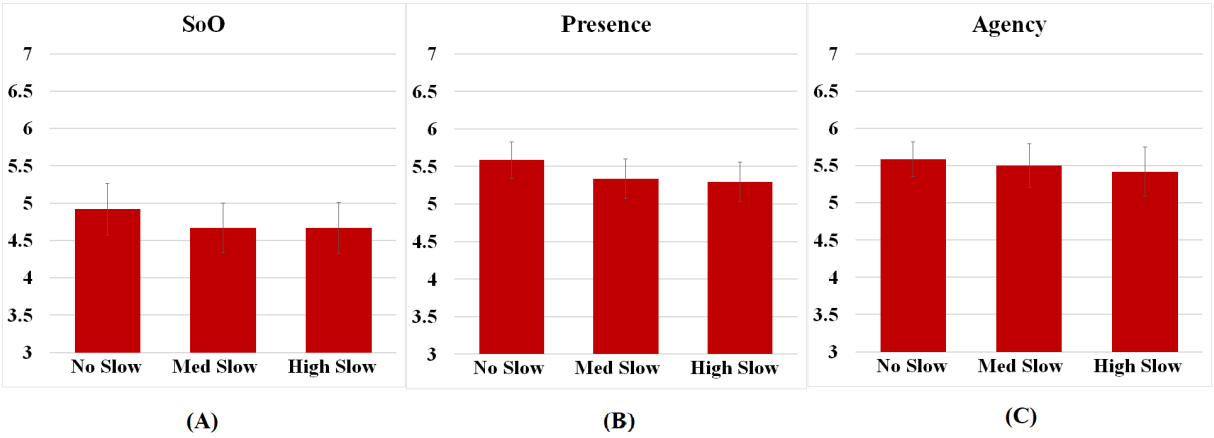

Fig. 3.4 The average of agency questionnaire including a sense of ownership (A), presence (B), and sense of agency (C) in Experiment 3 with a standard error.

3.3 Experiment 3

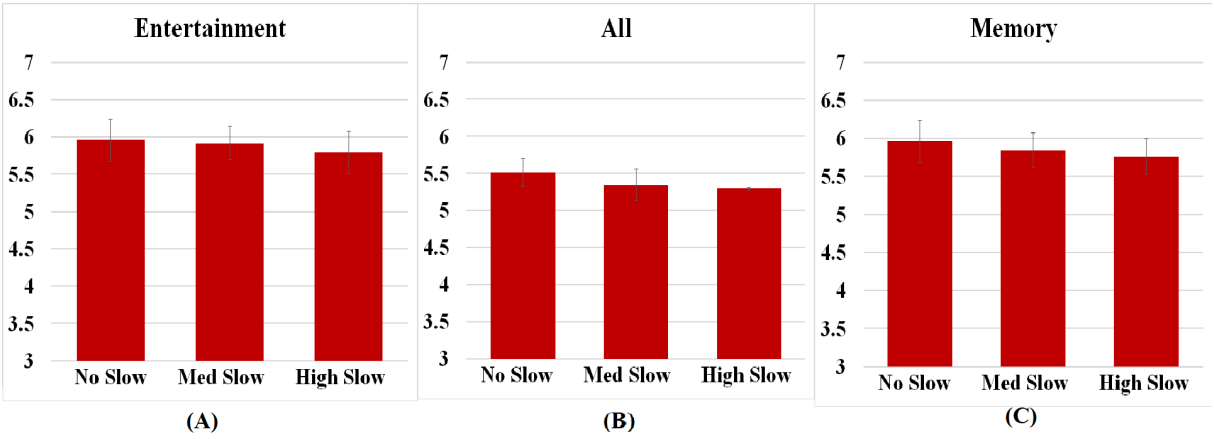

Fig. 3.5 The average of agency questionnaire including entertainment (A), all of the score in agency questionnaire (B), and memory scores (C) in Experiment 3 with a standard error.

