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Experiencing art by means of 3D printed replicas: enriching the interpretation of pot oiseau

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Figure 1: *a) Pot Oiseau licensed by Pablo Picasso (original artefact) ; b) 3D model of the pot; c) 3D printed replica of the pot.*

Abstract

Digitally fabricated artefacts or 3D replicas have the potential to enrich the interpretation of cultural assets by enhancing visitors' engagement with collections. However, it is still not well understood how replicas work as interpretative means and what are the actual visitors' attitudes towards them. The contribution of this paper is the development and evaluation of a 3D replica within a realistic interpretative scenario. This research deploys a case study focusing on a 3D printed pot representing an "authentic" reproduction of a pot made by Pablo Picasso, currently exhibited at the Brighton Museum and Art Gallery. By detailing the research processes and evaluation results, CH professionals can better perceive the dynamics of replicas as interpretative means within realistic situations; understand their positive contributions and weaknesses; and deploy methods and investigation themes, as presented in this paper. In this way, cultural heritage institutions and especially museums can be assisted when introducing replicas to support their audiences. The developments presented in this paper are part of a larger research project which proposes experience designs or experiential frameworks for the provision of 3D replicas to audiences. Our findings highlight that while there is enormous potential, there is also a need to re-educate people on how to engage with cultural heritage through new interpretative frameworks that are less rigid than those traditionally used in museums.

CCS Concepts

•***Computing methodologies*** → *Computer graphics;* •***Applied computing*** → *Arts and humanities;*

1. Introduction

Terms such as the "Next Industrial Revolution" or "Manufacturing Revolution", suggested by [And10, Mot11, Ber12], have been deeply connected with fabrication technologies and especially 3D printing, as these are gradually affecting not only the way material goods are produced, but the access people have to processes, services and products.

The cultural heritage (CH) sector has inevitably been one of the fields where digital fabrication technologies are being applied for a variety of purposes, such as conservation, restoration, exhibition loans, packaging, educational and creative activities. [NL, NRRK14, SCP*15, SCP*15, BBG17]. Lately, these efforts have also expanded to include the deployment of digital fabrication for repatriation processes [HEJ*13] and even controversial artistic activism against colonialist ownership of CH knowledge [Voo16, NAB16].

This paper focuses on the use of digitally fabricated artefacts or 3D replicas, as they are widely known, as "engagement vehicles" for the visitors of a CH setting. Hence, these are 3D replicas that mostly contribute to the realm of CH communication by enhancing education, learning, enjoyment, appreciation, skills, emotions and other connections to CH.

Traditionally made replicas have existed in the CH scenery for a long time working for communication purposes too. However, 3D

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replicas constitute innovative powerful means that lower the barrier for accessing and creating artefact copies both technically and cost-wise, contributing in this way to the democratisation of CH. These 3D replicas are also future-proof as they can be easily reproduced. Moreover, 3D replicas allow to protect original artefacts from handling and are safe for visitors, as they can be produced in a variety of durable nonhazardous materials. Amongst the main advantages of the digitally fabricated replicas over the traditional ones is that they provide the ability to change and manipulate the 3D replicas prior to their production in a way which was not achievable before. Hence, it is possible to easily manipulate the level of accuracy of a replica or even change its attributes and characteristics to satisfy visitors' requirements, contextual factors and even creative purposes. Such wide range of capabilities opens a huge area of opportunities and challenges for CH organisations interested in incorporating 3D replicas as part of their communication strategies. Therefore, the CH community is in need of detailed examples of replicas' deployment, along with a set of principles which can support the decisions of CH professionals regarding the adoption of 3D replicas as interpretative means.

To address these needs, the paper presents research which is part of a larger research project aiming at proposing effective ways to incorporate 3D replicas in interpretative contexts. The broader research conceptualises the interpretation of CH artefacts, by analysing a set of properties and general themes, when 3D replicas are used as part of an experience. Here, the framework is presented through the deployment of a replica to support the interpretation of the "Pot Oiseau" which is exhibited at the Brighton Museum and Art Gallery. Moreover, the paper includes findings about the effectiveness of the replica in terms of its physical characteristics (i.e. sensorial properties) and the audiences' perception of such experience.

The paper is structured as follows. Section 2 presents related work concerned with replicas as interpretative means. Section 3 describes the research reasoning and framework along with the design of the case study. Section 4 includes contextual information about the museum, the artefact and its artist. Section 5 presents the development of the replica and the complementing digital media, while section 6 discusses the evaluation of the case study. Section 7 is dedicated to discussion and conclusions along with future work.

