DEVELOPMENT OF A TOUCHABLE REPLICA FOR INCLUSIVE EXPERIENCES OF RELIGIOUS ARTIFACTS

Abstract
The main objective of this article is to introduce a first inclusive experience in a conventional museum that so far only exhibits religious sculptures and its evaluation by blind and partially sighted persons. For this reason, it was decided to develop a multisensory experience aimed at blind and partially sighted people, taking advantage of the potential of new 3D scanning and printing technologies. The experience is centered on a touchable replica of the bust of the *Cristo de la Sangre*, a masterpiece of the Baroque highly revered in Murcia. The complete process of the development of the replica is shown, form design and manufacturing, both combining technology and tradition. Apart from touch sense, the experience incorporates detailed audio descriptions and smells, to provide valuable extra information. Also, radio mobile technologies such as beacons, are used for guiding purposes. Blind and partially sighted people play an active role in this project, both in the design and validation of the experiences.

Keywords: 3D Digitization, 3D Printing, Multisensory Experience, Multimedia, Accessibility, Inclusivity, Visual Impairment, Beepcons.

Introduction

Traditionally, museums have been primarily visual spaces (Candlin 2003, Wilson et al. 2018). However, the development of digitization techniques and 3D printers have allowed the possibility of creating different products and models of objects, from small-scale reproductions, molds and pieces for restoration, to the development of life-size replicas in their museums, giving the possibility of interacting with them, something unthinkable to do with original works. These 3D replicas, together with applications for portable devices (mobile phones, tablets, etc.) games and avatars in sign language are some of the technologies that museums are incorporating into their current exhibitions (Solima, 2016).

These technologies, together with new interactive and sensory media, are increasingly being used to attract and reach new audiences such as people with some type of disability (Candlin, 2006). Without a doubt, being the group that most benefited from the introduction and search for new ways of interacting with heritage.

People with visual and/or hearing disabilities have participated in this research to show that different needs and requirements arise for different capacities. Moreover, museums, hand in hand with new technologies, can respond to those needs, as is shown in this paper. With the utilization of tools that have been designed to make heritage more accessible, including apps with information, audio-descriptions, multisensory resources, mainly tactile and olfactory, such as tactile reliefs and the use of aromas (Jafri and Ali, 2015).

Accessibility Experiences in Museums

Regarding accessibility in museums, pioneer experiences such as Walter Benjamin's Seminal Work highlighted that the use of replicas and touchable reproductions are a solution to improve the visitor experience without jeopardizing the museum's endowment (Benjamin, 1955; Solima and Tani, 2016).

On the other hand, technological innovation in these institutions, in addition to providing a response to face the demand for more advanced and complex services by users (Addis, 2002), is a consequence of the growing competition for the attention of visitors (Bonacini. 2011) and one of the four fundamental dimensions of accessibility, the digital one, identified by Solima in 2014.

The ocular-centricity and paradigms such as that of the "glass box" (Candlin, 2003; Dudley, 2010, 2012, 2015; Wilson et al., 2018) are clear exponents of the generalized tendency on the part of museums and exhibitions to focus the experience of the visitors in the sense of sight and in the overprotection of the works, relegating the accessibility on the part of the blind and partially sighted to a second plane. The cost-impact conflict in many cases justifies this *modus operandi* by limiting museums to exclusively fulfill their social function (Eardley et al., 2016; Walters, 2009). Nothing is further from the current museum conception enunciated by Wang, who attributes a greater commitment to the connection and complex interaction with the senses and experience, and adds to the educational function, that of a social hub, a center of contemplation and even healing (Wang, 2020).

The problem of museum accessibility, as well as the analysis of the main barriers -physical, cognitive and informational- has been widely studied (Addis, 2002; Vescovo, 2002; Rovidotti, 2004; De Luca, 2007; Walters, 2009; Solima, 2012; Rappolt-Schlightmann and Daley, 2013). While some authors point out the relevance of betting on visitor-centered approaches, while giving them an active role in their design (Goulding, 2000; Ballantyne and Uzzel, 2011; Solima, 2014; Eardley, 2016), others denounce the scarcity of research that considers their needs (Neümuller, 2014, Wilson et al., 2018).

In Eardley et al. (2016) it is justified that access to museums by the disabled is a majority issue and that the solution must consist of "access for all", focused on multisensory stimulation, which corresponds to the reality of the world in which we operate, while enhancing and benefiting learning (Montessori, 2013; Lillard and Else-Quest, 2006). This type of access was already identified years ago by Dodd and Sandell (1998). In this regard, Candlin suggests the implementation of non-visual learning routines (Candlin, 2003). From the pioneering study *The full sensory engagement - multisensory experiences* (Davidson et al., 1999), more and more people affirm the social, cognitive and even therapeutic value that the interaction with sensory objects provides, especially for people with disability (Hetherington, 2000; Candlin, 2004; Ee Coster, 2004; Clintberg, 2014; Vermeersch et al., 2018).

Although science has shown that the sense of vision predominates over the sense of touch, the importance of the latter is recognized by many of the cultures of the older civilizations (Williams, 1966). Touch is the sense that provides the most powerful emotional content (Gallace and Spence, 2010). Field and laboratory studies in the area of neurosciences affirm that touch can have a positive effect on our cognitive processes and on our general well-being (Jansonn-Boyd et al., 2007; Spence and Gallace, 2008; Ackerman et al. 2010).

Many sculptures are conceived and created by their authors to be touched, but the preservation of heritage deprives users of this experience, so the question to ask ourselves is: What do we lose by not being able to touch? (Tacha, 1963). In his works *Beginning of the World or Sculpture for the Blind*, the sculptor Constantin Brancusi tries to answer this question (Barassi, 2014). Candlin (2006) states that touch is frequently used to fill gaps/voids of vision by the blind and partially sighted. Other research points to the importance of adopting an active attitude while playing, as well as having freedom of movement, to shape a richer sensory experience, "haptic", rather than "tactile" (Gallace and Spence, 2010). Similarly, Wilson et al. (2020) discusses that modern museum practice provides for equal access for all, but access for blind and partially sighted (BPS) audiences remains problematic given the ocular centric nature of museums.

