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Designing an Interactive Exhibitor for Assisting Blind and Visually Impaired Visitors in Tactile Exploration of Original Museum Pieces

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Abstract

Blind and visually impaired visitors experience a lot of constraints when visiting museums exhibitions, giving the ocular centricity of these institutions, the lack of cognitive, physical and sensorial access to exhibits or replicas, increased by the inaccessibility to use the digital media technologies designed to provide different experiences, among other constraints.
This paper aims to present the design and implementation of an exhibitor to communicate original museum samples to blind and visually impaired patrons, without the need to be replicated, that interactively "tell stories about their lives" whenever picked up.
Tests performed with 13 partially sighted and blind participants at the main exhibition museum space, demonstrated very positive evaluations regarding pragmatic and hedonic qualities of the interaction, a positive capacity to mentally conceptualize the exhibits according to the audio descriptions, and how to enhance the experience of using more exhibitors like this one during a future visit to the museum.

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1. Introduction

The World Health Organization estimates that 253 million people live with visual impairment [1], of whom about 36 million are blind and around 217 million have moderate to severe vision impairment [2].

In Brazil, where this project was developed, the last Census, in 2010, allowed to estimate that about 6 million (3.2% of the population) have severe vision impairment and 506.377 citizens are totally blind [3].

Given the professional definition of Museum, widely recognized and disseminated by International Council of Museums (ICOM), since 2007, it is clear that museums must provide to all members of society the access to education, offering moments of study and leisure, in order to cooperate for its development, committing itself to safeguard and communicate their collections to the public [4].

In spite of being such privileged environments, visitors with visual disabilities still experience a lot of constraints when visiting these spaces, given that museum exhibitions still being designed to be visually enjoyed [5]–[7]. And this “ocular centricity of museums and galleries ensures that non-visual engagement with art and artefacts remains virtually inconceivable in all but the most innovative of institutions” [8, p. 2].

Additionally, the actual worldwide panorama of interactive technologies present in museums and galleries exhibitions – with the aim to attract visitors’ attention, make them want to go to its places and enhance their experiences while inside or outside them [9] – revealed that the most part of these solutions don’t facilitate neither the cognitive, physical, nor sensorial access for disabled publics [10].

A recent study reported that only 5.5% of blind and visually impaired people visit museums in Europe [11], what corroborates with the conclusion of [12], when stating that research in this field is still scarce, even though [7] argues that the desire to create accessible experiences for this patrons is challenging, especially when dealing with art.

In this sense, some researchers are trying to understand how to enhance the visit to museums for visually impaired patrons: several problems regarding the physical accessibility and a lack of training of the staff to deal with them were identified [6], [13]–[15]. On the other hand, in general, there are not facilities for the orientation and the mobility inside those places [12]–[14], [16]. Regarding the access to museum collections, namely physical and intellectual access to exhibits – which constitutes the main focus of this research – there is a literature consensus about the importance that the sense of touch assumes for somebody with visual disability, as the essence of their access, understanding and construction of mental images of museum artefacts, besides the epic dimension that this can assume in a museum environment [5]–[7], [17], [18].

Although, visitors reveal that they are not always allowed to touch real objects nor sculptures, neither the opportunity for touching replicas is always offered, and when it is possible, the tactile opportunities tend to represent only a very small fraction of the main collection, when compared with all the information available to sighted visitors [13], [19], [20].

Given these points, the present article aims to make a contribution to this field, by presenting the design development process, implementation and users’ pragmatic and hedonic evaluation of an exhibitor that was conceived to provide access to original pieces of the collection of the MM Gerdau - Mines and Metal Museum, and interactively communicate them.

Next section presents the accessible exhibitions technologically mediated for blind and visually impaired visitors in museums. Section 3 presents the interface development process and implementation. The *Pedras Sabidas* exhibitor evaluation and data analysis will be presented in section 4. Finally, section 5 presents the conclusions and future work.

