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The Effectiveness of the Attention Guidance Mechanisms in VR Museum

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ABSTRACT

The COVID-19 pandemic has led to a shift towards digital exhibitions on virtual platforms and the increasing use of VR devices. In most exhibitions, audiences are free to explore and understand the content. However, in themed museums, this freedom may result in missing important exhibits. In this study, we examine the effectiveness of various attention guidance mechanisms and user satisfaction in virtual museums. We designed an immersive VR experiment in a simulated virtual museum environment with four mechanisms: no guide, arrows, characters, and characters that acknowledge the user and environment. There were two guiding directions (left and right) and three museum spacial compositions (60-degree angle, 90-degree angle, and 180-degree angle). Through mixed-method analysis, we found that all three attention guidance mechanisms were effective in guiding users in the three museum spacial compositions. Among them, the virtual arrow had the longest visibility time, and the acknowledging character had the highest user satisfaction. In conclusion, attention guidance mechanisms in VR museums significantly improve user attention to the target. The acknowledging character and arrow have the best guidance efficacy, and spacial composition also has a significant impact on attention effectiveness.

Keywords: VR museum, Attention guidance mechanism, Spacial composition, Virtual reality

INTRODUCTION

The rise of new internet technology and the COVID-19 pandemic has led museums worldwide to adopt digital technologies for virtual experiences such as online visiting and viewing. Virtual museums can overcome the limitations of traditional exhibitions by reorganizing space in real-time, creating dynamic exhibitions, and transforming fixed exhibition halls into knowledge networks for free exploration (Davidedi, 2022). Representative virtual museum technologies include 3D scanning/printing, VR/AR, and mobile app development (Hou, 2022). VR museums offer users a more immersive and realistic experience by displaying cultural relics in virtual scenes.

Despite the widespread use of online platforms, the lack of effective navigation design continues to affect the quality of virtual museum user experience (Li, 2022). Attention guidance mechanisms have been widely studied (Fearghail, 2018 and Lange, 2020). Previous research shows that diegetic mechanisms, where the guide is part of the narrative background and provides information through action, offer a stronger sense of immersion (Cao, 2020). Non-narrative mechanisms like arrows, whose sole function is to guide attention, may have stronger recognition (Wallgrün, 2020). Virtual animals are also conducive to interaction and guidance for the audience (Norouzi, 2021).

While there has been analysis of the effectiveness of attention guidance mechanisms in VR environments (Norouzi, 2021), the comparison of the effectiveness of different attention guidance mechanisms in combination with museum's special spatial composition and guiding path requires further exploration. When arranging exhibitions, museums must consider the visiting order for users to understand the relevance between exhibits. Existing diegetic logic modes for virtual museums include spacial composition designs of causal clues, multi-dimensional integration of time and space, and temporal clues associated with multiple clues (Ge, 2022). These spacial compositions may impact guidance effectiveness.

The purpose of this study is to explore the effectiveness and user satisfaction of different attention guidance mechanisms in VR museums. An experiment was conducted in a VR museum virtual environment and simulated visit process.

The paper is organized as follows: Section 2 details our experiment, Section 3 and 4 describe and discuss our findings, and Section 5 summarizes our work.

MATERIALS AND METHODS

This section provides details about the experiment aimed at comparing the effectiveness and impact of different attention guidance mechanisms in various spatial structures of a virtual museum.

Participants

Thirty participants were recruited from the university (15 females and 15 males aged 21-25). They had normal hearing and vision, and no movement impairments. All participants were VR museum novice and the experimental scheme was approved by the university institutional review board. The user evaluation was conducted from October 9th to 11th, 2022.

Hardware

Participants experienced the VR museum environment using an HTC VIVE headset (90 Hz, 1440 × 1600 pixels) and a 16-inch Legion computer (R9 5900HX, RTX3080) served as the VR program execution device (see Figure 1). The VR perspective and interactive behavior were recorded by a screen capture application and a camera, respectively, and projected on a large-screen display.

Software

A virtual scene was created in Unreal Engine 4.27, with assets obtained from the UE4 assets store (see Figure 2). The scene was designed to simulate a realistic museum with decorative paintings, cultural relics, ornaments, and pendants, and a bright lighting environment was set up. The experiment also included virtual guide and arrow as attention guidance mechanisms. The

Figure 1: The hardware layout of the experiment (HTC VIVE, Legion and screens).