The basis for the application of new technologies to the museum field is the digitization of the pieces, particularly the registration of their geometries and textures, relief and color respectively. Research such as those developed by Remondino (2013), Scopigno (2014) and Melendreras, Marín and Sánchez (2020, 2021) focus on identifying the optimal workflow and techniques to develop this process with the highest efficiency and quality.

The main uses of digitization include, on the one hand, the development of digital products, such as virtual tours (Ballantynes and Uzzel, 2011), 3D models (as https://sketchfab.com/britishmuseum) and applications (web and mobile), and on the other, physical or material, such as the reproduction of scale replicas, the manufacture of souvenirs, etc. (see table 1 in Solima, 2016).

As far as the reproduction of replicas is concerned, 3D printing, unlike other methods based on subtractive manufacturing techniques or the creation of molds, in addition to being less expensive and invasive, "is simpler, less complex, requires less time (rapid prototyping) and, despite the need for editing and post-processing work, this provides great flexibility and adaptation in the final design of the object to be reproduced (shape, quality, etc.)" (Scopigno 2014, 2017).

The applications of 3D printing for the collective of the blind and partially sighted people are very numerous, highlighting those aimed at facilitating orientation (tactile maps), deciphering the content of digital and printed images (reliefs of web graphics, photos, and paintings), tactile exploration of remote, inaccessible, or large/small objects and those intended for education (Jafri and Ali, 2015), as well as others that are briefly described below.

First proposals for the manufacture of 3D touchable replicas in museums, aimed at the blind and partially sighted, are based on stereoscopy by Neumüller, who in turn demands further research in the identification of methodologies and workflows for the use of the (Neumüller and Reichiger, 2014). On the other hand, more recent research by Götzelmann (2017), in which they use the potential of printing technologies to create interactive prints, provides an overview of essential approaches for the creation of various tactile materials using 3D printers.

In the research of Reichinger et al. (2018) the development of a 2.5 D relief from a 3D scan is performed, which in addition, is used with their gesture-based interactive audio guide. In that research is presented a mixed perspective view projection technique and is developed a depth compression technique that preserves details to flatten less important parts. Similarly, D'Agnano (2015) creates a smart ring that allows one to navigate any 3D surface with the fingertips and in return obtain audio content that is relevant to the part of the surface that is currently being touched.

Following this, Ballarin et al. (2018), focuses on the technical validation of 3D replicas in terms of precision and metric accuracy, both for display, cataloging and study. In this way, it analyzes the metric characteristics of the printed model in relation to the original data and optimizes the process from the survey to the physical representation of the object. Whereas Navarro Delgado et al. (2012) through the use of 3D models with augmented reality or that of Di Gusseppeantonio di Franco (2015) who proposes the creation of multisensory 3D replicas.

An important aspect highlighted by Candlin (2003) is the importance that the physical properties of objects have for the blind and partially sighted, and more specifically the choice of the most appropriate material so that visual perception and tactile sensation are correlated (Spence and Gallace, 2008). Of special interest are the studies conducted by Wilson, focused on the evaluation of user preference on the physical properties of touchable 3D replica prints (Wilson et al., 2018). In their conclusions they highlight those replicas made of resin are the favorite 3D prints of users. The verisimilitude, understood as the realism, degree of detail, visual and tactile resolution with respect to the original, is the dominant factor in its preference, ahead of quality and robustness. The most reliable scales associated with this factor are good/bad quality, clarity/confusion, realistic/unrealistic, detailed/not detailed, boring/interesting. Parallel to this study, other experiences show the high level of satisfaction of the participating subjects after experimenting with playable replicas, even preferring interaction with them than observing the originals (Kantz 2013; Hoyt, 2013).

Regarding the implementation of practical experiences with 3D printed touchable replicas, some authors warn of a risk associated with the manipulation of objects -hazard, dirt, order, etc.- (Hetherington, 2000, 2003; Spence and Gallace, 2008) by groups of the blind and partially sighted. Only the eradication of these parameters guarantees an effective start-up of exhibitions of this nature (Solima and Tani, 2016).

Finally, the experiences centered on the exhibition of touchable replicas of museum objects from the outside are of great interest, as an extension of the museum to the outside. Its exhibition to sick people in hospitals, prolonging its educational function and even highlighting the healer (reminiscence), for both generating a positive impact on the well-being of the patient (Chaterjee et al., 2009).

(Place Figure 1 approximately here)

This is the current state of BPS research with 3D printing in cultural heritage. Here we have made a brief summary of the most important or most relevant research for us, on which we have based ourselves to carry out our research and project in this field.

Location: Museum Cristo de la Sangre (Spain)

The museum object of this study is owned by the *Archicofradía de la Sangre*[1], the oldest penitential brotherhood in the city of Murcia (Spain), created in 1411. Among its collections, it mainly houses polychrome wood sculptures dating from the seventeenth to the twenty-first centuries.

Nicolás de Bussy is the author of the *Cristo de la Sangre*[2], which dates from 1693, a unique sculpture of its kind, full of symbolism, as it represents the crucified Jesus stepping on the grape of the mystical winepress, while an angel collects the blood in a chalice that sprouts from its side, and that is the object of study of this article. It is a work of art with great religious devotion in the city but it is degraded by its annual procession every Easter. Hence, the Brotherhood decided to digitize this landmark piece for the historical heritage of the city, to protect and preserve it for the future, but also for a greater cultural and even devotional diffusion.

The museum institution was founded in 1994 in the Archpriest church of Nuestra Señora del Carmen de Murcia. Since December 2018, the museum has been located next to the church, in the premises of an old school. Especially noteworthy is its installation or museography with the sculptures in the same plane as the visitors, without pedestals, in dark rooms with strong lighting that enhances their dramatic sense.

