Personalizing Cultural Heritage Access in a Virtual Reality Exhibition: A User Study on Viewing Behavior and Content Preferences

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ABSTRACT

Leveraging digital technologies, museums now have the opportunity to embrace innovative approaches such as knowledge graphs, virtual reality, and virtual assistants to enhance the preservation and interactive presentation of cultural information. However, despite these advancements, personalizing the museum experience remains a significant challenge. Thus, this paper aims to investigate the necessary elements for offering personalized access to cultural heritage within a VR exhibition. To accomplish this, a user study was conducted to identify user preferences for tailored content descriptions, track user viewing behavior to gauge their interest in a VR exhibition, and determine preferred methods of information gathering. The study involved 31 participants, and the findings are expected to provide valuable insights for designing effective and engaging VR exhibitions that cater to diverse visitor interests.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; **Interaction paradigms**; **Virtual reality**;

KEYWORDS

Cultural Heritage, Knowledge Graph, Personalization, Virtual Reality

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1 INTRODUCTION

Digital technologies have increased museums' ability to preserve and present cultural heritage, opening up new opportunities for engaging visitors [5, 16, 19]. Innovative approaches such as Knowledge graphs [7, 12, 13, 22], virtual reality (VR) [10, 24, 29, 30], and virtual assistants [6, 9, 23, 32] have been employed to create immersive and interactive museum experiences. However, despite these advancements, there is still limited research on personalizing these experiences for individual users.

This paper aims to bridge this gap by exploring how to provide personalized access to cultural heritage in VR exhibitions. To accomplish this, we conducted a study that initially examined users' content preferences, specifically the information they typically seek about paintings when exploring a VR exhibition. This investigation aimed to identify their preferences and develop a way to model them. Secondly, we explored whether VR can be utilized to measure user interest. In this regard, we sought to determine whether user behavior, such as the time spent on paintings in VR, could serve as an indicator of user interest. Finally, we investigated the preferred methods for users to gather information, with the intention of suggesting improved approaches for delivering information.

The user study involved 31 participants who explored a VR exhibition of 19 paintings at their own pace while wearing a headset. During the exploration, participants engaged in a think-aloud process, sharing their observations, personal interests, and posing questions about the paintings and accompanying texts. Participants' audio and eye gaze data during the VR experience were recorded for subsequent analysis. Following the visit, participants completed a survey and were interviewed to gather their overall impressions of the VR exhibition and detailed insights about the three paintings they dedicated the most time to exploring.

The study findings suggest that visitors commonly seek information regarding the historical and social context of the artwork, the artist's intention, and the stories depicted within them. These findings align with previous research [4, 27]. However, such desired information is not always readily available in the immediate text accompanying the artworks but rather provided by guides or found in related documents. To address this issue, we propose structuring and incorporating this supplementary information into an existing knowledge graph encompasses the artworks in the exhibition, making it easily accessible to visitors. Additionally, to cater to individual user preferences, we emphasize the importance of modeling user interest in a separate knowledge graph. This approach allows for the identification of connections between cultural heritage content and user interests.

Our study highlights that user behavior, such as the time spent viewing specific paintings, can serve as an indicator of user interest. To capitalize on this finding, we propose leveraging a conversational agent that utilizes the knowledge graph containing relevant cultural data and the knowledge graph capturing individual information preferences to deliver tailored information to users. However, careful consideration must be given to factors such as the agent's communication style and the type and quantity of information provided. Further investigation is necessary to determine the optimal design and implementation of a conversational agent that effectively caters to users' information needs and enhances their overall experience within a VR exhibition.

The paper is organized as follows: Section 2 reviews related work on enhancing museum experiences for users. Section 3 describes our VR exhibition and user study, detailing the methods employed for data collection and analysis. Section 4 presents the results and discusses their implications for personalized museum experiences, outlining future research directions. Finally, Section 5 concludes the paper.

2 RELATED WORK

The related work section provides an overview of various studies that have explored the use of technology in improving users' museum experiences.