Figure 2: A virtual museum scene was created using unreal Engine 4.27, featuring a spatial composition of 180°, 90°, and 60° display environments arranged from left to right.

character model was obtained from MIXAMO and the arrow model was produced using Blender 3.1.

Attention Guidance Mechanisms

The attention guidance mechanism was based on existing solutions (Norouzi, 2021). In addition, a virtual character was added as an attention guidance mechanism, to enhance user immersion. Three different attention guidance mechanisms were set up: Arrows, Characters, and Act-Characters that acknowledge the user and the environment (see Figure 3). The guiding time for each mechanism was 6.5 seconds, with Act-Character having a 1.5-second confirmation time before guidance, during which it stays in place and waves its hands. This time is not included in the guiding time.

Figure 3: Three attention guidance mechanisms: the Arrow (right), the characters (left), and the act-characters that acknowledge the user and the environment (middle).

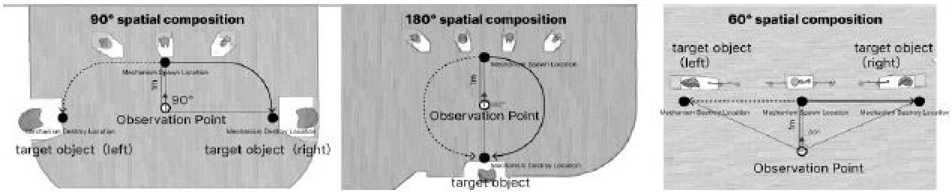

Figure 4: Three spatial compositions with navigation paths: the 60° display environment (right), the 90° display environment (left) and the 180° display environment (middle).

Spacial Compositions and Navigation Paths

Three different spacial compositions of the VR museum were set up to simulate different exhibit placements, with the same target, based on 60°, 90°, and 180° display environments. The final guidance target was located at the designated angle degrees from the initial observation point. Three navigation paths and two guiding directions were set according to the relationship between the three exhibits (see Figure 4). The attention guidance mechanisms were all located 1m directly in front of the participants' vision at the beginning, to ensure visibility. When the attention guidance mechanisms reached the final target, they disappeared immediately, ending the guidance.

Procedure

The experiment consists of two phases: a VR simulation experiment (approx. 10 minutes) and an oral interview (approx. 5 minutes).

After obtaining informed consent from each participant, they will stand on a flat floor and be assisted in wearing the VR headset. Participants will have three minutes to familiarize themselves with the experiment before starting. The task is to experience the attention guidance mechanisms in the VR museum and respond to the guidance. Their VR perspective and movements will be recorded by a screen recording program and camera. Participants will be divided into three groups (60°, 90°, and 180° display environments) based on different spacial compositions. Each participant will experience eight rounds of guidance experiments with all eight types of mechanisms (three different attention guidance mechanisms under two guidance directions and two no-guide groups). The order of mechanisms will be randomized to avoid order effects. Each round will be played automatically according to the program and will begin with a scene prompt tone. After each round, the screen will dim and participants will return to their initial position.

At the end of the experiment, participants will evaluate their satisfaction for each attention guidance mechanism on a 5-point Likert scale (1=very dissatisfied, 5=very satisfied).

Measurement

To evaluate the effectiveness of different attention guidance mechanisms, we conducted an evaluation through both objective and subjective measurement.

The objective measurement indicators are comprised of the following three categories:

Mechanism visibility time (MVT), which refers to the amount of time the attention guidance mechanism remained in the participants' visual field.

Reaction time, measured from the start of each scene to the moment the participant's reaction began to follow the guidance.

Guidance result, assessed based on whether the participant observed the target in the end.

Subjective measurement involves the use of a questionnaire to gauge the impact of the attention guidance mechanism on the participants' subjective experience.

RESULTS

The results of objective measurement are depicted in Figure 5 and Figure 6. To analyze the data, we employed ANOVA and descriptive statistics. Our findings indicate that the attention guidance mechanism has a significant impact on all objective measures.