3.4 Attractiveness Results

The results of the attractiveness questionnaire were showcased with the compilation of preferred culinary scores by the number of preference dishes that were chosen by the participants, distinguishing between interactive and non-interactive content presentation methods. Figure 3.6 presents a graph of the average comparison between interactive and non-interactive content, evaluated with attractiveness questionnaires in Experiment 1. The interactive content category exhibited an average selection rate score of 3.71 (SD = 2.58) with a standard error value of 0.53, whereas the non-interactive content category provided a slightly lower average score of 3.58 (SD= 3.36) with a standard error value of 0.69. However, the statistical analysis showed no significance by paired t-test (t (23) = 2.50, p = 0.40, Cohen's d = 0.043).

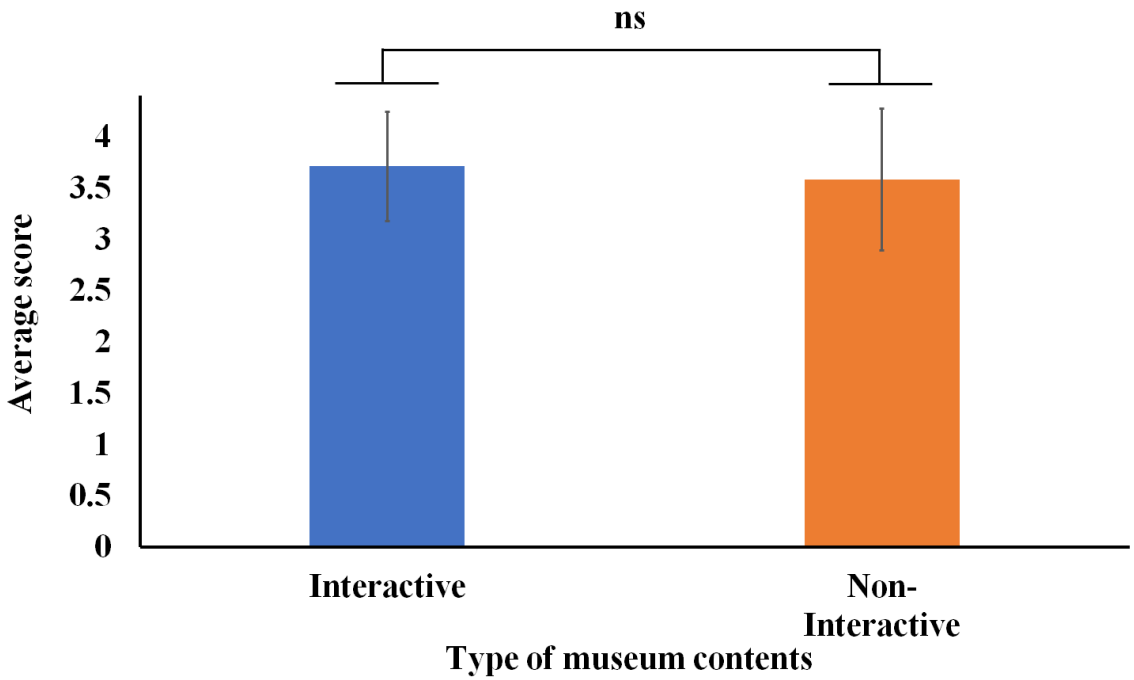

Fig. 3.6 The average score of interactive and non-interactive contents by evaluating the attractiveness questionnaire in Experiment 1 with a standard error.

