Wesee: Digital Cultural Heritage Interpretation for Blind and Low Vision People *

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Abstract. When museums worldwide are introducing digital technology to help the heritage interpretation for visitors, blind and low vision (BLV) people are still excluded by various challenges. What BLV people need in museums is an in-depth learning and independent exploration process. However, the audio guide provided in museums is mostly simple descriptions, and cultural relics can not be touched, which cannot meet the cultural needs of BLV people. In this paper, we designed and implemented *Wesee*, an interactive platform that combined interactive narrative, voice interaction, and tactile interaction, to help BLV people experience cultural heritage more independently and interactively. The preliminary evaluation was conducted with 20 BLV participants. The results show that this platform is effective in helping BLV people experience cultural heritage.

Keywords: Multi-model interaction · Digital cultural interpretation · Blind and low vision.

1 Introduction

The needs of blind and low vision (BLV) people are no different from those of sighted people when visiting museums. People won't lose interest in cultural heritage and historical knowledge because of blindness [8]. There have been growing efforts to make museums and cultural heritages accessible to BLV people. Museums often provide accessible services, including audio guides, tactile books, and accessible talks [5]. Some regular group tours offer special guides and explanation services [6]. However, there is still a gap between the current accessible design in museums and the needs of BLV people. The audio introduction provided to BLV visitors is relatively plain and simple, which cannot meet their profound cultural learning needs [2]. Although museums offer information that can be heard and

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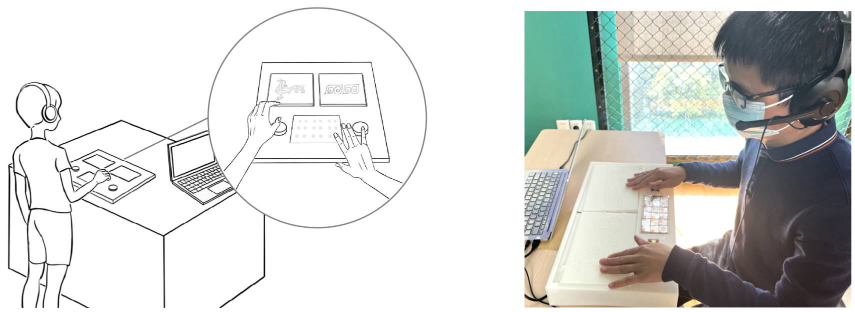
touched, they are still unable to visit independently. Research showed that only 5% of BLV people in Europe visited museums [4]. BLV people are a group from different backgrounds, what they need is diverse and interactive content rather than a unified introduction [8].



(a) (b)

Fig. 1. (a): *Wesee* is an interactive platform designed and implemented for the BLV people to help them experience cultural heritage more independently and interactively; (b): A blind participant was interacting with *Wesee*.

Digital technology should be more widely used to improve the accessibility of museums and enable BLV people to visit more independently. Hafizur Rahaman et al. proposed an interpretive framework (PrEDiC) [10] to help users attain the desired perceptual sense of heritage culture. This framework has been applied to many digital heritage projects and proved effective in interpreting digital cultural heritage. Based on this framework, we designed and implemented *Wesee* (Fig. 1), an interactive platform that can be used in museums to help BLV people experience cultural heritage more independently and interactively. Through *Wesee*, BLV people can experience interactive narration and perform auditory-tactile interaction. In addition, a comparative experiment was conducted with 20 BLV participants to verify the effectiveness of *Wesee*. The results show that this platform is effective in helping BLV people experience cultural heritage.

2 Related Work

Over the years, the accessibility of museums has garnered increasing attention. Existing works have offered approaches to help BLV people visit museums and learn about cultural relics. Kyle Rector et al. realized a live installation [11] that can provide different audio descriptions according to the spatial distance between BLV visitors and artworks to help them feel more immersed during their appreciation. Using a 3D printing board combined with a fingertip sensor, Tooteko [3] provided a cultural heritage accessible design that provided audio descriptions based on where BLV visitors are touching. The Victoria & Albert Museum proposed several measures for BLV visitors to improve the museum's accessibility, including audio description, tactile books, accessible talks, and events [5]. Art Beyond Vision is Fine Arts Houston's monthly gallery tour for BLV visitors [6] to explore exhibits through verbal descriptions and combining observations. Furthermore, several works provided facilities for the wayfinding of BLV visitors. To help BLV visitors better access multidimensional information, Xiyue Wang et al. designed 3D maps for each floor of a museum [13], and BLV visitors can stack them or place them on a touch screen to learn about different levels of detail. Saki Asakawa et al. developed a solution that can continuously track the location of BLV people and link the navigation and the audio introduction of the different exhibits [1].