2. Accessible exhibitions technologically mediated for blind and visually impaired visitors in museums

With the use of digital media, some museums are allowing visually impaired patrons having more inclusive available ways to understand and interact in exhibit context, contributing to better experiences during their visit to museums. In fact, “developments in technology have the potential to increase access and enable opportunities for disabled persons” [21, p. 26], besides the fact that offering the possibility to interact with touchable representations of exhibits can bring, as well, non-disabled visitors closer to museum collections, incrementing their sensorial experiences [22].

One of those technologies that museums are already using, are 3D printing and scanning, like at The Art Institute of Chicago, where blind and partially sighted visitors can touch three-dimensional replicas of selected objects from the collection, alongside with discussions about the original works of art being promoted by museum staff [23].

Another exhibition, the *Hoy Toca el Prado*, at the Prado Museum, carried out tactile reliefs of six famous works of art, which could be touched, in order to allow patrons with vision impairment to mentally recreate the paintings by feeling and understanding their depth, perspective and space [24].

Nevertheless, [25] agree that tactile perception should be supported by hearing information, since its multimodal combination help the formulation of mental images and leads to a more autonomous exploration of the physical world. However, the authors inform that technological examples of simultaneous union of both senses are quite rare in communication devices for the visually impaired, and in museums, this lack is substantial.

As an example, the digital model produced by scanning a 2500-year-old mummy of the Manchester Museum collection, was worked upon to recreate half of the sculpture as it would originally have appeared, and the other half as it is nowadays. Inside the replica, there were embedded touch sensitive sensors, that detect the tactile exploration made by visitors and trigger contextual audio-explanations that can be listened through headphones [26].

Another research project, *Tooteko*, developed for an exhibition at the Correr Museum, aimed to help visually disabled to independently sense church facades. By using augmented reality, during the tactile exploration of the piece visitors are wearing a ring sensor that detects and reads the NFC tags that were allocated inside the model, sending a Bluetooth signal to a smart device, responsible to identify the area and activate the audio related to it [25].

In its turn, other group of researchers [27] were developed a gesture-based interactive audio guide for the relief interpretation of the painting *The Kiss*, that accordingly to a specific region that is being touched, presents audio files to describe the painting. A similar project that comprises both hand-tracking system and an audio device was developed to give access to a bas-relief of the painting *Madonna with Child and Angels* [28].

A research project aimed at exploring how to integrate intellectual access to pieces of the collection with a way to assist visually impaired people during their navigation inside the Museum of Cycladic Art [29]. Visitors may use a smartphone to choose an exhibit that wish to know, and the app provides navigation instructions by taking advantage of passive infrared (PIR) motion sensors embedded in the room. When arriving to the object it is possible to touch it. The interaction is detected by five capacitive sensors, connected to a microcontroller that sends data to the smartphone, playing the audio files.

It is noted that the most part of discussed researches in this field aimed at replicate collection objects in order to be handled during the interaction, while this paper explores a solution designed to communicate original artefacts to blind and visually impaired visitors, avoiding the cost with constructing artefacts copies.

3. Interface development process and implementation

The following subsections will present the project history and methodology, the interaction design model, system architecture and software architecture developed, as well as the process of implementing the exhibitor.

3.1. Project history and methodology

The beginning of this project dates back to 2014 and a paper about the previous work was published [30], where the process of conceptualization and development of a high-fidelity prototype of a tangible user interface was presented, as well as data analysis regarding visitors' evaluation concerning hedonic and pragmatic aspects of the interaction with the interface, together with how to enhance the physical and intellectual access to the collection.

Given the positive results gathered from a sample of 138 participants in the study (9 of whom were blind), and the enhanced experience of visit accomplished while using the prototype, an international research project was established between the Museum and the authors of the present paper, with the aim to re-design and develop a final version of the *Pedras Sabidas* exhibitor, to permanently integrate the main Museum exhibition, taking into account the data collected from the former evaluation.

With this, the subsequent steps are, in essence, iterations of the methodology of participatory design [31], followed since the beginning of the research: users are actively involved during the various stages of the investigation, during which they cooperate with the researchers, to iteratively construct and refine a solution [32].