[1] Name of the very old catholic brotherhood founded at the end of the Middle Ages in Murcia, owner of the heritage mentioned in this article and of the Museum where the experience takes place. For more information: http://www.coloraos.com/

[2] Name of the polychrome wooden sculpture that represents the crucified Jesus Christ of great devotion by the Catholic faithful of the Region of Murcia (Spain).

In its mission to have a greater social projection and to be a main asset of the cultural fabric of the Region of Murcia (Cruz, 2021: 104), it is worth highlighting the digitization of part of its collections and the creation of a virtual visit (https://museo.museocristodelasangre.com) that allows a better knowledge of its funds. The touchable replica of the *Cristo de la Sangre* bust, as can be seen in Fig. 1, is present in the museum now and has been installed in the middle of the tour, integrated into the discourse, and in the chronological place where the original piece, that is set in its own chapel in the church, would be placed. The replica is accessible to all audiences, especially for blind and partially sighted people, thanks to the experience we have developed. We hope in the future that the digitization of the collections and the creation of the tactile replica of the bust will convince the *Archicofradía de la Sangre* of the need to continue making tactile replicas of other sculptures in the collection.

Methodology. Design and Manufacture

The methodology followed in this article, which is described below, includes four distinct phases:

In the first phase, the background of said study is presented based on a 3D digitization previously carried out and described in the publications cited in its section. Also, the choice of this sculpture for the study is analyzed due to its relevance in the locality and the previous considerations regarding the choice of the design and production of the experience.
In a second phase, the manufacturing process of the replica is developed, describing the aspects to be taken into account for the 3D printing, the realization of the polychrome of the piece, the added elements elaborated and the design of the piece of furniture exhibiting the piece.
In the third phase, the multimedia experience is developed, the technology used, the multimedia content incorporated and its description.
And in the fourth and last phase, the test with the participants and the survey is developed.

PHASE 1: BACKGROUND

I. The Digitization 3D

In previous researches, the *Cristo de la Sangre* was digitized using several different digitization techniques: photogrammetry, laser scanner and structured light scanner, obtaining very positive result, like are described in Melendreras R. et al., (2020) and Melendreras, R. et al., (2022). it was concluded that the combined use of medium and high resolution structured light scanners, the latter focused on the digitization of small elements such as teeth, beard, nose, etc., offered the best results in terms of precision as in terms of quality and efficiency.

Therefore, the 3D model obtained consists of a combination of data obtained from both types of scanners, specifically the Eva and Spider models from the manufacturer Artec 3D. As can be seen in the table 1, the values regarding the precision of the Spider model reach resolutions higher than those of the Eva model, and, therefore, obtain a higher level of detail on small elements. Regarding the digitization window, the Spider's is much smaller, which takes a longer time for digitization. However, regarding the texture, they obtain similar results, since the resolution and the color sensors of their cameras are identical.

(Place Table 1 approximately here)

II. Purpose of the Replica

The tactile replica is designed so that blind and partially sighted people can "know" the sculpture of the *Cristo de la Sangre*, its bust, as well as the history and traditions of the Archicofradía of which it is the owner.

Until now, the exhibition housed in the Cristo de La Sangre Museum was not aimed at this group because the patrimony and the design of the user experience were focused on the visualization of the exhibited carvings, of great artistic value and built-in polychrome wood, which cannot be touched for conservation reasons. Therefore, this initiative represents a step forward in inclusiveness and accessibility for this museum, a paradigm shift, as well as a pioneering experience in the exhibition of religious heritage, at an international level.

In the configuration of the project, in addition to tackling a multidisciplinary approach involving technicians in digital transformation, architects, sculptors and art experts participate, its main protagonists and beneficiaries, the blind and partially sighted, have been involved from the very beginning.

III. Previous Considerations and design

Based on previous research in this area (Wilson et al., 2018), due to its high resolution and consistency, additive manufacturing using high-density resin is chosen as the technique for the bust reproduction.

Early collaboration with organizations for the bind and partially sighted, as in our case ONCE (National Organization of the Spanish Blind), helped to make important decisions such as the reproduction of the replica with color, due to the fact that there are people with degrees of visual impairment that can perceive it. In this sense, we were advised to opt for the use of high color contrasts in the reproduction of the work.

To achieve the desired color resolution for the replica, it was necessary to use indirect 3D printing solutions such as Polyjet or Color Jet. The high cost of these solutions made us opt for resin printing of a single tone and the application of color through a subsequent polychrome process carried out by sculpture professionals.

In section 4.1. it was mentioned that to achieve the maximum resolution of the three-dimensional model obtained for the replica, the combination of two structured light scanners of different resolution was chosen. However, because the resolution of the model is much higher than that of current 3D printers, it is necessary to perform a decimation or reduction of the quality of the model so that the printing software can import it and configure the manufacturing process correctly.

The generated three-dimensional model of the complete body of the Christ contains 10 million triangles. Subsequently, it was sectioned, leaving only the bust, resulting in a mesh of 1.5 million polygons, which was finally decimated to 160 thousand polygons, almost a tenth, to be able to be entered in the Ultimaker Cura program to plan the additive manufacturing or 3D printing.

PHASE 2: MANUFACTURING OF THE REPLICA

I. 3D Printing of the Bust

For the realization of the bust in high resolution, it was decided to use the 3D printing technology SLA (Sterolithography), which uses a photosensitive resin that hardens the printed layers by means of ultraviolet light, due to the high resolution and geometric detail that it obtains as well as its ease of surface work for smoothing, adaptation and assembly of the final piece. (Gibson et al., 2015).

The SLA printer used is the Photocentric Hi-RES model, with a manufacturing volume of 195 x 147 x 230 mm. This equipment allows resolutions from 25 to 100 microns, deciding to use the highest. The chosen resin was the Photocentric FIRM model, with a total amount used of 2.8 liters. This resin is ideal for creating objects of great hardness and with a small compression capacity under high force.