Sernani et al. [28] proposed a system that combines the Internet of Things (IoT) and Artificial Intelligence (AI) to provide personalized museum visits, where users can ask for and receive information related to specific artwork through a mobile app. The system uses either voice or text messages, depending on the user's preference, and an indoor localization component based on Ultra-WideBand (UWB) radio technology to determine the user's location within the museum. Hashemi et al. [11] discussed the use of IoT in smart museums to improve personalized recommendations based on user's physical interaction behavior. They studied the similarity of users' onsite physical and online digital information interaction behaviors and how they can be used to improve onsite point-of-interest (POI) recommendations. Amato et al. [1] proposed a methodology that combines recommendation systems and agent-based planning techniques to create a personalized route for visitors to cultural heritage sites based on their preferences. The recommendation system suggests cultural items that are most suitable for the user, while the agent-based planning generates a sequence of steps to reach specific cultural goals.

Minkov et al. [18] proposed using personalized recommender systems to help visitors manage the information overload when exploring a large number of exhibits at museums and other cultural heritage sites. The system models user preferences and background knowledge about the museum's environment, considering physical and thematic relevancy. They introduced a personalized graph-based recommender approach that uses a heterogeneous graph scheme to represent user feedback, physical positions, and semantic themes. Pavlidis et al. [21] presents a new user satisfaction modeling framework that captures various aspects of user behavior during museum visits, including temporal, proximity, content-based, and obtrusion dynamics either in the form of an organized predefined narrative or a typical free-roaming visit. The framework has been tested with simulated data and can support minimax-based strategies (user dissatisfaction minimization). Tsiropoulou et al. [31] propose a human-in-the-loop approach for providing a personalized museum tour to maximize visitors' perceived Quality of Experience (QoE). The study identifies the most influential factors affecting visitors' QoE and quantifies them using a questionnaire answered by museum experts. Based on this, individual QoE functions are developed for different visitor styles to create a customized experience. A social recommendation and personalization approach is designed to create visitor profiles and recommend exhibits based on their interests.

Mu et al. [20] discuss the use of virtual reality (VR) in creating interactive audience experiences and how understanding user attention and behavior in VR can inform the creative process. The authors developed an abstract VR painting and an experimentation system to track user eye gaze and movement during art exploration. They conducted an experiment with 35 participants and analyzed the data using deep learning models to identify patterns in user behavior and connections between behavior and audience background. Dohan et al. [8] conducted a user experiment in an abstract VR painting exhibition where users walked naturally to explore the VR painting. They used deep learning models to model user mobility sequences and predict their future movements while engaging with the art exhibition. Pratisto et al. [25] review the existing research on Virtual Reality (VR) in the tourism industry and highlight the unexplored roles of system quality and user personality. The study aims to examine the relationship between VR quality (information quality, interactivity, and visual attractiveness) and user personality (openness to experience, conscientiousness, and social influence) in relation to usability, attitude, and behavioral intention. Puig et al. [26] explore the use of 3D reconstruction and virtual reality (VR) as a learning tool in museums to help visitors better understand the past. They present a case study on the use of VR in an itinerant archaeological exhibition of the Neolithic settlement of La Draga and analyze the qualitative and quantitative feedback from visitors. The study also includes an analysis of visitor navigation and interaction patterns. Meinecke et al. [17] propose a novel virtual museum experience that contextualizes a gallery's digitized artworks with related artworks from large image archives using multiple visualizations. The authors use the WikiArt dataset to enable comparative visual exploration and apply machine learning methods to extract multi-faceted information about the objects detected in the images and

compute similarities across them. Visitors of the virtual museum can interactively explore the artworks using different search filters, such as artist, style, or object classes detected within an image, providing a more engaging and interactive online tour experience.

Ardissono et al. [3] discussed the challenges of personalizing cultural heritage information for visitors. The authors emphasized the importance of personalization to help visitors navigate the vast amount of available information and access the most relevant content easily. They noted that personalization requires a system that can model the user's interests, knowledge, and personal characteristics, as well as contextual factors. However, personalizing for first-time users is particularly challenging. The authors also highlighted the social nature of tourism and the need to model and support groups and communities. They surveyed research in this area, starting from earlier systems in kiosks and summarizing the evolution of personalization techniques in museum websites, virtual collections, and mobile guides. They concluded by highlighting current challenges and identifying areas for further research.