3.2. Interaction design model, system architecture and software architecture

Given the positive pragmatic and hedonic results pointed out by visitors, specially by blind ones, during the evaluation phase of their interaction with the prototype, it was agreed to maintain the same interaction model, but expand it to five samples of the collection: when an exhibit if lifted, the interface provides sound and graphical information about it along with the handling, that smoothly stops when the sample is putted down. In addition, if users wish to explore in detail differences about two of the samples, they must handle, at the same time, two of the five exhibits, so a comparison by themes in common and individual characteristics are presented, while they can tactile explore both.

With the aim to give response to unexpected events, that [32] identify as essential to guarantee that users don't get lost anytime and as contributors to a better interaction experience, the system alerts visitors by audio feedback each time more than two samples are handled, as well as informs them how to use the exhibitor and about the existence of the comparison mode.

Regarding the system architecture, it was necessary to re-design the whole scheme, as show in Fig. 1, as well as the physical structure of the exhibitor, in order to provide a more pleasant interaction with it and a cleaner interface from the aesthetic point of view.

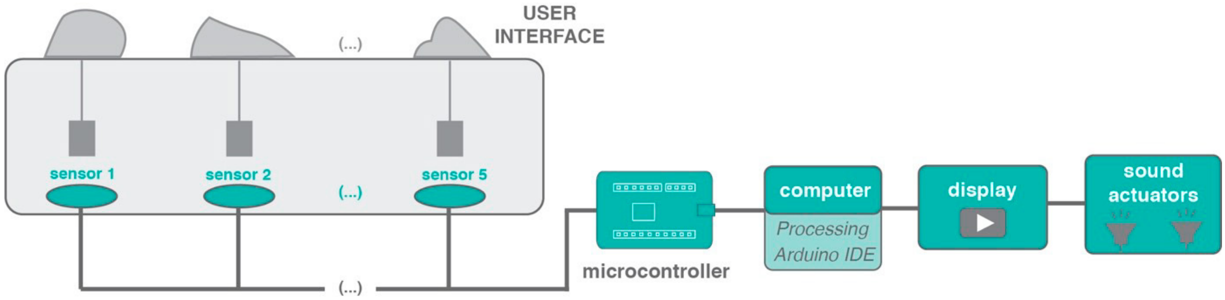

Fig. 1. Simplified scheme of the implemented physical system architecture.

At the "user interface" area, it was intended to focus the visitors' attention only on the five exhibits that were attached to a steel cable – visible in Fig. 2 (c) – with a counterweight at the other end, each one. This solution, on one hand, allowed embedding the sensors on an area inaccessible to users, so it helps in its conservation and avoids damage due to misuse. On the other hand, it functions as a "constraint", a design principle pointed out as essential [32], so it restricts per se the kind of user interaction that can take place while using the exhibitor. Additionally, it guarantees the safety of the original artefacts, avoiding dropping and consequent damage, as well as its theft.

The interaction is sensed by five force sensitive resistors, that are connected to analogic pins of a microcontroller board (Arduino Leonardo). This one connected via USB to a computer that receives the external data corresponding to user actions and analyses it. The multimedia contents are presented according the number of exhibits that are being handled as visual and sound information, respectively, by a display and speakers.

Given the target audience of this project, it was crucial taking into consideration the whole spectrum of visual impairments, what means that even though the decreased ability to see, some of the visitors still have some vision capacities. For this reason, close-up photos of the exhibits were taken by the geosciences team, in order to allow a detailed view of the most significative parts of the pieces, as well as their original colours, what could be difficult for some people to see while handling the exhibits. At the same time, it was important to guarantee that visually enabled visitors still have access to multimedia contents, so the previous evaluation considerations were followed to re-design the graphic content, giving priority to images with a short text description of each one. One of those images can be seen in Fig. 2 (d).