Due to the size of the bust and wanting to print it in full scale, it is necessary to prepare it for printing in several sections, one of these pieces can be seen in fig. 2, following the process as follows:

1. The three-dimensional model of the bust is divided into 12 parts of similar volumes to be printed individually on the printer; it is thus decided to be a model with a volume much higher than the maximum printing volume of the equipment.
2. Next, an internal vacuum is generated in each part, leaving an outer wall 2.5 mm thick.
3. Subsequently, support structures are made to all the pieces. It is decided to generate them on the side of the piece with less geometric detail to avoid possible imperfections caused by them as much as possible and to facilitate their elimination.
4. Next, each piece is printed.
5. Finally, immediately upon completion of your printing, the excess adhered resin is wiped off with isopropyl alcohol and allowed to cure (harden) in daylight to obtain its final mechanical properties.

(Place Figure 2 approximately here)

Each piece printed can be seen in fig. 3, whereas the approximate printing times of each piece can be observed in Table 2.

(Place Figure 3 approximately here)
(Place Table 2 approximately here, please next to Figure 3)

With the pieces completely cured, the assembly and joining process of all of them is carried out, following the following works:

1. First, we proceed to the elimination of the points of union of the supports using a mini grinder with a sanding head.
2. Immediately afterwards, the joints are chamfered, approximately between 2 and 3 mm at 45º to have a subsequent resin filling surface and make a suitable joint between pieces.
3. Next, a first gluing is carried out using Cyanoacrylate to assemble all the parts of the bust.
4. Next, with the bust already joined, proceed to fill the previously beveled joints with the same resin. For this filling, thin layers of the same resin were applied with a small brush and allowed to cure with a UV light lamp. This process was repeated successively until all the joints were completely filled.

5. Subsequently, we proceed to remove excess material from the joints with a mini grinder and to go over the joints of the bust with different water-based paper sandpaper to smooth the joints and remove the marks from the printing layers of the entire model.

6. Finally, the bust is internally filled with polyurethane foam to give the bust greater hardness and eliminate the possibility of breakage or deformation of the material (as can be seen in fig. 4).

(Place Figure 4 approximately here)

II. Polychrome of the bust

Following the recommendations made by ONCE, prior to the polychrome of the bust, an in-depth study of the original polychrome of the Christ was carried out, making use of all the digital resources available at our disposal: high-resolution 2D photographs of the initial photogrammetric process (36,4Mpix - Camera: Sony alpha 7R Format: RAW), historical photographs from the Arch Confraternity archive, the image file of the texture of the 3D model itself and the 3D model of the bust uploaded to Sketchfab in .obj format.

The results of this study showed that the original carving of the *Cristo de la Sangre* already has a high inherent color contrast, appreciable between the pale tones of the skin and the dark tones of the hair and beard. Therefore, it was decided that the polychrome could be made in a 100% realistic way, emulating the original, reproducing even the smallest details

The polychrome process was carried out following the steps described below: (Please see fig. 5 for details).

1. *Analysis of the material and previous tests.*

The sculptors responsible for the polychrome had never worked on the resin material. For this reason, partial samples are provided for testing. In these initial tests, the disadvantage compared to clay or wood, the absence of porosity, an aspect that makes it difficult for any type of paint to adhere and dry. With the different tests, it was concluded that any type of acrylic, water or oil paint, applied directly on the piece, adhered very well to the material. However, a direct application was found to be very vulnerable to scratching or rubbing off. So, it was decided to apply a gesso base prior to polychrome.

2. *Polychrome techniques: preparation of the base.*

Gesso is a preparation mainly based on plaster and glue, widely used in the world of painting to give the first layers of primer to frames and slats as a preparatory base for later painting with oils, tempers, etc. After its preparation in the workshop, two coats of the product were applied, achieving a white finish that perfectly held onto the resin. In this way, it was achieved that the bust had a porous base, where the polychrome could adhere without problems.

3. *Polychrome process.*

The bust was polychromed in the traditional way, using a colored base with an oil finish and final varnishes. It contains two bases of acrylic color, another two of oil color, glazes and specific nuances to imitate the passage of time and age in a current painting. Another important drawback found, as a result of the resin, was that the drying process was twice as slow between layers due to its low and slow absorption. Particular attention was paid to color contrasts. Enhancing the white of the skin, the dark of the hair or the red of the blood, as seen in the original polychrome of Christ. In addition, emphasizing areas with lack of depth such as in the mouth, or highlighting the wrinkles and cuts of the wounds on your forehead, neck, shoulders and chest. In turn, the glazing of the eyes stands out to make them look like glass and make the reproduction more vivid.

Taking into account its touchable characteristics, it was finally finished by applying a layer of varnish with a type of brushed satin to give a smooth and reliable touch to the relief, protect against dirt and facilitate cleaning of the replica at the same time.

(Place Figure 5 approximately here)

III. Additional elaborations:

Two additions to the replica were made such as the wig and the crown as can be seen in Fig. 6.

Wig

Regarding the wig made for this bust, and taking into account its main recipients and use, four main characteristics were taken into account that differ slightly from the original Christ wig. These were:

1. The length of the hair: Being a bust and not showing the full back of the Christ, it was considered unnecessary to reach the length of the original hair that would reach the waist. Therefore, it was decided to reach a length of approximately 35 cm according to the size of the bust, and just 3 cm beyond the edge of the support base.
2. The cranial volume: it was considered that it was also not necessary to use the amount of hair that the original images that parade usually need, since being observable from a closer distance instead of on top of a throne, an exaggerated wig would be seen and unconvincing. It was decided to reduce the amount of hair with respect to the original.
3. The parting of the hair: This wig is made with the particularity of being tangible. For this reason, the hair is parted in mesh fabric with a brown background as is done today in wigs. This technique is more long-suffering and durable than the one used in the original wig, which uses white sheets of thread or cotton, as was done centuries ago.
4. The tone of the hair: The tone of the hair used for the wig is slightly darker than that of the usual wigs, thereby seeking to increase the contrast with the polychrome of the face.