3.4 Attractiveness Results

Each feature of the interactive content was examined to identify statistical relationships. Figure 3.7 presented a graph of the average comparison between interactive and non-interactive content features, evaluated with attractiveness questionnaires in Experiment 2. Three features of interactive content, including allowing participants to compress the presence of video accessibility, the ability to manipulate 3D models, and the inclusion of a button for accessing information content, yielded average selection scores of 1.75 (SD = 1.33), 1.46 (SD = 1.14), and 1.46 (SD = 1.14), respectively. In contrast, the non-interactive content category obtained a slightly lower average score of 1.21 (SD = 1.14) with a standard error value of 0.27, 0.23, 0.23, and 0.23. Despite the slight discrepancy in the averages that favored interactive content, the statistical analysis of these results was not significant using ANOVA (F (3, 23) = 1.79, p = 0.16, $\eta^2_G = 0.003$).

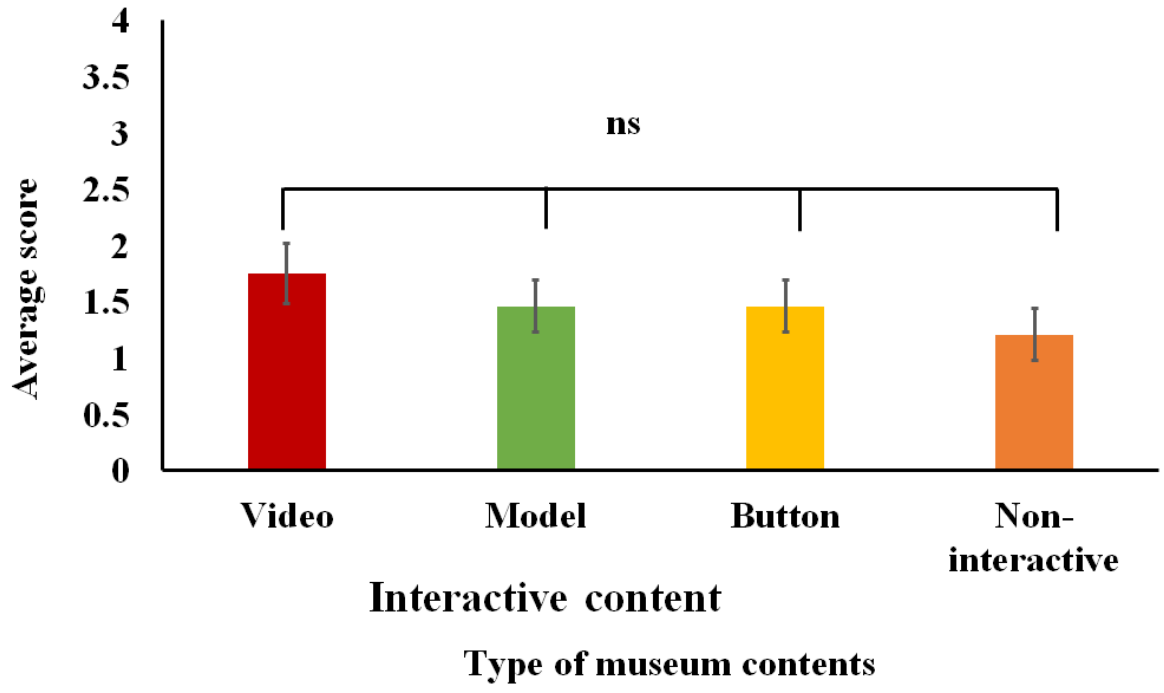

Fig. 3.7 The average scores of all features within the interactive and non-interactive by evaluating the attractiveness questionnaire in Experiment 2 with a standard error.

3.4 Attractiveness Results

In Experiment 3, within the context of slow-motion agency, the findings from the attractiveness questionnaire revealed average selection scores of 2.29 (SD = 1.98), 2.46 (SD = 2.04), and 2.00 (SD = 1.84) with the standard error value of 0.08, 0.08, and 0.07 as illustrated in Figure 3.8. However, the statistical examination of these outcomes did not yield significance using ANOVA (F (2, 23) = 0.79, p = 0.46, $\eta^2_G = 0.033$).