In what concerns to software architecture, it was followed a *Model-View-Controller* approach. According to Krasner and Pope, the *model* of an application is the central structure, responsible only for transmitting to the controller changes in its state [33]. In this case, the model is defined by the sensors, that are connected to Arduino Leonardo (*controller*), which contain the input devices and is an interface between its associated models and views. The microcontroller board runs a program that reads sensors values each 100ms, in order to guarantee and efficient response by the system, each time users performs any action. In its turn, the *view* request data from the model and display the data. The computer runs Processing 3.0 that performs graphical and auditory transformations, according to the number of exhibits visitors are handling. To guarantee a smoothly audio connection between what is playing and the next user action, as well as the sound information will not stop abruptly, it was implemented a code in Processing program that ensures that this happens.

3.3. Implementation of Pedras Sabidas exhibitor

The physical structure of *Pedras Sabidas* exhibitor was designed from scratch, in partnership with a product designer collaborator, during which phase were strictly followed the Smithsonian guidelines for accessible exhibitions [34]. This allowed us to ensure that furniture dimensions are accessible to all visitors, that objects are displayed within viewing distance of visitors who are short, seated or standing, as well as it was necessary to safeguard that a cane visitor will correctly detect the interface. However, the designed solution did not provide knee clearance for wheelchair users.

Regarding the surface were exhibits were placed, it was agreed by researchers and Museum work team to coat it with durable velvet, with the goal of providing users with a pleasant touch experience that contrast with the hardness of the samples. Another concern while designing the exhibitor was to ensure that it has a mobility feature, since it would facilitate its change to other locations in MM Gerdau, each time the event calendar requires so. On the exhibitor, technical project was created an area to embed a compact display and the respective sound system, instead of using a projector as what happened for the prototype, which additionally allowed better results in terms of content visualization and a better exhibit lighting.

About the audio contents, new texts were recorded (for each geological sample and comparisons between them), focusing on the description of the pieces in a language more touch-oriented and not so much for the vision, [7], [35]. “An ideal museum will be one where visitors can appreciate the charm of tactile culture with hands, fingertips and whole body, not simply learn through looking at exhibits” [35]. With this in mind, there were included detailed descriptions about the textures, shapes, roughness and tactile relevant parts of the exhibits, alongside with educational information like scientific aspects, forming process, industrial uses, curiosities and provenance.

Finally, the physical components of the system were assembled inside the exhibitor. A photograph of the final product is shown in Fig. 2 (a), where the five geological samples are disposed on the velvet surface, and the phrase “pick up a sample”, written in Portuguese on display, invites visually enabled visitors to start using the exhibitor.

4. *Pedras Sabidas* exhibitor evaluation and data analysis

The evaluation tests involved the usage of *Pedras Sabidas* exhibitor at MM Gerdau main exhibition space, by visually impaired visitors from State Public Library Luiz de Bessa and São Rafael Institute – a group photograph is presented at Fig. 2 (b) – during 28 and 31 of March, and 27 of April of 2018. By using a questionnaire as research instrument for data collection, the main goal was to understand pragmatic and hedonic qualities about the interaction (asked in 6 questions), if the audio descriptions contents were clear and relates with what can be sensed while handling the geological samples (5 questions), as well as comprehend how to provide an interesting experience of using more exhibitors like this one during a future visit to MM Gerdau (4 questions).

Before starting the individual test, the 13 participants were guided to the exhibitor and were only told that to use it, they would have to lift an exhibit. There was not imposed any limit of time for interacting with it. For data collection, the questionnaire was read in loud voice and the answers registered in accordance; it was used SPSS software for data analysis. Given the limited number of obtained answers, it was decided to make use of descriptive statistics and exploratory data analysis, which already allows to observe the pertinence with respect to the answered questions, to follow with future studies.

The data analysis will be presented below, in three sub-sections: sample characterization; interaction aspects with the interface and presented audio contents; and considerations about how to enhance the experience of using this kind of exhibitor.

a b c d

Fig. 2. (a) *Pedras Sabidas* exhibitor at MM Gerdau Museum exhibition space; (b) Group of visually impaired study participants; (c) and (d) Participants using *Pedras Sabidas* during evaluation tests.