The manufacture of the crown also entails some modifications with respect to the traditional process, since its spines should not puncture the user because they are touchable.

Crown

The crown was made following the 18th century Murcian technique used by the famous sculptor Francisco Salzillo (Murcia, Spain, 1707-1783). The material used is a rope, of the rope type, which is bathed with "rabbit tail" and once drained it is braided to give the desired shape with the perimeter of the head. Rabbit glue is a glue that uses animal collagen, in this case rabbit collagen, to create the base of the adhesive. In our case, the perimeter was 53 cm by 4 cm in height. With the desired shape, it is finally bathed in a liquid mixture of the same glue and plaster. The crown spines were made with poxilin, a putty that hardens when drying and allows it to be worked to round the tips, eliminating the risk of puncturing during interaction. Finally, it is decorated with a dark brown and gold cream base with touches of bitumen.

(Place Figure 6 approximately here)

IV. Replica furniture design

From ONCE we were informed that the interaction of objects should be done free of obstacles and at a comfortable height for the hands, more or less at the level of the belly.

In this way, it was decided to build a rectangular base 1.10 meters high with a base adjusted to the perimeter of the bust of 40 cm wide by 30 cm deep. The base, made of black lacquered wood for consistency with the existing ones in the museum itself, was left hollow and registrable, due to the fact that a counterweight was installed inside to prevent it from tipping over and a special radio-frequency transmitter (beacon) to facilitate the location of the bust by users inside the museum.

As a result of the multimedia content developed for the experience, it was decided to manufacture and attach two additional 3D tactile reliefs to the sides of the base, one of the Arch-brotherhood emblems and the other of the angel that collects the blood of Christ, both printed in plastic ABS, painted in bronze color and varnished in glossy acrylic to resist touching.

Finally, two plaques were installed on the front of the pedestal, the main one, horizontal and inscribed in Braille, that contains the title of the project and thanks to the people who have made this project possible. Below this, a methacrylate plate with the same information in plain text.

PHASE 3: MULTISENSORY EXPERIENCE.

This phase is necessarily conceived as multisensory because to enjoy a complete experience, visually impaired people need both the sense of touch and other senses such as hearing and smell, the senses serving them as a vehicle to both guide interaction and illustrate with greater precision the context of the work.

I. Accessible Technologies

To improve accessibility, regular use wireless signaling technologies are incorporated into the experience. The initial objective is that a blind and partially sighted person can easily reach the zone where the bust is placed across the museum. To this end, it was decided to use Beepcons ®, a technology developed by the Ilunion company for ONCE, and which consists of a beacon-type radio transmitter device that uses Bluetooth Low Energy (BLE) technology. Through an app installed on their smartphones, users detect the beacon that guides them to the bust by acoustic signals. Once there, the Beepcons app itself plays a preliminary audio description of the object and then invites the user to click on a web link (https://www.iluniontecnologiayaccesibilidad.com/beepcons) that leads to multimedia content hosted on YouTube, specially created to guide the visitor through the multisensory experience.

II. Multimedia Content of the Experience

Initially, only audio content was going to be developed to blind people. But finally, and well assessed by ONCE, it was decided to design an audiovisual content, taking in account those disabled people with residual vision. A video montage was developed using the VideoPad editor in .mp4 format with Full HD quality (1920x1080) and a duration of 15 minutes. (https://www.youtube.com/embed/9x9KjRw7qb8?v=9x9KjRw7qb8).

The central axis of the experience is a voice-over, by the known journalist Miss Encarna Talavera, who in addition to providing precise instructions to the visitor -on how to position themselves around the pedestal, invite hand disinfection, interaction, etc.- makes three different stories, corresponding to the phases in which the experience is divided. During each story, the narration, in the foreground, is combined with images and specially chosen background music, as well as the texts, developed by a specialist, Mr. José Emilio Rubio.

In the first place, the history of the *Archicofradía de la Sangre* is narrated, followed by its main traditions and its processional parades, to last stop at the carving of the holder, the Santísimo Cristo de la Preciosísima Sangre or Cristo de La Sangre, the work of the sculptor Nicolás de Busy, and object of this study.

<u>Description of the Experience</u>

The multisensory experience has a simple structure for the visitor to understand. Fundamentally, it consists of paying attention to multimedia content, since it contains precise instructions on how to carry it out. In its development, the times and pauses necessary to carry out various operations such as correct positioning, disinfection of hands or a reasonable time for interaction have been taken into account. To this end, it has a common structure in each of the phases into which it is divided.

The initial phase is the welcome and introduction. After this, the stories that make up the bulk of the experience begin.

The structure of the stories is also very simple and common to all:

- First, instructions are given on how to position yourself with respect to the bust base.
- Next, a narrative voice-over is played in which a large amount of historical and descriptive information about the museum and its heritage is provided.
- At the end of it, you are invited to disinfect your hands with hydroalcoholic gel.
- And after this starts a touch phase:
  1: Emblem of the brotherhood Relief: After the narration of its story.
  2: Angel Relief: After the narration of the traditions.
  3. 3D Bust: At the end of the narration of Christ.

Parallel to the narration, an additional sensory component, smell, is introduced. Smells of wax and incense are introduced in order to recreate the passage of the parades through the streets or the context of Christ in his chapel.

Finally, the last announcement is to thank the visitor for his attendance and to conclude the experience. (You can see the interaction in fig. 7). In this sense, the feedback after it is important, and a special survey is designed in Google Forms to collect the first impressions. (You can see in fig. 8).

(Place Figure 7 approximately here)

PHASE 4: DESCRIPTION TEST AND PARTICIPANTS

Limitations

This study has been carried out under the circumstances of Covid19, therefore, the representativeness of the group is subject to such conditions. Due to state health restrictions, at that time, no more than 10 people could gather for educational or social events.