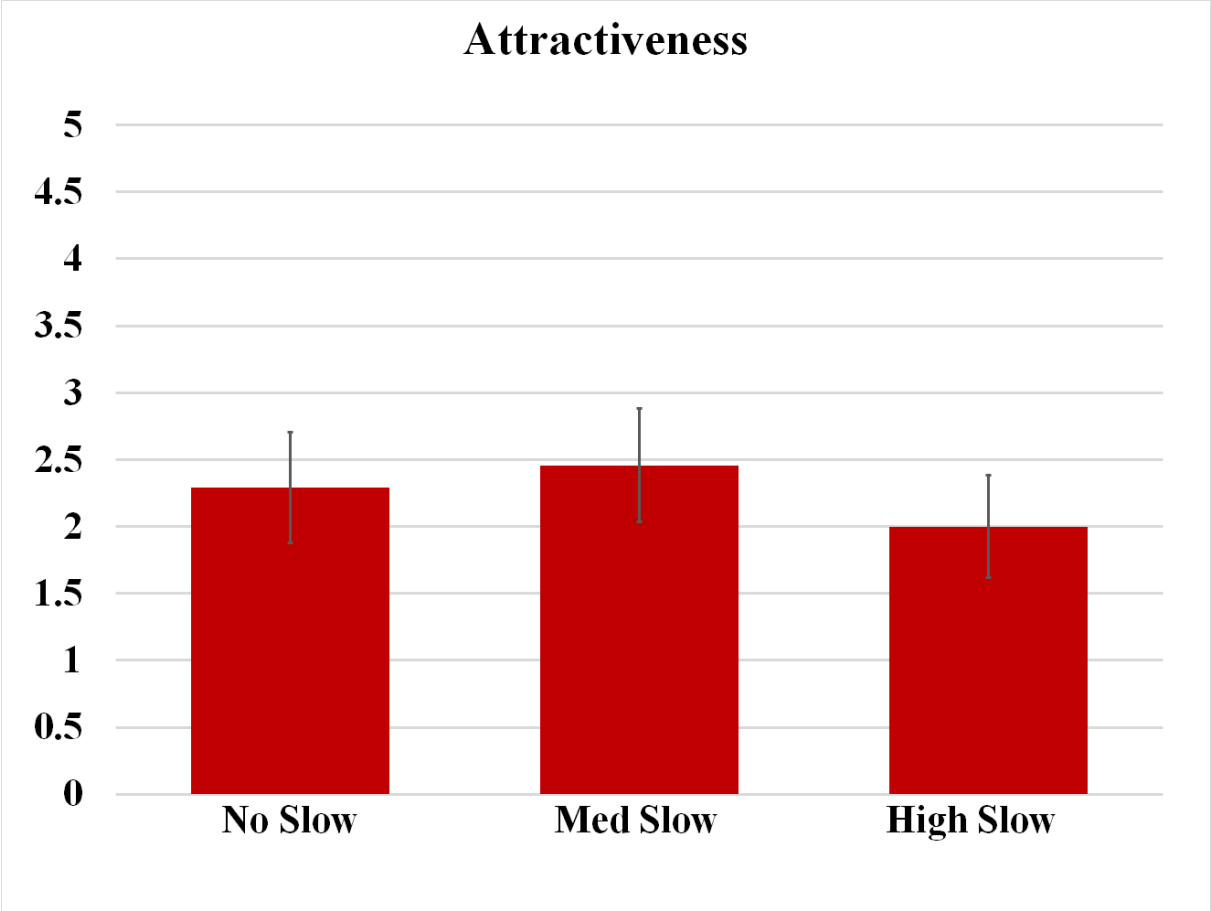

Fig. 3.8 The average scores of all features within the agency by evaluating the attractiveness questionnaire in Experiment 3 with a standard error.