4.1. Sample characterization

As presented in Table 1, 23.1% of the 13 study participants are in the 15-25, 26-35 and 36-45 age groups, and 30.8% have between 46 to 55 years old. According to the results, all of them had some degree of visual impairment: 5 were totally blind (38.5%), 5 have profound low vision (38.5%) and 3 have moderate low vision (23.1%).

Regarding their gender, 4 visitors were female, i.e., 30.8% of the total and 69.2%, male (9 users).

Table 1. User's age according to their degree of visual impairment.

Visitor's age by degree of visual impairment	≤ 15	15-25	26-35	36-45	46-55	56-65	≥ 66
Total blindness	-	1	1	1	2	-	-
Profound low vision	-	1	1	2	1	-	-
Moderate low vision	-	1	1	-	1	-	-

In order to better understand the evaluation group characteristics, it was asked if they are used to use technologies in their daily lives, to which all answered affirmatively. The most common are using voice commands to instruct speech synthesizer while using their smartphones, laptops and applications like Facebook and WhatsApp, screen readers – like NVDA (NonVisual Desktop Access) software, that 2 participants specified – and one visitor said he also wears a Braille watch.

When asked if they ever had the opportunity to handle exhibits on other museums, 53.8% answered "no" and 6 participants (46.2%) said that this was not their first time.

4.2. Pragmatic and hedonic aspects of the interaction and evaluation of audio information

In order to gather data concerning qualities of using the exhibitor and users' opinions about the audio contents, the questions followed a format of semantic differentials, whose poles are opposite adjectives, ordered into a Likert scale of intensity of 5 points.

Fig. 3 shows the global means (μ) of results obtained for each dimension. According to it, participants positioned the interaction as "simple" ($\mu = 4.77$; $\sigma = 0.599$), "pleasant" ($\mu = 5$; $\sigma = 0$) and "motivating" ($\mu = 4.85$; $\sigma = 0.555$). With regard to audio contents, visitors considered them as "relevant" ($\mu = 4.85$; $\sigma = 0.376$), "interesting" ($\mu = 4.85$; $\sigma = 0.376$) and set the duration as near to "ideal" ($\mu = 3.31$; $\sigma = 0.751$).

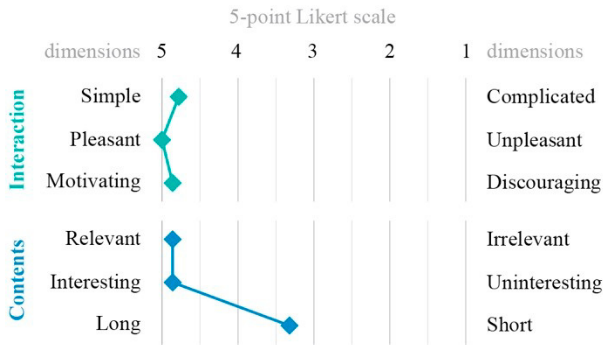

Fig. 3. Semantic differential chart regarding aspects of the interaction with the exhibitor and audio contents.

When asked about the audios presentation, 84.6% of the sample preferred to hear the educational contents out loud, as it was implemented, and 15.4% (2 visitors) said it should happen using headphones.

Another concern was trying to comprehend how blind and visually impaired participants feel more comfortable with knowing how to use the exhibitor by themselves and how the artefacts' name should be communicated to them. For the first question, only 3 participants (23.1%) pointed that the exhibitor must inform them about how to use it as it was implemented (by a voiceover that can be listened), while 76.9% consider it should be added a Braille information as well. About the second one, 3 visitors (27.3%) consider that the name should be revealed when a sample is handled – as implemented – and 72,7% answered that a Braille sign with the name should be placed next to each exhibit, in addition to audio information. Two of the 13 visitors did not answer to this question.

With the aim to understand if audio descriptions about the physical characteristics that could be sensed while handling the exhibits was clear, all participants answered "yes" to the question "was it easy to relate exhibits to audio descriptions?". Additionally, all of them considered that surface roughness, waviness and weight differences of the five geological samples were appealing from the tactile point of view.