Previous works have improved the experience of BLV people in visiting museums in different ways. However, the BLVs prefer to explore the museum's cultural heritage independently and own a complete experience [2]. One study by Vaz et al. examined the trend in visiting museums from the perspective of BLV visitors [12]. They found that museums worldwide continue to provide innovative experiences for the sighted. However, to varying degrees, millions of BLV people still face difficulties in accessing the information they want and enjoying the exhibits independently. A study investigating BLV people in museums and galleries [2] reported that the accessible education of museums could not meet the needs of BLV people because the audio tours were often general and simple, and what they want was a more comprehensive and in-depth introduction. Moreover, museums' one-to-one tour guide service often lacks clear publicity and contact information. For various reasons, BLV people need to spend a lot of time and energy to get the resources and information they want in museums and exhibitions.

In recent years, human-computer interactions have been constantly applied in museums to improve cultural heritage interpretation as an effective learning and communication tool that increases sighted visitors' awareness and empathy to heritage [9]. Developments in digital technology and human-computer interaction have also opened up many new possibilities for museum experiences for BLV people. However, the process of digital heritage interpretation for BLV people has not been discussed. Based on a digital heritage interpretation framework (PrEDiC) [10] that has been proposed, we implemented an interactive platform called *Wesee*. This platform can be used in museums to help BLV people experience cultural heritage more independently and interactively.

3 *Wesee*

We designed and implemented a platform named *Wesee* (Fig. 2). The platform consists of a tactile integration board, a headset, and a control system that control the overall process. *Wesee* is designed according to the interpretive framework (PrEDiC) proposed by Hafizur Rahaman in 2018 [10], which puts forward a set of methods to help the users to attain the desired perceptual sense of heritage culture and artifacts. Presentation, culture learning, embodiment, and dialog interaction are considered four aspects of digital heritage interpretation.

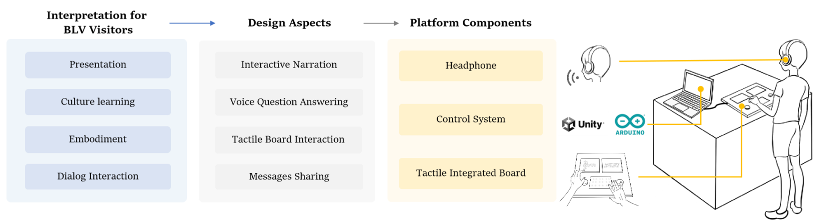


Fig. 2. Based on the interpretive framework (PrEDiC), we designed and implemented a platform named *Wesee*.

Wesee combines interactive narrative, voice interaction, and tactile interaction to show BLV users the historical stories and cultural connotations of *Chinese rites of the Zhou Dynasty*. The interactive narration of this platform is based on non-linear storytelling rather than simple audio descriptions. Users can conduct voice questions answering in the interactive narration. And the tactile integration board displays 3D patterns and braille for users. Tactile interaction on the tactile integrated board is combined with voice interaction to achieve multi-modal interaction in the experience. Users can share messages with other participants through voice or braille dialog.

3.1 Presentation-Interactive Narration

The effective presentation helps users access new information in a simpler and freer way. We designed an interactive narration to present the content of *Chinese rites of the Zhou Dynasty*, which combines background music, sound effects, and picture descriptions. Users experience it from a first-person perspective under guidance. During the experience, BLV users can choose the introduction content through the physical buttons on the tactile integration board. They can also select ritual objects (bronze or jade) and patterns (phoenix pattern or moire pattern) to learn about further. This way can provide immersion in the context and help BLV users raise their interest and engagement in the experience.

3.2 Culture Learning-Voice Question Answering

Cultural learning enables users to construct cognition of cultural heritage and gain an in-depth understanding of symbolic meanings of heritages. So we design voice questions answering in the interactive narration. The questions are based on verified cultural knowledge and historical allusions. After the user says the answer, the system recognizes the keywords and gives a corresponding reply. In this process, the BLV user's concentration will be improved, and the understanding and memory of the content will be deepened.