In the comparison of mechanism visibility time (see Figure 5), we discovered that the three spatial compositions have a significant impact and that the mechanism visibility time was longest in the 90-degree angle spatial composition. A highly significant difference was observed between the act-character and character ($p < 0.001$), with the act-character mechanism having the longest visible time. In the 60-degree and 90-degree spatial compositions, there was a statistical difference between the arrow and act-character ($p < 0.05$), while under the 180-degree spatial composition, there was a statistical difference between the arrow and character ($p < 0.05$).

Regarding reaction time (see Figure 6), we found that the three spatial compositions had a highly significant difference in the average reaction time ($p < 0.001$), with the shortest reaction time in the 90-degree spatial composition. There were significant differences between the no-guide group and the other attention guiding mechanisms ($p < 0.01$), indicating that the reaction

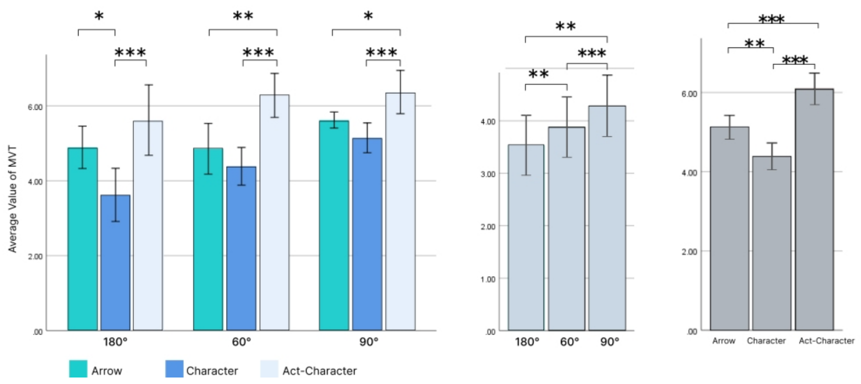

Figure 5: MVT: combinations of spacial compositions and attention guidance mechanisms (left), MVT: three spacial compositions (middle) and MVT: three attention guidance mechanisms (right).

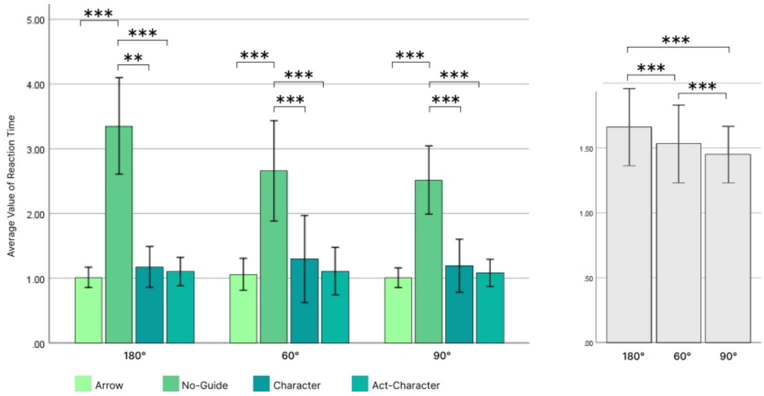

Figure 6: Reaction time: combinations of spacial compositions and attention guidance mechanisms (left) and reaction time: three spacial compositions (right).

			Bool .00	1.00	Total
AGMs	Arrow	Count	15	45	60
		Expected Count	28.0	32.0	60.0
		% within AGMs	25.0%	75.0%	100.0%
	No-Guide	Count	52	8	60
		Expected Count	28.0	32.0	60.0
		% within AGMs	86.7%	13.3%	100.0%
	Character	Count	29	31	60
		Expected Count	28.0	32.0	60.0
		% within AGMs	48.3%	51.7%	100.0%
	Act-Character	Count	16	44	60
		Expected Count	28.0	32.0	60.0
		% within AGMs	26.7%	73.3%	100.0%
Total		Count	112	128	240
		Expected Count	112.0	128.0	240.0
		% within AGMs	46.7%	53.3%	100.0%

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	59.598[a]	3	.000
Likelihood Ratio	64.341	3	.000
N of Valid Cases	240		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 28.00.