4.3. Visitors considerations about how to improve the experience in the future

With the aim to study participants' considerations to improve the experience of using exhibitors like this one, it was asked if a tactile map that indicates were the samples are located would provide a better use experience, using a 5-point scale from "completely agree" to "completely disagree": 5 participants (38.5%) completely disagreed with it and other 5 completely agreed. The other 3 visitors answered, respectively "disagree" (2^{nd} point of the Likert scale), "agree" (4^{th} point) and "don't agree nor disagree" (3^{rd} point). Given that, it was not possible to conclude if a tactile map would enhance their experience ($\mu = 3$; $\sigma = 1.871$).

About the number of exhibits, 76.9% of interviewed visitors agree that the Museum must provide a larger number to interact with (50% considerer it should be available more than 20 geological samples; 40% agrees with a number between 5 and 10 samples; one visitor (10%) considers it should have between 16 and 20 exhibits) and 3 participants (23.1%) think that the actual number of exhibits is ideal.

In order to record new audio information, 3 interviewees (25%) said that more attention should be given to scientific aspects of exhibits, 66.7% think that actual contents are ideal and one (8.3%) answered “others”, and suggested exploring more information about the physical aspects of each museum object. One of the 13 participants did not answer this question.

When asked were to dispose, in MM Gerdau, more three exhibitors like this one, with the aim to create a permanent accessible circuit, 69.2% (9 participants) consider it must be distributed across all three floors of MM Gerdau and 4 visitors (30.8%) agreed this circuit must be concentrated only in one Museum floor (2 participants specified the floor where evaluation tests took place, for that).

Additional, comments were registered: “Braille is not always a solution, because someone has to tell the person were Braille signs are; sound can replace this kind of information”, “there should have different voiceovers with more content to explore, in case someone is interested in deepening his/her knowledge”, “it is very important to permanently have the exhibitor in the museum, so I’ll be able to have something to see anytime”, “sharing information is best without headphones, since it allows escorts to listen information at the same time and have conversations about”, “in addition to touch, contextual audio information is very important to understand the piece as a whole”, “it must be included subtitles for deaf visitors and sign language for its interpretation”, “the exhibits name and information about how to use the exhibitor must be in large print fonts as well” and “because there is not a tactile floor for guidance, a museum staff should be available to escort people during their visits to MM Gerdau”.

5. Conclusions and future work

Designing assistive technology applications for blind and partially sighted visitors in museum exhibitions context – beyond using audio guides – is challenging, since there is a strong visual culture inherent to these institutions and the opportunity for haptic perception of exposed objects is conditioned by various issues, like conservation ones.

This study focused on re-designing and implementing a solution to communicate original artefacts from MM Gerdau main collection to visually impaired patrons, overcoming the costs to replicate the pieces, that interactively “tell stories about their lives” whenever picked up.

The evaluation results demonstrated positive rates about pragmatic and hedonic qualities of the interaction with *Pedras Sabidas* exhibitor, and audio description information showed to be suitable in helping to concept mental images of the five geological pieces. The main limitation of evaluation tests regards with the number of participants. Future investigation will try to apply a larger number of questionnaires, aiming to apply statistical tests of inferential analysis to understand if there is a relationship between visitors’ visual acuity, their ages, the interaction with the solution and nature of presented contents.

In general, the visitors’ experiences about using the exhibitor were very positive, but future studies must contemplate the integration of Braille signs, as well as develop accessible information for deaf visitors. Additionally, the designed solution did not provide knee clearance for wheelchair users, so future exhibitors must focus on the design for all approach.

This project was awarded by Ibermuseus Program, on museums education practices, and the prize will be invested to implement a permanent accessible circuit of interactive exhibitors based on the evaluation results of the presented research, in order to enhance the visitors’ experiences while visiting the museum and provide a larger access to original samples of the collection.