3.3 Embodiment-Tactile Board Interaction

Embodiment provides effective feedback and helps users engage actively. Tactile interaction will promote embodied interaction of BLV users and encourage their active participation. We implemented a tactile integrated board(Fig. 3a) as the tactile interaction carrier of *Wesee*, including three interaction areas: pattern display area, braille display area, and physical buttons. The pattern display area emerges different three-dimensional patterns according to the narration. The braille display area displays the braille content. The entity button allows users to select interested content in interactive narration. The tactile integrated board can display patterns and braille, enhancing BLV visitors' concrete and abstract cognition.

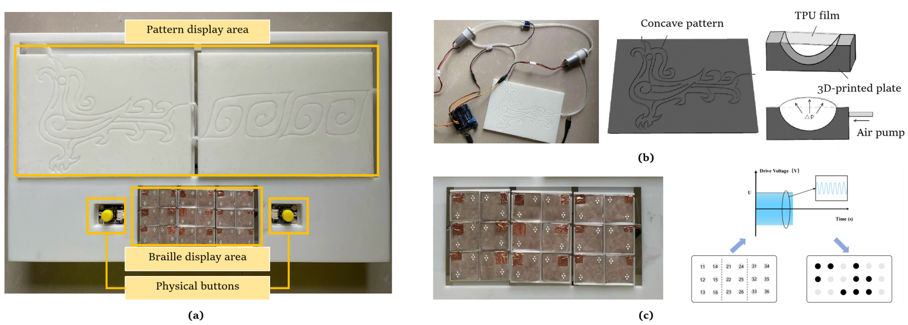


Fig. 3. (a): There are three interaction areas on the tactile integrated board; (b): The pattern display area uses the pneumatic actuator to emerge different three-dimensional patterns; (c): Constant sinusoidal alternating current (AC) voltages applied to different electrets cause them to vibrate, thus forming braille.

Fig. 3b shows the pattern display area, which uses the pneumatic actuator to emerge different three-dimensional patterns according to the user's choice. Similar to Ye Xing's work [14], the pattern display board is made of polylactic acid (PLA) and a flexible membrane of thermoplastic polyurethane (TPU) material. The 3D-printed plate is engraved with a concave pattern of external outline and internal texture. TPU film is used for sealing bonding with an inflatable interface and connected to the air pump. By controlling the air pump to drive different parts, the film changes under the action of air pressure, forming touchable patterns. Two pattern display boards are distributed respectively on the tactile integrated board's card slot, which makes it possible to present more patterns. Fig. 3c shows the braille display area based on previously proposed flexible electret actuator arrays by Jiang Tao [7]. A braille unit is composed of six electrets arranged as a 3*2 matrix. The current braille, most widely used in China, consists of three braille units. Therefore, the braille display area adopts a 3*2*3 matrix design. Constant sinusoidal AC voltages applied to different electrets cause them to vibrate, thus forming palpable braille. Two push-type physical buttons are distributed on the left and right sides of the integrated board, through which users can issue interactive commands.

3.4 Dialog Interaction-Messages Sharing

Dialogue allows users to explore and contribute at the narrative level to enhance the interaction. Communication and dialogue of BLV users are mostly carried out through voice and braille. Therefore, through the process of message sharing, users can be encouraged to leave voice messages and share them with other participants. The voice messages left by users are recorded and translated into braille. Other users can listen to the voice messages or read the messages by touching the braille display area on the tactile integrated board.

4 Preliminary Evaluation

To verify the effectiveness of the *Wesee* platform in cultural heritage interpretation for BLV people, we tested its performance through controlled experiments.

4.1 Participants and Procedure

20 BLV participants were recruited to participate in our preliminary experiment. The experiment was agreed upon by the participants, and we obtained the informed consent of the experiment from participants to participate in this study. Participants are between 24 and 52 years old, including 7 females and 13 males.

The entire process of the experiment is presented in Fig. 4a. After filling out the background prior questionnaire, the experimental group (EG, n=10) experienced our platform *Wesee*, and the control group (CG, n=10) simulated the tour of the traditional museum and listened to the audio introduction by wearing headphones (Fig. 4b). The information provided by the two groups of participants was consistent. After the experience, both groups filled out a questionnaire designed based on a 5-point Likert scale to evaluate the interpretation effect. According to the framework, our evaluation points include presentation, embodiment, cultural learning, and dialog interaction. All the evaluation spots were designed in the questionnaire, with seven questions ranging from 1 (not at all) to 5(extremely). The questionnaire content is provided in the supplementary material. Finally, we conducted semi-structured interviews with the participants at the end of the study. The whole process was video and audio recorded for further analysis.