Finally, Barth et al. [4] examined the types of content that visitors would expect from a voice-based AI conversational system in a museum. They analyzed conversation logs from a nine-month deployment of a voice-based interactive guide in a modern art museum in Brazil and identified eight types of content that visitors asked about. They found that more than half of the visitors asked about the meanings and intentions behind the artwork, followed by facts about the artwork and author-related questions. They also found relationships between the visitor's overall evaluation of the experience and the types of questions asked. Based on these findings, the study identifies implications for designing content for museum voice-based conversational systems.

In summary, the literature review encompasses a range of studies focusing on integrating IoT and AI to provide personalized museum visits, using personalized recommender systems to manage information overload, and developing personalized museum tours to maximize visitor satisfaction. Additionally, recent studies have focused on using VR to create interactive experiences and understand user attention and behavior in VR. However, there is a need for further research on capturing and modeling user interest and preferences in VR, as well as utilizing VR to measure interest and provide personalized recommendations for artwork descriptions or visiting routes. These insights can contribute to more engaging and tailored museum experiences for visitors.

3 METHODOLOGY

In the study, we have three main goals: 1) to collect information about users' content preferences, 2) to track their viewing behavior and their interest, and 3) to find a user-preferred method of gathering information. Participants are asked to "think aloud" during an exhibition visit and complete a survey afterward about their preferred information on the paintings. We also track their viewing behavior in a VR exhibition to understand their interests and preferences and ask later for their level of interest in each painting in the survey. Lastly, we ask about their preferred information-gathering method in both the survey and the interview.

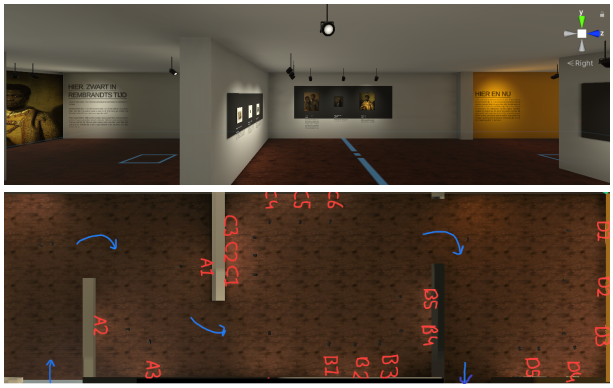


Figure 1: VR Exhibition "HERE: Black in Rembrandt's Time" featuring 19 paintings organized into three different rooms

3.1 VR exhibition

In 2020, the Museum Rembrandthuis organized a special exhibition called "HERE: Black in Rembrandt's Time," with the objective of presenting an accurate and respectful representation of people of color during the 17th century in and around Amsterdam. This exhibition aimed to challenge the stereotypical portrayals often found in later artwork by showcasing individuals of color in prominent roles within the paintings. The collaboration between the University of Twente and the Museum Rembrandthuis has resulted in the recreation of this exhibition using Unity, as depicted in Figure 1. The virtual exhibition showcases a curated selection of 19 paintings from the original exhibition, which have been arranged into three distinct rooms based on their subject matter.

The Museum Rembrandthuis contributed basic information and background stories for all the paintings displayed in the virtual exhibition. Each painting is accompanied by a text panel that includes its title, creator, creation date, and a brief description of the artwork along with relevant contextual information. To maintain the structured information about the featured paintings, a knowledge graph was created for this exhibition [14]. The knowledge graph includes additional details about the paintings such as their genre, material, artistic movement, and more.