Development

The study and validation of the experience described above follows the Design Thinking ® methodology, understanding as such, that methodology that allows users to really understand through surveys or an in-depth interview.

The choice of the chosen sample is made based on the criteria of the authors of the study, focusing on two different groups: Art experts (sculptors, restorer, art historian, museologists and educators) and the blind and partially sighted. The subjects in the first group tried to find different professional profiles within the areas of art to which we had access. In addition, due to the health restrictions imposed by the country's government, we had to look for professionals close to the geographical region to facilitate their participation. Whereas the profiles and people of this second group, were selected and chosen by the ONCE, mainly finding the profiles of congenital total blindness, total blindness caused, residual visual (partial blindness-severe visual impairment), and deaf-blind. As a particularity, it was also decided to carry out the same test and survey to the interpreter guide who accompanied the deafblind person, although their answers have not been entered in the results.

The group of art experts was made up of five professionals and the group of blind and partially sighted of seven. The sanitary conditions and restrictions imposed in the country due to Covid-19, recently released from isolation, were a problem in finding volunteers with visual impairments of different types who wanted to participate in the study. The survey is designed with practically the same questions for the two groups, containing a total of 29 questions for the art experts and 23 questions for the group with visual disabilities. The difference lies in the fact that some more questions are added to the group of art experts, related to the validation of the experience in the museum context and the dissemination of heritage.

The experience lasted 25 minutes, including the 15 minutes of the multimedia story and palpation periods of 5 minutes. After the experience, the survey is carried out individually in an office of the Museum. All participants gave their consent prior to the visit.

The survey is divided into three sections:

- Section 1: Corresponding the first five questions to personal issues, name, profile, background, etc.
- Section 2: Questions related to experience auditory, olfactory and touchable including the additional elaborations. (See table 3)
- Section 3: Questions related to personal, emotional or opinion aspects in general matters.

(Place Figure 8 approximately here)

Results and discussion

The statistical data (you can see in Table 3) shown below are based on the questions in Section 2 of the survey process, as described above, through which we intend to collect the users' evaluation of the tactile, olfactory and auditory experience.

Due to the small sample size of the study participants and with the intention of providing a reliable estimate that can be extended to the whole population, it was decided to analyze the results using the Student’s t distribution with a 95% confidence interval. Nevertheless, the resulting average values shown in Figures 9 and 10 should be interpreted with caution.

(Place Table 3 approximately here)

The graphs (Fig. 9) show that the blind and partially sighted have been more critical in the evaluation of the totality of the experiences. While, the group of art experts evaluated the experiences positively and uniformly.

(Place Figure 9 approximately here)

In turn, the olfactory experience is the one that generates the greatest discrepancy on the part of the blind and partially sighted, showing the widest confidence interval and the lowest average evaluation. On the other hand, the auditory experience also shows a high valuation by both groups, although without reaching those obtained in the tactile experience. On the other hand, the tactile experience reveals the lowest confidence intervals, possibly influenced by the ratings given to the robustness (Q2) and the elaborated additions (Q4 and Q5) of the replica, as shown in the following graphs (Fig.10):

(Place Figure 10 approximately here)

As for the results obtained in Section 3 of the survey, designed with open-ended questions, they have allowed us to gather valuable feedback about the experience, oriented both to its optimization and to the development of future experiences in the museum environment.

A summary of the most relevant contributions is as follows:

1. Possibility of creating scale replicas of the entire object and another in detail, for example, the bust.
2. Improve the lighting in the room. People with partial blindness need more indirect lighting (elimination of dark areas).
3. Rearrange the order of the experience. They prefer to attend to the full audio description first and then focus on the tactile experience.
4. Improve signage and guidance in the museum by installing podo-tactile markings on the ground.
5. Increase the height of the pedestal, raising it by approximately 20 cm.
6. Provide even more realism to the polychrome. E.g., give volume to the painting of the drops of blood.
7. Add more smells.
8. Add more music to the multimedia audio description.
9. Add more touchable elements to the experience, such as textiles and other memorabilia.
10. To make a global and detailed description of the museum environment where the experience is located.

Conclusions

A first inclusive multi-sensory experience aimed at blind and partially sighted people has been successfully developed in a traditional Easter museum, taking advantage of the potential of new 3D scanning and printing technologies.

The innovative manufacturing process of the replica based on 3D printing provides significant knowledge and skills "in sculpture" by perfecting the technique of polychrome on resin, how it concludes Wilson et al., 2018 in the study about physical properties of 3D printed replicas.

Digital tools enhance learning and bring heritage closer to those who otherwise would not have access to it. In addition, they allow customizing the design of the user experience and personalizing content. In this sense, accessible mobile applications and multimedia content are very powerful tools to guide the blind and partially sighted people of what they are going to experience. As also concluded by D'Agnano et al. (2015), di Guseppantonio et al, (2015), and Wang, S. (2020). in their studies introducing the application of new technologies with an inclusive purpose.

Regarding validation, a larger sample of people in the validation process would have been desirable, but due to health protocols (COVID-19) it was impossible to convene a larger number, giving priority to their profile and representativeness. The group of blind and partially sighted people evaluates more rigorously the sensory experience than the art experts. They value very positively the tactile quality of the manufactured replica, both for its definition and materials, as for integrating different textures (hair, face and crown). On the other hand, art experts highly value the possibility of touching the replica because, in addition to providing them with an unprecedented experience, it gives them a better understanding of the work and its details.
The introduction of aromas (incense and wax) is also highly valued by this group. On the other hand, the group of experts in art and education accredits both the rigor of the technical execution of the replica and its validity for the general public.

The joint work with organizations for the blind has been decisive along the project, both for designing the experience, for validating it and for taking feedback to improve it in the future.

Among the considerations to take into account for future projects, we highlight the connection of this and future experiences with the museum, the implementation of the improvements suggested by the majority of the blind and partially sighted volunteers and the introduction of new inclusive technologies, such as the guiding system Navilens®.

