Exploring the potential of enriching museum visit experience of blind visitors using advanced technologies

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Abstract

With the advancements in technology, it has become possible to enhance the way people interact with museums and to create more inclusive, accessible, and equitable environments. However, the potential of these technologies has not been fully explored in the context of museums in general, and particularly for visitors with disabilities such as blind people.
During a semester long course on "Advanced Technologies in Development and Rehabilitation", four multidisciplinary teams of students from the University of Haifa collaborated to develop prototypes of four series of interactive tangible objects aimed to enhance the museum visit experience for blind visitors, each with different interaction techniques, with the goal of making museum exhibits more accessible and engaging for individuals with visual impairments.
A follow up research will evaluate the functionality and ease of use of the prototypes. The evaluation of the suggested concepts will follow User-Centered Design (UCD) research methods, including usability tests and satisfaction questionnaires. Based on the results of the tests, design guidelines will be development to inform the future development of tangible systems for museum that enhance the visit experience for blind visitors.

Keywords

interaction design, museum accessibility, accessibility for blind, 3D printing, 3D scanning [1]

1. Introduction

Traditional museum exhibitions, often consisting of objects behind glass or hanging pictures, can be unengaging and inaccessible for individuals who are blind or partially sighted. Encouraging inclusivity within museums and galleries can lead to a more diverse audience, allowing a broader range of visitors to fully engage with and gain value from the cultural offerings [1]. To ensure it, museums should adopt universal guidelines such as the "Smithsonian Guidelines for Accessible Exhibition Design" [2]. Accessible exhibitions can involve removing physical barriers, offering guided tours or workshops, and providing scheduled accessible visits with audio guides [3,4,5]. Some museums focus on tactile art or provide tactile representations of specific pieces. With 3D printing advancements, museums can create tactile replicas of artwork [6,7,8]. In recent years, museums have started adopting innovative technologies to enhance accessibility for visually impaired individuals. These technologies include touch sensors for improved tactile reproductions, virtual haptic exploration, and audio guides utilizing smartphones, NFC, and hand gestures [9,10,11]. However, Vaz et al. [12] found that despite these efforts, blind and visually impaired individuals still face barriers and a lack of assistive technologies, leading to limited participation in museums. To address this gap, students from the University of Haifa's departments of informatics systems and occupational therapy worked on making the Hecht Archeology Museum more accessible for blind visitors. They developed four different interaction concepts and demonstrated them with blind volunteers. The next step is to convert these prototypes into functional systems and evaluate them in a realistic setting. The study will include

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usability tests, satisfaction assessments, and overall visitor feedback regarding the sense of control, level of interest, and joy. The results will provide valuable insights and guidelines for future development of such objects in a relevant context.

2. Background and related work

The design and development of tangible, interactive artifacts that enable rich and meaningful experience for blind visitors is a challenging task. Such process requires multidisciplinary approach that includes exhibition designers, curators, registrars, conservators, collections managers, designers, editors, developers, educators, and other exhibition team members. Each of these individuals offers insights into the exhibition medium. The process should be accompanied, and the results evaluated by blind users themselves ("Nothing about us without us") to ensure that the target audience will receive a solution that optimally matches their expectations for a meaningful museum visit experience [13]. This collaborative approach is essential for developing solutions that truly meet the needs of the target audience.

2.1. Guidelines for museum accessibility for blind visitors

The "Smithsonian Guidelines for Accessible Exhibition Design" offers museums a set of guidelines as well as design tools to meet the world accessibility standard [2]. Guidelines specific to accessibility for the blind are indicated below:

- "Exhibitions must make exhibit content accessible at multiple intellectual levels and present it through more than one sensory channel".
- "People with visual impairments need printed information in audio and tactile formats".
- "Select tactile objects so that they provide a coherent explanation of the
- exhibition topic. Touchable objects must be related to each other -by context and in space to provide true access to exhibition content for people who have visual impairments".
- "Include touchable objects, such as models and reproductions, within the
- actual exhibition space. This allows people with visual impairments equal ac-cess to the objects without having to separate from their friends or family who are not blind or have low vision".
- "Provide alternative forms of labels (e.g. Braille, audio, large print) within the exhibition space".

2.2. Principles in design tactile technologies for blind individuals

A wide literature review conducted by Horton et al., identified five optimal device characteristics that researchers should consider when developing assistive devices for blind to address accessibility issues [14], as summarized in Table 1.

2.3. New technologies and the 3D revolution

New technologies such as 3D printing and 3D scanning, and programmable microcontrollers can help make museums more accessible to blind visitors by creating tactile replicas of museum objects. 3D printing can produce replicas (a tactile version) of exhibits allowing blind visitors to experience and explore these objects through touch [8,15].

The technologies of scanning and printing enables the creation of physical models with intricate details and textures, making the experience more immersive and initiative for these individuals. Additionally, audio descriptions or soundtrack can be added to those replicas to enhance the experience for blind users. It can be done by integrating microcontrollers and sensors. Cho emphasizes the importance of combination of several interfaces to allows more efficient user–machine communication, which cannot be accomplished by means of a single interaction mode alone [16]. It improves accessibility by providing blind individuals with more control over their environment, making it easier for them to interact with tangible technology and access information and resources.