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References

[1] World Health Organization (2017) “Vision impairment and blindness,” Fact Sheet. [Online]. Available: http://www.who.int/mediacentre/factsheets/fs282/en/. [Accessed: 17-Feb-2017].

[2] Bourne et al. (2017) “Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis”. Lancet Glob Health, **5** (**9**): 888–897.

[3] IBGE (2012) “Censo Demográfico 2010: características gerais da população, religião e pessoas com deficiência”. Rio de Janeiro: IBGE.

[4] Desvallées, André and François Mairesse (2010) “Key Concepts of Museology”. Paris: Armand Colin.

[5] Cachia, Amanda (2013) “Talking Blind: Disability, Access, and the Discursive Turn”. Disability Studies Quarterly, **33** (**3**): 1–20.

[6] Ginley, Barry (2013) “Museums: A Whole New World for Visually Impaired People”. Disability Studies Quarterly, **33** (**3**): 1–15.

[7] Johnson, Jeremy (2018) “Sensory: Please Touch the Art”. Art Education, **71** (**1**): 12–15.

[8] Candlin, Fiona (2004) “Don’t Touch! Hands Off! Art, Blindness and the Conservation of Expertise”. Body and Society, **10** (**1**): 71–90.

[9] Gilbert, Sophie (2016) “Please turn on your phone in the museum: cultural institutions learn to love selfies and social media”. Atlantic, **3**: 32–33.

[10] Vaz, Roberto, Paula Fernandes, and Ana Veiga (2018) “Interactive Technologies in Museums: How Digital Installations and Media are Enhancing the Visitors’ Experience,” in *Handbook of Research on Technological Developments for Cultural Heritage and eTourism Applications*, J. M. F. Rodrigues, C. M. Q. Ramos, P. J. S. Cardoso, and C. Henriques, Eds. Hershey PA, USA: IGI Global, pp. 30–53.

[11] Dash, Kalpana and Günther Grohall (2016) “Economic impact of creating and exhibiting 3D objects for blind and visually impaired people in museums”. Economica Institut für Wirtschaftsforschung.

[12] Mesquita, Susana and Maria João Carneiro (2016) “Accessibility of European museums to visitors with visual impairments”. Disability & Society, **31** (**3**): 373–388.

[13] Argyropoulos, Vassilios and Charikleia Kanari (2015) “Re-imagining the museum through ‘touch’: Reflections of individuals with visual disability on their experience of museum-visiting in Greece”. ALTER, European Journal of Disability Research, **9** (**2**): 130–143.

[14] Reich, Christine, Anna Lindgren-Streicher, Marta Beyer, Nina Levent, Joan Pursley and Leigh Ann Mesiti (2011) “Speaking Out on Art and Museums: A Study on the Needs and Preferences of Adults who Are Blind or Have Low Vision”. Boston; New York.

[15] Small, Jennie, Simon Darcy and Tanya Packer (2012) “The embodied tourist experiences of people with vision impairment: Management implications beyond the visual gaze”. Tourism Management, **33** (**4**): 941–950.

[16] Dİnçer, F., H. Özçİt, İ. ÇİfçĪ, B. Sezer, C. Kahraman, and Ş. ŞahĪnoglu (2017) “A Research to Determine Expectations, Satisfactions and Difficulties of Visually-Impaired persons: a case study in accessible museum implementations in Instanbul”. Conference proceedings, 7th Advances in Hospitality & Tourism Marketing & Management (AHTMM) Conference, Famagusta, Cyprus, pp.213-225.

[17] Candlin, Fiona (2003) “Blindness, art and exclusion in museums and galleries”. International Journal of Art & Design Education, **22** (**1**): 100–110.

[18] Morgan, Jennie (2012) “The multisensory museum”. Glasnik Etnografskog Instituta SANU, **60** (**1**): 65–77.

[19] Chick, Anne (2017) “Co-creating an Accessible, Multisensory Exhibition with the National Centre for Craft & Design and Blind and Partially Sighted Participants”. REDO 2017 Cumulus International Conference, Kolding Design School, Kolding Denmark.