Tactile experiences are best valued by blind and low vision visitors, but benefit all visitors if they are available, because tactile learning is also valued by anyone who has the ability to feel through touch.

References

Ackerman, J.M., Nocera, C.C. and Bargh, J.A. (2010). Incidental Haptic Sensations Influence Social Judgments and Decisions. *Science* 25, 328 (5986): 1712-1715.

Addis M. (2002). Nuove tecnologie e consumo di prodotti artistici e culturali: verso l'edutainment. *Micro & Macro Marketing* 1: 33-60.

Ballantyne R., and Uzzell D. (2011). Looking Back and Looking Forward: The Rise of the Visitor-centered Museum. *Curator: The Museum Journal* 54, 1: 85-92.

Ballarin, M., Balletti, C., and Vernier, P. (2018). Replicas in Cultural Heritage: 3D Printing and The Museum Experience, in *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII-2: 55-62.

Barassi, S. (2010). *The sculptor is a Blind man: Constantin Brancusi's Sculpture for the Blind. Sculpture and Touch*, edited by Peter Dent. 2014. Ashgate.

Benjamin W. (1955). *L'opera d'arte nell'epoca della sua riproducibilità tecnica*. Turin: Einaudi.

Bonacini E. (2011). *Nuove tecnologie per la fruizione e valorizzazione del patrimonio culturale*. Roma: Aracne.

Candlin, F. (2003). Blindness, Art and Exclusion in Museums and Galleries. *The International Journal of Art and Design* 22 (1): 100-110.

Candlin, F. (2004). Don't touch! Hands off! Art, Blindness and the Conservation of Expertise. *Body and Society* 10: 71–90.

Candlin, F. (2006). The Dubious Inheritance of Touch: Art History and Museum Access. *Journal of Visual Culture* 5, 2: 137-154.

Chatterjee, H. J., Vreeland, S., and Noble, G. (2009). Museopathy: Exploring the Healing Potential of Handling Museum Objects. *Museum and Society* 7: 164-177.

Clintberg, M. (2014). Where Publics May Touch: Stimulating Sensory Access at the National Gallery of Canada. *The Senses and Society* 9: 310–322.

Cruz, P. A. (2021). Museo Cristo de La Sangre: un referente cultural de la Región de Murcia. *Los Coloraos*: 104-105.

D'Agnano, F., Balletti C., Guerra F. and Vernier P. (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 Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 1: 207-213.

Davidson, B., Heald, C. L., and Hein, G. E. (1999). Increase Exhibit Accessibility Through Multisensory Interaction. in *The Educational Role of the Museum*, edited by E. Hooper-Greenhill, 2nd ed., 223-38 London: Routledge.

De Coster, K., and Loots, G. (2004). Somewhere in Between Touch and Vision: In Search of a Meaningful Art Education for Blind Individuals. *International Journal of Art and Design Education* 23: 326–334.

De Luca M. (2007). Comunicazione ed educazione museale. in *Comunicare la cultura*, 97-106. Milan: Franco.

Di Guseppantonio Di Franco P., Camporesi C., Galeazzi F., and Kallmann M. (2015). 3D Printing and Immersive Visualization for Improved Perception of Ancient Artifacts. *Presence* 24, 3: 243-264.

Dood J., and Sandell, R. (1998). *Building Bridges: Guidance for Museums and Galleries to develop New Audiences*. London: Museums and Galleries Commission.

Dudley, S. H. (2010). Museum Materialities: Objects, Sense and Feeling. in *Museums Materialities: Objects, Engagements, Interpretation*, edited by S. H. Dudley, 1-15. Oxon: Routledge.

Dudley, S. H. (2012). *Museum Objects: Experiencing the Properties of Things*. London: Routledge.

Dudley, S. H. (2015). What, or Where Is the (Museum) Object?: Colonial Encounters in Displayed Worlds of Things. In *The International Handbook of Museum Studies: MuseumTheory*, edited by Witcomband K. Message, 41-62. Chichester: John Wiley & Sons.

Eardley, A., Mineiro, C., Neves, J., and Ride, P. (2016). Redefining Access: Embracing Multimodality, Memorability and Shared Experience in Museums. *Curator: The Museum Journal* 59: 263-286.

Gallace, A. and Spence, C. (2010). The Science of Interpersonal Touch: An Overview. *Neuroscience and Neurobehavioral Reviews* 34: 246–259.

Gibson, I., Stucker, B., Rosen D. (2015). Additive Manufacturing Technologies. Springer-Verlag NY, 978-1-4939-2113-3, https://doi.org/10.1007/978-1-4939-2113-3.

Götzelmann, T. (2017). 3D-Druck für blinde Menschen: Vom statischen Druck zu interaktiven Objekten. *Informatik Spektrum* 6.

Goulding C. (2000). The Museum Environment and the Visitor Experience. *European Journal of Marketing* 34: 261-278.

Jafri, R., and Ali, S. (2015). Utilizing 3D Printing to Assist the Blind. In *International Conference on Health Informatics and Medical Systems (HIMS'15)*. Las Vegas, Nevada.

Jansson-Boyd, C. V., and Marlow, N. (2007). Not Only in the Eye of the Beholder: Tactile Information Can Affect Aesthetic Evaluation. *Psychology of Aesthetics, Creativity, and the Arts* 1: 170–173.

Krantz, G. (2013). Leveling the Participatory Field: The Mind's Eye Program at the Guggenheim Museum. *Disability Studies Quarterly* 33, 3.

Hoyt, B. O. (2013). Emphasizing Observation in a Gallery Program for Blind and Low-VisionVisitors: Art Beyond Sight at the Museum of Fine Arts, Houston. *Disability Studies Quarterly* 33, 3.

Hetherington, K. (2000). Museums and the Visually Impaired: The Spatial Politics of Access. *The Sociological Review* 2, 48: 444-463.

Hetherington, K. (2003). Accountability and Disposal: Visual Impairment and the Museum. *Museum and Society* 1: 104–115.