Table 1
Device characteristics that should take in consideration when developing assistive devices for blind to address accessibility issues (Horton et al., 2017).

Characteristics	Description
Multimodal	Providing both tactile and auditory feedback to the user is often most effective, especially for conveying complex information
Adaptable	Utilizing simple and flexible platforms for a variety of different applications
Portable and affordable	Using hardware platforms such as adapted touch screens or computers, when possible, as opposed to more expensive pin matrices and force feedback technologies
Refreshable	Displaying new information rapidly and responsively
Multitouch	Providing as many points of contact as possible and allowing the user to explore freely, ideally using both hands.

2.4. Related work

Vaz et al. provides a comprehensive report that examines the integration of new technologies in museums, specifically focusing on the experiences and expectations of blind and visually impaired visitors [12]. The authors categorize their findings into five subsections: (1) Haptic Devices for the Exploration of Virtual Copies, (2) Touch Replicas Digitally Augmented, (3) Gesture-Based Interactive Tactile Reliefs, (4) Assistive Navigation for Self-Guided Tours, and (5) Hybrid Solutions. One notable advancement in this field is the Museum in a Box, which is a small Raspberry Pi-powered box with internet connectivity and integrated speakers. When a museum object is placed on the box, it triggers an audio response. The Museum in a Box includes a collection of postcards and 3D printed objects with NFC stickers attached [6]. Another example of innovative technology for blind accessibility is TooTeko [17]. It incorporates a special ring that allows users to "see" through NFC sensors embedded in tactile works. By touching different parts of the surface, corresponding audio descriptions are played through a smartphone app. The system consists of a high-tech ring, a tactile surface with NFC sensors, and a tablet or smartphone app. TooTeko facilitates simultaneous exploration of an object with both hands while receiving related audio content. The ORASIS project [9] takes a more inclusive approach by making both physical exhibits and the museum space accessible to blind visitors. They enable blind individuals to interact with exhibit replicas using gestures in an exhibition room. The prototype system involves a smartphone or tablet application, a microcontroller, passive infrared sensors for navigation assistance, a 3D replica created through scanning, and capacitive touch sensors on the replica. Continuous tracking of the user's location and orientation allows for two interaction modes: Navigation and Art Explanation. Other projects focus on addressing navigation challenges and promoting independent museum visits. These initiatives employ accurate localization and context-awareness to provide turn-by-turn guidance and detailed audio content when visitors are near specific artworks, combining indoor navigation assistance with accessible audio content for visual art [18].

With the advancements in Information and Communications Technology, museums can better fulfill accessibility guidelines by incorporating instrumented 3D printed replicas enhanced with audio commentary. This study aims to focus on improving the experience of blind visitors by utilizing these technologies to offer a more immersive and enriching museum experience.

3. Research goals & question

The proposed research is a design study that aims to evaluate different interac-tion approaches, using improved versions of four prototypes, offering four dif-ferent interaction techniques with the end users. The study findings could inform the development of more accessible and inclusive museum experiences for blind visitors.

The abstract research questions this proposal is aimed at addressing is: "How can advanced technologies enrich the museum visit experience for blind visitors?"

To answer the above research questions, the following specific research ques-tions will be addressed:

RQ1: Artifacts – How can we arrange number of artifacts in a way that will create a thematic experience for blind visitors?

RQ2: System Activation: Tangible vs. Wireless – What activation technique work better to allow sense of control for the blind users?

RQ3: Audio Control – what are the essential audio control features to additional-ly allow sense of control for blind users?

RQ4: What are the guidelines that should be followed for designing a meaningful experience for blind visitors?

4. Method

4.1. Participants

This project will engage 24 blind users to evaluate the usability of the four prototypes. To control the potential confounding or effects of the order in which the prototypes are presented, a within-subjects counterbalanced comparison will be used [19]. They will be recruited with the help of organizations in Israel are dedicated to assisting the visually impaired.

4.2. Tools

Demographic questionnaire

A demographic questionnaire will be used. It will include questions related to age, gender, native language, blindness from birth compared or blindness at late age, education, ethnicity, occupation, habits of visiting exhibitions. By collecting this information, we might better understand the target audience and ensure that the design meet their needs and preferences. Additionally, the demographic data can help to identify patterns within the participant population, which can be useful in drawing meaningful conclusions from the study results.

Usability tests

Usability is important stage in development as it can be a deciding factor in whether a user enjoys or is frustrated by performing a task with a device [20].

Nielsen offered various commonly approaches to evaluate usability. These methods include usability testing, observation, thinking aloud, questionnaires, interviews, and focus groups [21]. Questionnaires are an effective means of finding subjective preferences and are easy to repeat and compare, Interviews are effective in obtaining in-depth information about user experience. A full usability test involves determining what will be measured, recruiting appropriate users, having the users perform representative tasks, and collecting data to be analyzed. The test itself may involve evaluating one or multiple concepts for comparison [22] (Ulrich & Eppinger, 2003).