3.2 Procedure

VR Visit. The study was approved by the ethics committee at the University of Twente, the Netherlands. All participants provided written consent prior to data collection to ensure their anonymity and confidentiality. Upon consenting, participants were directed to the VR exhibition and given instruction to explore at their own pace. They were encouraged to engage in "think aloud" activities, which involved describing their observations, expressing their interests, and asking questions while viewing the paintings and reading accompanying texts. Their voices and eye gaze were recorded for subsequent analysis. After the VR visit, participants were invited to fill out a survey and participated in interviews to gather their feedback on the overall VR exhibition experience and their detailed impressions of the three paintings they spent the most time exploring during their visit.

Survey. This study employed a survey to collect demographic information from participants, as well as their level of interest in the 19 paintings featured in the VR exhibition and the specific details they sought. The survey encompassed inquiries about participants' gender, museum visiting habits, familiarity with VR technology and VR museums, and preferred methods of obtaining exhibit information. Participants were also requested to rate their interest in each painting on a scale of 1 to 5. Additionally, the survey contained 19 specific questions pertaining to different aspects of the paintings, such as context, material, and historical significance, with participants rating their level of interest in each question on a scale of 1 to 5. Lastly, participants were given the opportunity to provide any additional information they desired to learn about the paintings.

Interview. During the interview sessions, we initiated the conversation by discussing the participants' familiarity and comfort level with VR technology. Following that, we specifically selected three paintings for each participant, based on their extensive viewing time. We then encouraged participants to elaborate on the reasons that motivated their deep engagement with these particular paintings. Additionally, we inquired about their preferred approach to obtaining information about paintings in a museum setting.

Data analysis. For our analyses, we utilized Python 3.10 within the Anaconda environment. Specifically, we conducted a Spearman's correlation to explore the potential relationship between user viewing behavior and their level of interest.

3.3 Participants

The study included a total of 31 participants, with an equal distribution of gender, consisting of 15 females, 15 males, and one participant who preferred not to disclose their gender. The majority of participants (23) fell within the age range of 20 to 29 years old, while 7 participants were between 30 and 40 years old, and only one participant was over 40 years old.

In terms of museum visiting habits, more than half of the participants reported occasionally visiting museums, with a frequency of a few times a year. The remaining participants indicated that they rarely visited museums, with a frequency of once a year or less.

Regarding experience with virtual reality (VR), 21 participants had tried VR before but were not familiar with it, while 8 participants had extensive experience with VR and considered themselves familiar with the technology. Only 4 participants had prior experience with VR museums. Additionally, 7 participants were familiar with some of the artworks displayed in the experiment.

4 RESULTS & DISCUSSION

This section reports the results of our data analysis on user content preferences, the correlation between user viewing behavior and their self-reported interests, as well as the preferred methods of information gathering.

4.1 Indicating user-preferred content in VR

Figure 2 presents the survey results, providing insights into user preferences concerning diverse aspects of painting information. These findings align with prior research [4], confirming that users display a predominant interest in delving into the historical and social context of the artwork, understanding the artist's intention, and uncovering the narratives surrounding the depicted individuals and elements.

However, our current knowledge graph has limitations in addressing users' comprehensive information needs. While it can effectively handle factual data-related queries, such as locating specific artworks or providing basic characteristics, it may not fulfill users' deeper information requirements. To overcome this limitation, we plan to enrich the knowledge graph by incorporating additional information using ontologies specifically designed for cultural heritage information modeling, such as CIDOC CRM[1] or Linked Art Data Model.[2] These ontologies provide a structured framework for describing objects, individuals, events, and other entities pertinent to cultural heritage, along with their interrelationships.

During the survey, we also probed users about the information they desired. As detailed in Table 1, participants expressed various interests. Some sought basic information, like the artist's ethnicity or whether the depicted person is real. Others expressed a desire for contextual information, such as the social impact of the painting or the significance of the collection. Additionally, some participants showed an inclination towards technical aspects, such as the painting's layers or the ability to compare similar works by the same artist. Collectively, these responses underscored the participants' yearning for more comprehensive information to enhance their exhibition experience.