Lillard, A. S., and Else-Quest, N.M. (2006). An Evaluation of Montessori Education. Science, 313: 1893–1894.

Montessori, M. (2013). *The Montessori Method*. Transaction Publishers.

Navarro I., and Fonseca, D. (2012). Architecture Degree Project: Use of 3D Technology, Models and Augmented Reality Experience with Visually impaired Users. *Systemics, Cybernetics and Informatics* 10, 2: 57-62.

Neumüller, M., and Reichinger, A. (2013). From Stereoscopy to Tactile Photography. *PhotoResearcher* 19: 59–63.

Neumüller M., Reichinger A., Rist F., and Kern C. (2014). 3D Printing for Cultural Heritage: Preservation, Accessibility, Research and Education, in *3D Research Challenges in Cultural Heritage*, edited by M. Ioannides and E. Quak, 119-34. Heidelberg: Springer.

Melendreras, R., Marín, T., Sánchez, P. (2020). Flujo de trabajo para la digitalización 3D mediante fotogrametría de las tallas de madera policromada del Santísimo Cristo de la Sangre y su ángel. *E-rph,* 27, 52-83. https://doi.org/10.30827/e-rph.v0i27.17901

Melendreras, R., Marín, T., Sánchez, P. (2022). Comparative analysis between the main 3D scanning techniques: Photogrammetry, terrestrial laser scanner and structured light scanner in religious imagery: The case of the Crist of the Blood. *Journal on Computing and Cultural Heritage,* 15, issue 1, article n.18, pp.1-23. https://doi.org/10.1145/3469126

Melendreras, R., Marín, T., Sánchez, P. (2022). The sculpture of the Christ of the Blood: Structural mechanical analysis based on 3D models and video techniques for the study of recurrent pathologies. Journal of Cultural Heritage, 54, pp. 59-67. https://doi.org/10.1016/j.culher.2022.01.001

Rappolt G., and Daley S. G. (2013). Providing Access to Engagement in Learning: The Potential of Universal Design for Learning in Museum Design. *Curator: The Museum Journal* 56, 3: 307-321.

Reichinger, A., Garcia, H., and Travnicek, C. (2018). Designing an Interactive Tactile Relief of the Meissen Table Fountain. in *Computers Helping People with Special Needs*, 209-16. New York: Springer.

Remondino F. (2011). Heritage Recording and 3D Modeling with Photogrammetry and 3D Scanning. *Remote Sensing* 3, 6: 1104-1138.

Rovidotti T. (2004). Multisensorialità come chiave di accesso al museo per persone con limitazione visiva. *Tiflologia per l'integrazione* 11, 4: 24-27.

Scopigno R., Cignoni P., Pietroni N., Callieri M., and Dellepiane M. (2014). Digital Fabrication Technologies for Cultural Heritage (STAR). in *Eurographic Workshop on Graphics and Cultural Heritage*, edited by R. Klein and P. Santos. Darmstadt: Eurographic Association.

Scopigno R., Cignoni P., Pietroni N., Callieri M., and Dellepiane M. (2017). Digital Fabrication Techniques for Cultural Heritage: A Survey. *Computer Graphics Forum* 36: 6-21.

Solima L. (2014). Digital Resources and Approaches Adopted by User-Centred Museums: The Growing Impact of the, in *Handbook of Research on Management of Cultural Products: E-Relationship Marketing and Accessibility Perspectives*, edited by L. Aiello, 181-189. Hershey: IGI-Global.

Solima, L., and Tani, M. (2016). Do not Touch! How 3D Printing can open the way to an accessible museum! in *XXVIII Sinergie Annual Conference: Management in a Digital World. Decisions, Production, Communication.* Udine: University of Udine.

Solima L. (2012). *Il museo in ascolto. Nuove strategie di comunicazione per i musei statali*. Soveria Mannelli: Rubbettino.

Spence, C, and Gallace, A. (2008). Making Sense of Touch. In *Touch in Museums: Policy and Practice in Object Handling*, edited by H. Chatterjee, 21-40. Oxford: Berg.

Spence, C. (2010). Multimodal Interactions: Visual-Haptic. In *Encyclopedia of Perception*, edited by E.B. Goldstein, 597-9. Los Angeles: Sage.

Tacha, A. C. (1963). Brancusi: Legend, Reality and Impact. *Art Journal* 22: 240–241.

Vermeersch, P. W., Schijlen, J., and Heylighen, A. (2018). Designing From Disability Experience: Space for Multi-sensoriality. in *Proceedings of the Participatory Design Conference*, Hasselt & Genk, Belgium, 20–24 August.

Vescovo F. (2002). Accessibilità. *Paesaggio urbano* 1: 9-11.

Walters D. (2009). Approaches in Museums Towards Disability in the United Kingdom and the United States. *Museum Management and Curatorship* 24, 1: 29-46.

Wang, S. (2020). Museum as a Sensory Space: A Discussion of Communication Effect of Multi-Senses in Taizhou Museum. *Sustainability* 12, 7, 3061.

Williams, T. R. (1966). Cultural Structuring of Tactile Experience in a Borneo Society. *American Anthropologist* 68: 27–39.

Wilson, P .F., Stott, J., Warnett, J. M., Attridge, A., Smith, M. P. and Williams, M.A. (2018). Museum Visitor Preference for the Physical Properties of 3D Printed Replicas. *Journal of Cultural Heritage* 32: 175-185.

Wilson, P., Stott, J., Warnett, J., Attridge, A., Smith, M. and Williams, M. (2018). Evaluation of Touchable 3D-Printed Replicas in Museums. *Curator: The Museum Journal* 60, 8.

Wilson, P., Griffiths, S., Williams, E., Smith, M. P., Williams, M. A. (2020). Designing 3-d Prints for Blind and Partially Sighted audiences in Museums: Exploring the needs of those living with sight loss. *Visitor Studies* 23, 2. https://doi.org/10.1080/10645578.2020.1776562