[20] Hayhoe, Simon (2017) “Blind Visitor Experiences at Art Museums”. London: Rowman & Littlefield.

[21] Freeman, A., S. Adams Becker, M. Cummins, E. McKelroy, C. Giesinger and B. Yuhnke (2016) “NMC Horizon Report: 2016 Museum Edition”. Austin, Texas: The New Media Consortium.

[22] Bernardo, Ángela (2016) “Museums that are Accessible Thanks to Technology”. OpenMind, 2016. [Online]. Available: https://www.bbvaopenmind.com/en/museums-that-are-accessible-thanks-to-technology/. [Accessed: 09-May-2017].

[23] Association of Art Museum Directors (2015) “Next Practices in Digital and Technology”. [online book].

[24] Museo del Prado (2015) “Hoy toca el Prado”. Museo Nacional del Prado: Exposición Hoy tocal el Prado. [Online]. Available: https://www.museodelprado.es/actualidad/exposicion/hoy-toca-el-prado/29c8c453-ac66-4102-88bd-e6e1d5036ffa. [Accessed: 01-May-2017].

[25] D’Agnano, F., C. Balletti, F. Guerra and P. Vernier (2015) “Tooteko: a case study of augmented reality for an accessible cultural heritage. Digitization, 3D printing and sensors for an audio-tactile experience”. ISPRS - International Society for Photogrammetry and Remote Sensing. Spatial Inf. Sci., **XL-5/W4** (**5**): 207–213.

[26] Reichinger, Andreas, Svenja Schröder, Christian Löw, Sam Sportun, Peter Reichl and Werner Purgathofer (2016) “Spaghetti, Sink and Sarcophagus: Design Explorations of Tactile Artworks for Visually Impaired People”. Proceedings of the 9th Nordic Conference on Human-Computer Interaction, **82**:1–82:6.

[27] Reichinger, Andreas, Anton Fuhrmann, Stefan Maierhofer and Werner Purgathofer (2016) “Gesture-Based Interactive Audio Guide on Tactile Reliefs”. Proceedings of 18th International ACM SIGACCESS Conference on Computers & Accessibility (ASSETS'16), 91–100.

[28] Buonamici, Francesco, Rocco Furferi, Lapo Governi and Yary Volpe (2015) “Making Blind People Autonomous in the Exploration of Tactile Models: A Feasibility Study”. UAHCI: 9th International Conference, Proceedings, Part II, Eds. Cham: Springer International Publishing, 82–93.

[29] Anagnostakis et al. (2016) “Accessible Museum Collections for the Visually Impaired: Combining Tactile Exploration, Audio Descriptions and Mobile Gestures”. Proceedings of the 18th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct, 1021–1025.

[30] Vaz, Roberto, Paula Fernandes and Ana Veiga (2016) “Proposal of a Tangible User Interface to Enhance Accessibility in Geological Exhibitions and the Experience of Museum Visitors,” *Procedia Comput. Sci.*, vol. 100, pp. 832–839.

[31] van Dijk, Jelle et al. (2016) “Empowering People with Impairments: How Participatory Methods Can Inform the Design of Empowering Artifacts”. PDC '16 Proceedings of the 14th Participatory Design Conference: Short Papers, Interactive Exhibitions, Workshops, **2**, 121–122.

[32] Preece, Jenny, Helen Sharp and Yvonne Rogers (2012) “Interaction design: beyond human-computer interaction”. United States of America: John Wiley & Sons.

[33] Krasner, Glenn and Stephen Pope (1988) “A description of the model-view-controller user interface paradigm in the smalltalk-80 system”. Journal of Object Oriented Programming, **1** (**3**):26-49.

[34] Smithsonian Institution (n.d.) Smithsonian Guidelines for Accessible Exhibition Design. Washington, D.C.: Smithsoninan Access. Program.

[35] Hirose, Kojiro (2013) “Research on Methods of ‘Touching the World’-The Aim of the Exhibit Area of Tactile Learning in Japan’s National Museum of Ethnology”. Disability Studies Quarterly, **33** (**3**).