In addition to enriching the exhibition's knowledge graph, we propose utilizing a user model to deliver personalized information to individual users. By constructing a structural user model similar to the exhibition's knowledge graph, we can better match user preferences with existing information (triples) about the cultural content and identify relationships between different users. This enables us to offer descriptions that align with each user's preferences. For instance, some users may be primarily interested in the stories behind the paintings, while others with a background in history or art may prefer information such as the painting's date or style.

In our future work, we aim to explore the potential of using *voice recordings* to identify users' interests in the content of information. Initial analysis of some recordings suggests that this approach may be feasible. For example, when examining *The Market in Dam Square* painting (Figure 3a), many participants expressed a desire to find specific information within the painting, such as the presence of a black figure that some participants had difficulty locating. Participants also suggested that incorporating icons or directions within paintings could aid in identifying specific objects. Furthermore, participants showed curiosity about the fate of a building in the painting that no longer exists in the current Dam Square. By leveraging voice recordings, we can potentially extract valuable insights into users' content preferences and tailor the provided information accordingly.

Another avenue for investigation is the use of *eye gaze* to understand users' information-seeking behavior. By analyzing the user's eye gaze, we can gain insights into their visual attention and infer the information they are seeking. For example, as shown

[1] https://www.cidoc-crm.org/
[2] https://linked.art/

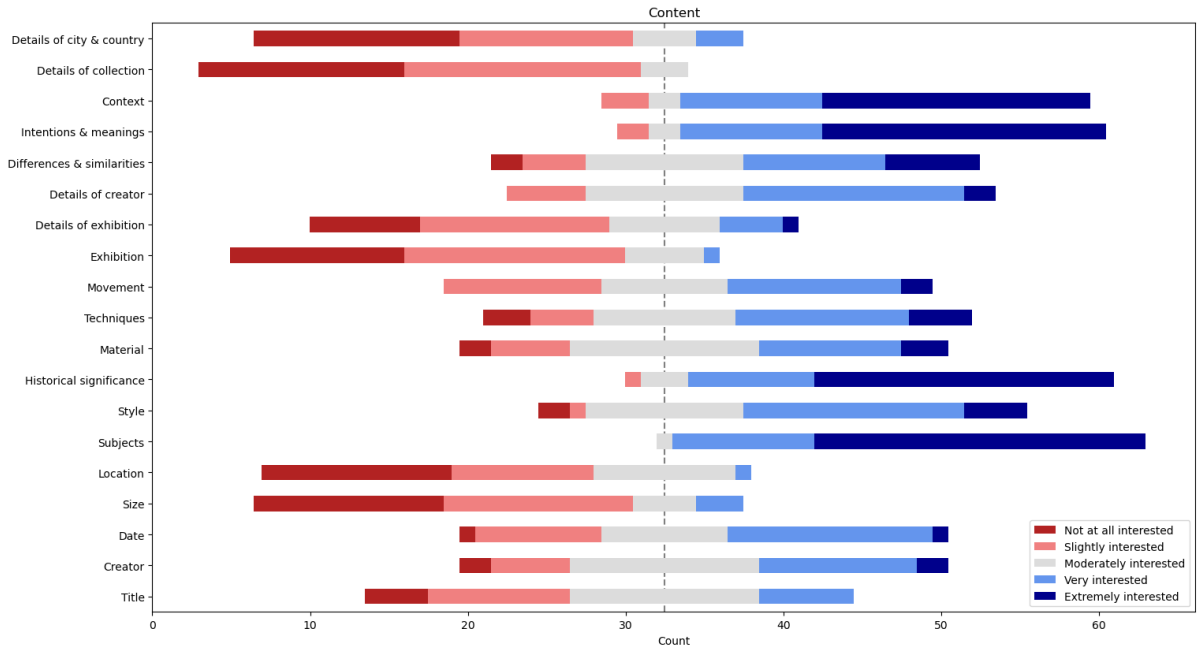


Figure 2: The level of participants' interest in various types of artworks information

Figure 3b, if users focus their gaze on a particular building within the painting, it indicates their interest in knowing more about it. This approach necessitates enriching the knowledge graph with information about the subjects depicted in the painting, a category of information that users expressed interest in. By leveraging eye gaze data, we can tailor the information presented to users and further enhance their overall experience.