Chapter 4

Discussion

This study aimed to discriminate the influence of interactive and non-interactive content on memory and attractiveness retrieval within a virtual reality museum of Thai cuisine. The study findings revealed a significant memory enhancement when utilizing interactive content compared to non-interactive content. This conclusion was reached by analyzing the average of the correct rate obtained from the memory questionnaires in experiment 1. The average score of the interactive content demonstrated a higher magnitude than non-interactive content and statistical significance, providing evidence of substantial differences between interactive and non-interactive content.

An additional analysis was conducted on the question formats used in the memory questionnaire to investigate the relationship between interactive and non-interactive content. The interactive content exhibited a higher average score than non-interactive content, with statistical significance, when participants were presented with questions containing pictures. However, no statistical significance was observed for questions without pictures. The results indicated that the question format of the questionnaire with pictures afforded the participants the opportunity to achieve a higher score for interactive content than for non-interactive content. This suggests that the interactive contents used in this study were more effective with nonverbal than verbal information.

However, only slight average differences were observed for each feature of the interactive and non-interactive content in Experiment 2. The interactive feature with pressing the button to view information archived a higher average score than any

interactive and non-interactive features, while the interactive feature with handling 3D objects provided the lowest average score. The interactive feature by pressing the button to play the video, and the non-interactive feature had a close average score. No statistically significant differences were found in any features. The identification relationship between memory and each feature of both interactive and non-interactive content did not differ significantly. This suggests that the utilization of various interactive content features in the virtual domain simultaneously improved memory enhancement compared to selecting any single feature of interactive content.

The result of slow-motion conditions revealed a lack of significant differences between agency and memory. This implies that the incorporation of diverse interactive content features in the virtual domain concurrently enhanced memory compared to employing slow-motion agency.

The attractiveness questionnaire was evaluated to identify the influence of attractiveness on interactive and non-interactive content. Statistical significance was not observed in all comparisons involving each interactive and non-interactive content feature. The results indicated that the interactive and non-interactive content did not significantly impact the attractiveness of the participants.

Furthermore, an additional examination of attractiveness concerning agency did not produce statistically significant results. The findings suggested that the slow-motion content did not significantly influence the attractiveness perceived by the participants.

The relationship between recognition memory and perceived attractiveness among the participants from the same group was evaluated using two questionnaires. These questionnaires assessed the variables under the same information and the same exhibition content with or without interaction. In contrast, memory exhibited statistical significance, as the average score of interactive content was obviously higher than that of non-interactive content. Statistical significance was not observed in the context

of attractiveness to exhibits between interactive and non-interactive content. These findings suggested that attractiveness had no notable correlation with memory and that the utilization of interactive content played an important role in enhancing memory without the contribution of attractiveness.

Chapter 5

Conclusion

This study demonstrated that interactive content, incorporating features such as button-activated video viewing, access to additional information, and free manipulation of 3D objects, significantly enhanced memory compared to non-interactive content and agency within a virtual reality museum context. However, neither interactive nor non-interactive content along with agency significantly impacted attractiveness, and the interactive content enhanced the memory without contributing to attractiveness. These findings underscored the importance of interactive content in VR museum environments, as it significantly improved the memory of visitors. These insights contribute to the ongoing efforts to enhance the design and implementation of VR technologies in museums with the aim of enhancing the overall visitor experience. Future efforts may identify a more difference-efficient type of interactive content mechanism to enhance memory.

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Appendix A

Memory questionnaire data score in Experiment 1

Participant Number	Interactive Score	Non-interactive Score
1	6	6
2	11	7
3	6	7
4	6	6
5	5	3
6	6	7
7	8	6
8	6	5
9	10	11
10	5	6
11	7	7
12	8	9

Participant Number	Interactive Score	Non-interactive Score
13	10	8
14	8	9
15	9	6
16	8	5
17	7	7
18	9	4
19	6	6
20	8	8
21	11	6
22	8	5
23	7	4
24	8	6