The System Usability Scale (SUS) is a dependable and efficient tool for assessing usability [23]. It employs a 10-item questionnaire with five response choices ranging from "Strongly agree" to "Strongly disagree." Developed by John Brooke in 1986, this scale enables the evaluation of diverse products and services, such as hardware, software, mobile devices, websites, and applications. Using both questionnaires give a holistic view of user satisfaction and can indicate the success of implementing these technologies in future museum settings.

User Evaluation of Satisfaction with Assistive Technology questionnaire (QUEST)

QUEST is used to evaluate a person's or caregiver's satisfaction with an assistive technology device and related services [24] and to gain an overall opinion, and ranking the prototypes from best to worst. User satisfaction is scored on 12 short questions divided into two factors: Satisfaction with Device (eight items, e.g., device durability) and Satisfaction with Service (four items. e.g., efficiency of service). Each item is rated on a five-point scale from very satisfied (5) to not satisfied at all (1). The final part of the questionnaire consists of a list of the 12 satisfaction items of which a client is asked to select the three most important items in order of priority.

4.3. Procedures

The evaluation of the suggested concepts will follow UCD research methods [14] within a within-subjects design. The participants will receive a general explanation on the study, and then for each prototype a specific explanation of how to operate the system (for example: using NFC scanning or pushbuttons). A camera will be positioned in the usability test area to record the entire test sessions. The participants will be asked to use the prototype verbalize what they were doing, thinking, and feeling as they are performing the tasks (thinking aloud) [21] Their behaviors will be observed and recorded to identify design flaws that cause user errors or difficulties. During these observations, the time required to complete a task, task completion rates, and number and types of errors, will be recorded and later be coded. The within-subjects design will allow for each participant to serve as their own control and be exposed to all levels of the independent variable, which will minimize random noise and make it less likely that a real difference that exists between conditions will stay undetected or be covered by random noise.

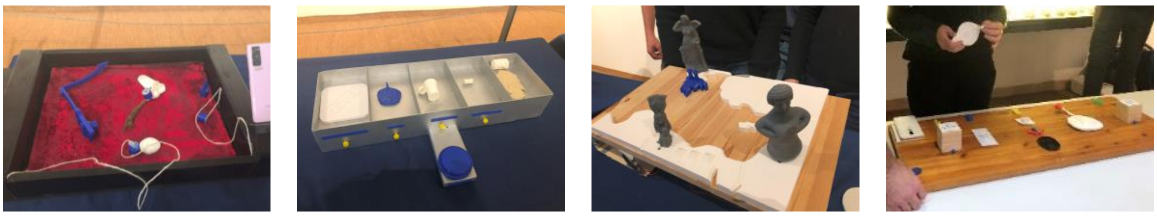

Figure 1-4: The four conceptcs developmet and enitialy testes with two blind users. Left to right: Ancient armory, Writing, Mythology and religion, and the story of late Bronze Age anthropomorphic sarcophagi.

Table 2
Four different approaches to interact with 3D printed replicas will be tested.

Project	Main surface	Objects arrangement	Operation system
Ancient armory	Central box for placing all the exhibits	No order	Each object should be scanned using RFID reader and tags
Writing	Four boxed	Separately	A button located in front of the box should be pressed to hear explanation
Mythology and religion	3D map with four sockets	Different location on the map	Taking exhibit out of its socket will activate a micro switch that automatically plays an audio file
Anthropomorphic sarcophagi	A surface with jigsaw puzzle-like shape based on the objects positioned within it	Linear order	Each object should be scanned using RFID reader and tags

4.4. Results analysis

To assess the usability of the design, statistical analysis will be conducted on the quantitative data that will be collected from user testing and answers of questionnaires. Descriptive statistics will be used to summarize the data and identify any patterns or trends. Inferential statistics, such as t-tests, will be used to compare the performance between blindness from birth compared to blindness at late age. The results of the statistical analysis will then be interpreted in conjunction with qualitative feedback to gain a comprehensive understanding of the design's strengths and weaknesses.

5. Expected contributions

When reviewing the literature in the context of making museum more accessible for blind visitors, we typically see two types of studies: (A) An evaluation of a single project with blinds in museums [6, 9, 11, 15, 17, 18, 25]. (B) Comprehensive reports on museums accessibility using data analysis of Semi-structured interviews to create participants profiles, examine museum visit habits, and suggest solutions to enhance their future museum experience [3, 12, 26, 27]. And yet, recent review point there is a need for more research to foster blind and visually impaired people's engagement with cultural heritage [28]. The framework of this study offers a unique opportunity to evaluate and compare the performance and satisfaction from the interaction with four different working prototypes which are similar enough in terms of the amount and type of information they make accessible but differ in the way they allow them to be manipulated and interact. Such an opportunity is not common, and the ability to compare different elements of the same interactions with the same participants can lead to better understanding of visitors' needs and expectations and to the development of more precise guidelines that optimize knowledge accessibility for blind visitors in the museum. The research could also contribute to the broader field of accessible design and human-computer interaction devices and interfaces, by providing valuable insights into the design and development of tangible systems for blind visitors.

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