These approaches, incorporating user models and utilizing voice recordings and eye gaze, have the potential to significantly improve the personalization and effectiveness of information delivery, allowing us to cater to individual users' preferences and create a more immersive and engaging exhibition experience.

4.2 Indicating user interest based on user behavior in VR

Figure 4 displays the mean level of interest and mean time spent by participants on each painting, along with their respective standard deviations. Furthermore, Figure 5 provides a breakdown of the number of participants who indicated high, low, or moderate interest in each painting. To examine the correlation between the time spent on paintings and participants' interests, we conducted a Spearman correlation analysis. The results revealed a significant positive correlation (correlation coefficient = 0.658, p-value = 0.002) between the mean interest and mean time spent on paintings. Additionally, we observed a significant overall difference (p-value = 0.000) in the time spent on paintings according to the level of interest, indicating that time can serve as an indicator of user interest.

However, we acknowledge that the subject matter of the paintings may have influenced the time participants spent on them. As part of our research, we conducted interviews with participants regarding their experiences with the three paintings they spent the most time on, as well as their reasons for doing so. We discovered that the majority of participants devoted considerable time to a painting depicting Dam Square in Amsterdam (Figure 3a). Participants mentioned that the intricate details capturing various buildings and people in the square were the primary reasons for their extended engagement. A similar experience occurred with a map painting. Additionally, some participants reported spending time on paintings simply because they encountered them first during the study. We also found that participants invested substantial time in a photograph that they initially mistook for a painting. They noted that the engaging story accompanying the painting's description held their attention. Notably, participants also spent time examining a Rembrandt painting featuring a black individual with a bow and arrow case. Their interest was piqued by the narrative behind the painting and the person depicted. Moreover, two modern art paintings, each depicting a woman, garnered significant attention. The first painting intrigued participants due to its portrayal of a political activist, while the second painting stood out with its vibrant and colorful depiction of the subject. Hence, it is evident that certain paintings require less exploration time, while others demand more.

Furthermore, we observed that participants' museum visitation habits influenced the time spent on paintings. Based on our study,

Table 1: Additional information participants desired to know as indicated in the survey

Index	Other information that participants wanted to know
1	Whether the artist is black (mostly clear from context but not always), whether the depicted person is real, whether the painting was well liked or controversial at the time.
2	Information about why this painting was added to the VR exhibition. I.e. I would expect it to be included to shed light on a specific part of the story the exhibition is telling.
3	Social impact of the painting.
4	I noticed that sometimes I started seeing paintings as set. While some info texts did mention that a painting is part of a grouping, the connections between paintings in the set in terms of color, point of view, etc. could be highlighted more. But this is also something I very much like figuring out myself, always looking for patterns. So, I am not sure whether adding the info explicitly would take away some fun for me.
5	Maybe if there are more interpretations for each painting. Or hidden meanings.
6	Depends a bit on the context, maybe why something is significant enough to be in this collection together with other works of art. So, the "why it matters".
7	It would be interesting to know a bit about the clothing of the people portrayed. I'm especially interested in clothing with embroidery inserts and would be nice to know where it comes from. Was that the fashion at the time? Was it more practical or just for aesthetics? How about the tailoring? Also, another interesting thing would be to give more detail about what people considered 'fantasy' at that time. There were two portraits in the exposition that were described to be fantasy paintings but there was no explanation of the elements which would classify those paintings as fantasy.
8	Would be cool if the painting would directly point me toward other paintings of the same maker/related paintings to compare.
9	It would be great if I can be presented with other information connected to the painting and explore them myself other than just the descriptions below since they are quite concise and short.
10	What are similar works? Is there also different media about authors, like interviews or audio/video?
11	A portrayed person's story, and how they relate to possible people we've learned about in history.
12	How the layers of a painting overlap and what it looks like if you can remove and add a layer. Maybe a bit difficult, but will be very interesting
13	Message/goals of the painter.