Appendix B

Question Type score in Experiment 1

Participants	Non* Picture	Non* No picture	In** Picture	In** No picture
P1	3	3	4	2
P2	3	4	5	6
P3	2	5	4	2
P4	2	4	2	4
P5	1	2	3	2
P6	4	3	1	5
P7	3	3	4	4
P8	1	4	5	3
P9	5	6	6	4
P10	2	4	2	3
P11	1	6	3	4
P12	4	5	4	4

*Non = Non-interacitve ** In = Interactive

Participants	Non* Picture	Non* No picture	In** Picture	In** No picture
P13	5	3	5	5
P14	3	6	4	4
P15	2	4	4	5
P18	3	2	3	5
P17	4	3	3	4
P18	1	3	4	5
P19	2	4	5	1
P20	2	6	5	3
P21	2	4	6	5
P22	1	4	4	4
P23	0	4	3	4
P24	2	4	4	4

*Non = Non-interacitve ** In = Interactive

Appendix C

Attractiveness questionnaire data score in Experiment 1

Participant Number	Interactive Score	Non-interactive Score
1	8	4
2	5	7
3	3	3
4	9	4
5	2	1
6	5	2
7	3	0
8	4	2
9	7	11
10	0	1
11	1	0
12	2	4

Participant Number	Interactive Score	Non-interactive Score
13	3	6
14	2	1
15	1	0
16	1	0
17	1	2
18	3	2
19	3	0
20	2	4
21	8	9
22	7	8
23	6	10
24	3	5

Appendix D

Memory questionnaire data score in Experiment 2

Participant Number	Non-interactive Score	Video	3D Model	Button
1	5	3	2	2
2	4	3	4	4
3	1	2	2	3
4	2	4	3	2
5	4	3	4	0
6	3	2	4	4
7	0	4	2	2
8	3	1	3	3
9	5	5	3	2
10	3	4	3	2
11	2	0	2	2
12	4	4	3	2

Participant Number	Non-interactive Score	Video	3D Model	Button
13	4	1	1	3
14	3	3	3	2
15	1	3	3	2
18	2	3	1	5
17	2	0	2	2
18	3	5	5	4
19	5	5	2	5
20	3	1	2	4
21	2	4	3	4
22	0	1	3	3
23	3	3	3	3
24	2	3	2	5

Appendix E

Attractiveness questionnaire data score in Experiment 2

Participant Number	Non-interactive Score	Video	3D Model	Button
1	1	0	3	1
2	1	1	0	1
3	1	0	1	3
4	1	1	2	2
5	4	2	3	3
6	0	0	1	1
7	3	4	3	1
8	0	2	1	0
9	1	1	1	0
10	1	2	2	1
11	1	1	0	0
12	1	1	1	0

Participant Number	Non-interactive Score	Video	3D Model	Button
13	0	0	3	2
14	1	2	1	1
15	0	3	2	2
18	1	1	1	1
17	0	1	1	2
18	1	4	1	1
19	1	2	0	1
20	1	2	0	1
21	1	3	0	1
22	3	4	2	4
23	4	4	4	4
24	1	1	2	0

Appendix F

Sense of ownership data score in Experiment 3

Participant Number	No Slow	Medium Slow	High Slow
1	3	4	4
2	2	3	3
3	6	6	6
4	6	5	3
5	6	5	5
6	4	3	3
7	7	7	7
8	3	2	3
9	2	4	6
10	6	6	6
11	7	7	7
12	5	5	5

Participant Number	No Slow	Medium Slow	High Slow
13	5	5	5
14	6	6	6
15	7	7	7
16	3	3	3
17	5	6	5
18	3	3	3
19	3	3	5
20	7	2	7
21	5	4	4
22	5	4	3
23	7	7	5
24	5	5	1

Appendix G

Presence data score in Experiment 3

Participant Number	No Slow	Medium Slow	High Slow
1	5	4	5
2	3	4	4
3	6	6	5
4	6	6	6
5	6	6	6
6	6	5	6
7	7	7	5
8	3	3	4
9	5	5	4
10	7	6	7
11	4	4	4
12	4	3	5