			.00	1.00	Total
SCs	180°	Count	48	32	80
		Expected Count	37.3	42.7	80.0
		% within SCs	60.0%	40.0%	100.0%
	60°	Count	40	40	80
		Expected Count	37.3	42.7	80.0
		% within SCs	50.0%	50.0%	100.0%
	90°	Count	24	56	80
		Expected Count	37.3	42.7	80.0
		% within SCs	30.0%	70.0%	100.0%
Total		Count	112	128	240
		Expected Count	112.0	128.0	240.0
		% within SCs	46.7%	53.3%	100.0%

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	15.000[a]	2	.001
Likelihood Ratio	15.319	2	.000
N of Valid Cases	240		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 37.33.

Figure 7: Guidance results: four mechanisms (left), and guidance results: three spacial compositions (right).

time of the no-guide group was significantly longer. There were no significant differences in the guiding duration among the arrow, pedestrian, and wave mechanisms.

The guidance results were analyzed using the chi-square test as 0 cells had an expected count less than 5 (see Figure 7). The success rates of the four mechanisms were, in order from high to low: arrows (75%), act-characters (73.3%), character (51.7%), and no-guide (13.3%), with highly significant differences ($\chi 2 = 59.6$, $p < 0.001$). The success rates of the three guidance paths, in order from high to low, were 90 (70%), 60 (50%), and 180 (40%), with significant differences ($\chi 2 = 15.0$, $p < 0.01$).

Finally, we collected questionnaires and analyzed the subjective satisfaction data of participants on the four mechanisms (see Figure 8). Participants

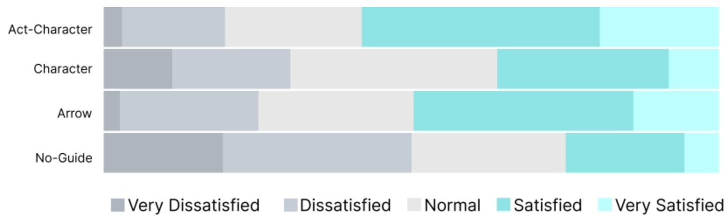

Figure 8: Satisfaction of attention guidance mechanisms.

preferred the arrow and act-character mechanisms, with the highest satisfaction expressed for act-characters, followed by the arrow. Participants had the lowest satisfaction with the no-guide mechanism.

DISCUSSION

The Effectiveness of Visual Characters

As a diegetic mechanism, act-characters have been found to be an effective attention guidance mechanism, as they effectively capture the participants' attention. While characters are also effective, they are more easily perceived as simply passing by when they lack interactive behavior. In terms of user satisfaction, act-characters were preferred by most participants due to their harmonious nature. However, some participants found the characters to be frightening, indicating that the horror valley effect should be considered in future studies.

High Identifiability of Arrows as a Attention Guidance Mechanism

The shortest average reaction time for arrows indicates that they are easily identifiable, which is consistent with previous research (Wallgrün, 2020). This may be due to their directionality and participants' inherent understanding of arrows. Arrows also performed best in terms of guidance results, making them a better option than characters without interactive behavior in terms of both user satisfaction and effectiveness.

Impact of Spacial Composition on Guidance Effectiveness

The spacial composition can impact the reaction time and mechanism visibility time for the participant, which may be reflected in the different guidance paths, directions, and the distance between the guide and the target object. In the 180° spacial composition, the participant needs to turn around, leading to potential interruptions during the process. Additionally, the distance between the participant and the guide object in the 60° spacial composition increases as the guidance progresses. The relationship between spacial composition and guidance effectiveness merits further investigation.

CONCLUSION

This study compared the effectiveness and user satisfaction of three attention-guided mechanisms (arrow, figure, wave) and a blank control group in three

VR museum spacial compositions (60°, 90° and 180°) by evaluating mixed measurement data. Our experiment found that attention guidance mechanisms can significantly improve user attention to the target, with act-characters and arrows showing the highest effectiveness. In addition to the comparison of guidance mechanisms, we also concluded that the spacial composition affects guidance effectiveness, with 90° spacial being the most effective.

Future work should focus on exploring the impact of spacial composition on guidance effectiveness, including variables such as guidance object location, path, and distance, as well as evaluating the effectiveness of additional attention guidance mechanisms. Additionally, examining the impact of various existing virtual guides on guidance effectiveness and user preferences is of interest. Furthermore, exploring user information acceptance during VR museum experiment is also worth investigating.

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