(a) (b)

Figure 3: The *Market in Dam Square* painting and example of eye gaze analysis in the painting

we categorized participants into two groups: those who rarely visit museums (once a year or less) and those who occasionally visit them (a few times a year). Conducting a Spearman correlation analysis revealed a correlation coefficient of 0.487299 and a two-tailed significance of 0.005429, indicating that frequent museum-goers may display greater interest in thoroughly exploring paintings and spending more time doing so.

Our findings suggest the feasibility of developing a prediction model to measure interest based on the time spent on paintings. However, to enhance the model's accuracy, it is crucial to consider

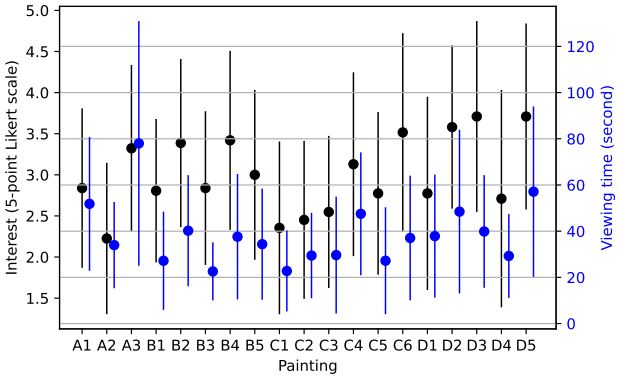


Figure 4: Mean level of interest and mean time spent by participants on each painting, accompanied by their respective standard deviations.

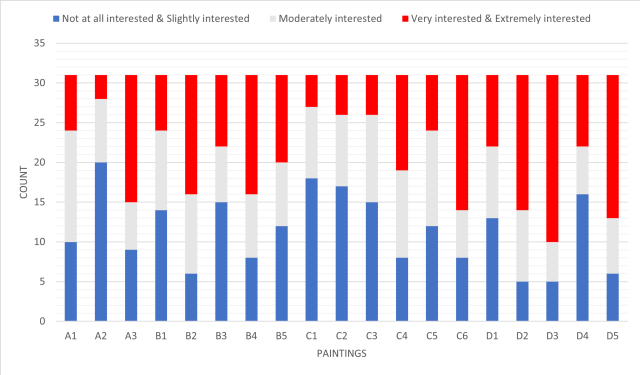
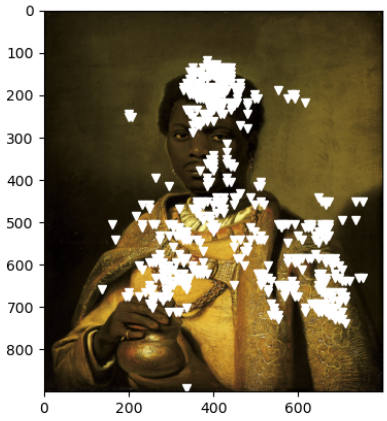
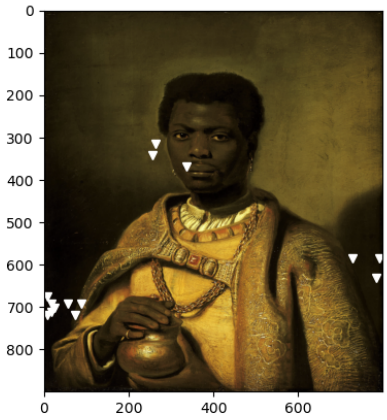


Figure 5: Number of participants who has a high (red), low (blue), or moderate (gray) interest in each painting



(a)



(b)

Figure 6: Eye-gaze data of two participants who had high (a) and low (b) interest in the painting *King Caspar*

parameters such as the subject matter of the painting. We propose utilizing this model as an indicator of user interest in paintings and incorporating it into our proposed user knowledge graph to generate personalized recommendations for each user.