Participant Number	No Slow	Medium Slow	High Slow
13	6	6	6
14	7	7	7
15	6	7	7
16	6	4	5
17	6	5	5
18	6	6	6
19	7	7	7
20	5	6	4
21	5	5	5
22	6	5	5
23	7	7	7
24	5	4	2

Appendix H

Agency data score in Experiment 3

Participant Number	No Slow	Medium Slow	High Slow
1	4	6	6
2	4	4	3
3	5	5	6
4	6	5	4
5	7	7	7
6	4	3	4
7	7	7	5
8	5	5	3
9	4	5	6
10	6	6	6
11	7	7	7
12	4	4	4

Participant Number	No Slow	Medium Slow	High Slow
13	6	6	6
14	7	7	7
15	7	7	7
16	5	5	5
17	5	6	6
18	7	5	7
19	5	5	1
20	6	2	5
21	6	7	7
22	5	4	5
23	6	7	6
24	6	7	7

Appendix I

Entertainment data score in Experiment 3

Participant Number	No Slow	Medium Slow	High Slow
1	5	5	5
2	6	5	5
3	7	7	7
4	6	6	6
5	3	5	1
6	6	6	6
7	7	7	7
8	6	6	6
9	6	6	6
10	7	6	7
11	7	7	7
12	3	3	4

Participant Number	No Slow	Medium Slow	High Slow
13	6	6	5
14	6	5	6
15	7	7	7
16	5	6	6
17	6	6	6
18	7	7	7
19	7	7	7
20	5	4	5
21	7	7	7
22	6	5	5
23	7	7	6
24	5	6	5

Appendix J

All data score of Agency Questionnaire in Experiment 3

Participant Number	No Slow	Medium Slow	High Slow
1	4.25	4.75	5
2	3.75	4	3.75
3	6	6	6
4	6	5.5	4.75
5	5.5	5,75	4.75
6	5	4.25	4.75
7	7	7	6
8	4.25	4	4
9	4.25	5	5.5
10	6	6.5	6
11	6.25	6.25	6.25
12	4	3.75	4.5

Participant Number	No Slow	Medium Slow	High Slow
13	5.75	5.75	5.5
14	6.5	6.25	6.5
15	6.75	7	7
16	4.75	4.5	4.75
17	5.5	5.75	5.5
18	5.75	5.25	5.75
19	5.5	5.5	5
20	5.75	3.5	5.25
21	5.75	5.75	5.75
22	5.5	4.5	4.5
23	6.75	7	6
24	5.25	5.5	3.75

Appendix K

Memory questionnaire data score in Experiment 3

Participant Number	No Slow	Medium Slow	High Slow
1	2	6	8
2	5	7	4
3	3	4	5
4	6	7	5
5	3	6	7
6	8	6	6
7	5	6	5
8	6	5	5
9	4	5	6
10	6	3	4
11	3	6	7
12	2	4	5

Participant Number	No Slow	Medium Slow	High Slow
13	7	6	3
14	7	9	3
15	4	3	5
16	6	5	6
17	6	7	10
18	9	5	6
19	3	5	5
20	6	4	4
21	7	4	4
22	5	5	5
23	9	5	6
24	2	2	5

Appendix L

Attractiveness questionnaire data score in Experiment 3

Participant Number	No Slow	Medium Slow	High Slow
1	4	2	4
2	3	2	4
3	0	1	0
4	5	2	2
5	2	1	0
6	3	1	2
7	2	1	1
8	1	4	1
9	1	2	1
10	1	0	5
11	4	3	1
12	2	0	0

Participant Number	No Slow	Medium Slow	High Slow
13	1	2	3
14	1	3	0
15	6	6	4
16	1	1	0
17	1	1	2
18	1	2	2
19	3	7	3
20	2	1	0
21	0	3	2
22	3	3	3
23	0	3	1
24	8	8	7