4.2 Results

We collect and analyze all the questionnaire data. Firstly, We analyze the reliability and validity of the questionnaire. The Cronbach's α of interpretation effect ($Cronbach\alpha = 0.893, KMO = 0.716$) is greater than 0.8, and KMO is greater than 0.7, showing the questionnaire has good reliability and validity.

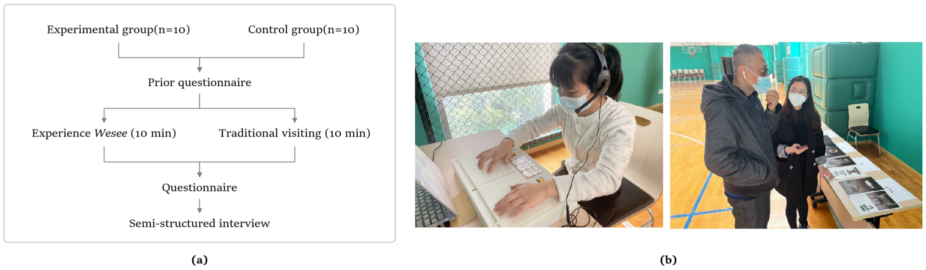


Fig. 4. (a): Overall process of the experiment; (b): The experimental group experienced our platform *Wesee* and the control group simulated the tour of the traditional museum and listened to the audio descriptions.

Secondly, we study the difference between the *EG* and *CG* groups through variance analysis. The two groups show significant differences in presentation ($F = 20.307, p = 0.000$), embodiment ($F = 5.696, p = 0.028$), cultural learning ($F = 16.2, p = 0.001$), and dialog interaction ($F = 5.236, p = 0.034$). All the detailed analysis results are provided in the supplementary material. In addition, we show the average level and fluctuation degree of samples in different groups through the box chart. As shown in Fig. 5.

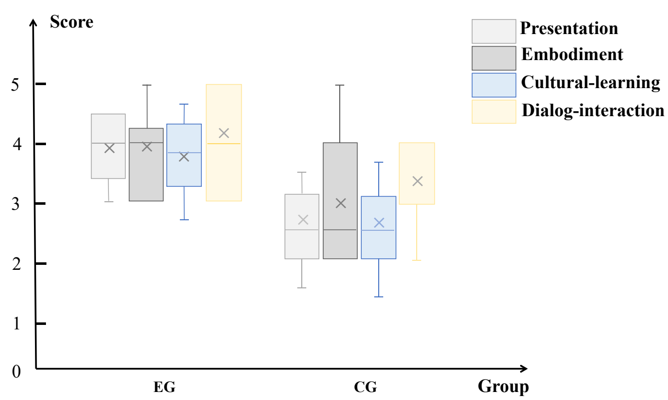


Fig. 5. Questionnaire data boxplot of interpretation effect

4.3 Discussion

According to the results, the questionnaire used in the experiment has good reliability and validity, and the difference between the *EG* and *CG* groups is significant. The box chart shows that the score of *EG* is higher than that of

CG in both dimensions. And the data of *EG* shows less fluctuation than *CG*, showing a higher consistency.

Results show that *Wesee* is significantly better than traditional visiting in the effect of interpretation. This phenomenon is also confirmed in the interview. P4 mentioned that *"It (Wesee) tells cultural stories in the form of stories. At the same time, some patterns can be touched, which is a feast for the senses of hearing and touch... It left a deep impression on me"*. For the traditional visiting, P16 said, *"Offline museum explanation is a simple introduction of some basic information. We can't see the appearance of the cultural relics, nor can we touch them. It is difficult to form their appearance just by listening to them."*

5 Conclusion and Future Work

In this paper, we implemented an interactive platform called *Wesee* based on the interpretive framework of PrEDiC. In addition, we designed and developed a tactile integrated board as the carrier of tactile interaction. A preliminary experiment was conducted with 20 BLV participants, and the results show the platform's effectiveness.

In the future, we will further enrich the interactive ways of *Wesee* in the dialogue and message sharing, and explore the possibility of allowing multiple BLV users to participate together. The display of different types of cultural heritage will be further explored to improve the flexibility of *Wesee* in the presentation content. We will optimize the structure and function of the tactile integrated board to achieve a more diverse content presentation in the pattern display area. The braille display area will be enlarged to enable the long presentation of braille content. Moreover, it is a potential tool for BLV children to learn braille, and we will carry out relevant applications and research. In addition, we will collaborate with local museum institutions to conduct more extensive applications in museums.

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