In the future, we will further investigate the correlation between user behaviors (e.g., eye gaze, position, questions asked) and their interest in paintings. For example, we aim to examine differences in eye gaze patterns between interested and uninterested individuals to determine if there is a correlation. Figure 6 illustrates the eye gaze patterns of two participants, one who displayed interest and one who did not, while observing a painting of King Caspar. The interested participant demonstrated detailed scrutiny of various parts of the painting, whereas the uninterested participant briefly glanced at the painting. This finding suggests a potential correlation between eye gaze patterns and user interest in paintings.

4.3 Indicating user-preferred methods for information gathering

According to Figure 7, the most popular method among participants for gathering exhibition information is reading the exhibition labels, followed by listening to audio guides and attending guided tours. In our interviews, most respondents expressed a preference for taking their time to view paintings of interest and reading their descriptions. If they desired more information, they preferred using audio guides rather than attending guided tours, as the tours often followed pre-set routes that did not accommodate their individual preferences. However, some participants did appreciate having a knowledgeable guide who could provide insights into the stories behind the paintings and their relationships with each other.

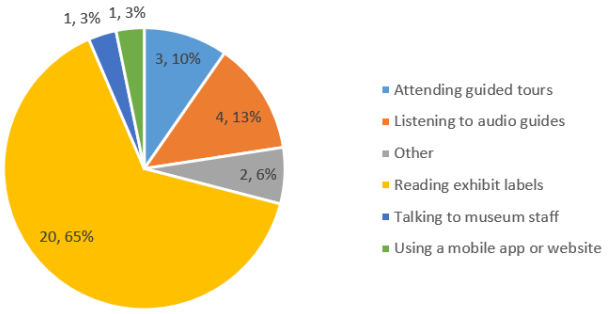


Figure 7: Participants' preferred methods for gathering exhibition information

Previous research has explored the use of chatbots [15, 32–34] and virtual assistants [2, 6, 23] to assist people in acquiring information about museum artifacts through text or voice. We believe that a conversational agent could also be a valuable tool for providing visitors in VR with relevant additional information. However, designing such an agent requires careful consideration of several factors.

Firstly, the agent should not be intrusive and should only be available to users when they require assistance, similar to an audio guide. Users should not feel obligated to use it and should be able to appreciate the museum at their own pace. Secondly, the agent should be capable of tailoring its descriptions to match the user's interests, thereby enhancing their enjoyment by providing information that is of particular interest to them. The user model approach discussed in the previous section could be valuable in achieving this goal. Finally, for those who prefer guided tours, the agent should provide personalized visiting routes and recommendations based on their interests to enhance their tour experience. To accomplish this, the agent should be able to identify the user's areas of interest. We believe that the method for measuring user interest in virtual reality, as discussed earlier, would be beneficial for this purpose. By leveraging these capabilities, users could enjoy a museum experience that is customized to their preferences.

Our future objective is to develop this conversational agent for VR and evaluate its effectiveness in providing information and enhancing user engagement and enjoyment. Additionally, as we are utilizing VR technology, we will also explore other methods of delivering information, such as using arrows, highlighting specific elements, and so on, in our ongoing research.

5 CONCLUSION

This paper presents the findings of a user study involving 31 participants who explored a virtual reality (VR) exhibition, focusing on their preferences for content and viewing behavior. Our analysis revealed that participants expressed a keen interest in learning about the stories behind the paintings, their historical and social contexts, and the intentions of the artists. While this information is typically provided by museum guides, we propose that in VR, it could be made accessible through a conversational agent, given that the agent has access to a knowledge graph containing relevant structural data and a user model that captures individual content preferences. The study also indicated that users prefer to have control over the pace of viewing paintings and do not favor guided tours that follow predefined routes, as these do not cater to their individual preferences. Consequently, when designing a conversational agent for VR, it is crucial to consider multiple factors to ensure it meets user needs. Additionally, we examined user viewing behavior to explore the connection between participants' interest levels and the time they spent observing paintings. While a significant difference was observed, we acknowledge that other factors, such as the painting's context, may also influence viewing time. This finding underscores the importance of considering multiple factors when designing prediction methods to gauge user interest based on time spent in VR.

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