2. Related work

Digital fabrication technologies and especially 3D printing are gradually establishing a stronger presence in the heritage domain. [SCP*15, SCP*14, BBG17] reviewed a variety of applications where these technologies facilitate CH management processes.

With regards to the communication of CH information, replicas "invite" audiences to have more holistic experiences of artefacts that are usually out of reach, placed behind glass displays or not physically accessible. In this way, replicas become interpretative means and can be included in an exhibition along with text, photographs and other informative content. Gradually, heritage organisations incorporate replicas into their experiential framework as standalone exhibits (with or without the original artefact) to support understanding, appreciation and enjoyment of CH.

Figure 2: *Replica as interpretative material in the new Archaeology Gallery of the Brighton Museum and Art Gallery.*

There are many examples of using digitally fabricated replicas as supportive material in exhibitions. For instance, [GBD*14] mention that for the exhibition of the Etruscan heritage at the Museum of the History of Bologna a detailed full-size 3D print of the Sarcophagus of the Spouses (located in Rome) would be presented in the didactic area of the museum. Hence, people would be able to access by sight and touch an iconic artefact of the Etruscan world which is located elsewhere. Furthermore, the authors argue that having the 3D print along with a variety of digital applications at the centre of the exhibition could lead to better results, satisfying both cultural institutions and the public.

3D printed reliefs representing illustrations of Santiago Ramón y Cajal, the father of modern neuroscience, have also been included in an exhibition that the National Institutes of Health organised in USA under the Intramural Research Program in 2014. The digitally fabricated reliefs were presented along with Cajal's original illustrations to support the exhibition experience in more holistic tangible ways [Nat15].

Amongst the protagonists in the scenery of digital fabrication, the company Factum Arte and Factum Foundation, have produced several replicas -or facsimiles as they prefer to call them- of artworks that have been presented in exhibitions or used for a variety of purposes (conservation, restoration and other). Some of their projects can be found on the company's and foundation's websites [Faca, Facb]. One of their most well-known projects is a replica of Tutankhamun's tomb in the Valley of the Kings in Egypt, which is accessible for the public.

Lastly, the Brighton Museum and Art Gallery itself has deployed 3D printed replicas in its new Archaeology Gallery (launched in January 2019) to enhance visitors' engagement with artefacts and local history narratives in more profound ways. An example is the

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replica of the neolithic Whitehawk chalk block, which is available for people to touch and is placed close to the original artefact that is located in a glass display (see fig.2). The museum also deployed a replica-puzzle as hands-on activity for children to enjoy, while engaging with pottery artefacts from its collections [RS18].

3. Research framework for the interpretation of replicas as part of the CH experience

In order to understand how 3D replicas can enhance the interpretation of CH artefacts, the research conceptualises such experience as the constant negotiation between the physical, personal and social contexts [FD92, FD13]. The research also investigates how 3D replicas are perceived and what is the outcome of an experience that includes the encounter with a replica. To investigate this, a case study was designed in collaboration with the curator of Decorative Art at the Brighton Museum and Art Gallery. The study examines how a target audience responds to the use of a replica within an interpretative framework and how this experience can be evaluated through the quantitative and qualitative means that we propose.

Museum walks or field walks [AM16] proved to be valuable methodological tools to employ when designing the case study. Hence, when discussing with the Decorative Art curator about fabricating the replica of an object, while walking around the galleries, the curator suggested some of the "highlights" of the collection. These were objects with interesting appearance, form or story around them. Such objects usually intrigue visitors and are often used by the curators as "engagement vehicles" when organising a talk or workshop. After such a museum walk, a list of objects that could be good candidates for replication was generated. This list was further examined with respect to feasibility as for the imaging and fabrication processes and the bird pot was chosen.

The bird pot (pot Oiseau by Pablo Picasso) is exhibited in the "flagship" gallery of the Brighton Museum and Art Gallery [Roya]. Apart from the fact that it was made by a famous artist, the pot constituted a good candidate, as it has a matte finish that allows acquisition by a structured light scanner and a rather unusual shape that would demand some experimentation during the fabrication phase. Moreover, this particular artefact could initiate an discussion about value and authenticity, as the object in the glass display of the museum is an "authentic replica" of a Picasso's ceramic, made by the workshop that he personally licensed to replicate his designs. The interpretative experience around the pot was also enhanced by complementary audio-visual content which supported the physical and tactile exploration of the replica.

The target audience for this study consisted of random adult visitors of the Brighton Museum and Art Gallery. The participants might have either been people without previous experience in the arts and heritage or people with some kind of connection to CH (i.e. working in a CH institution, archive). The data collection included information about past experience and specialist knowledge, in order to examine whether requirements with respect to replicas change when people have a closer relationship with CH. The selection of this audience was also related to museum figures and strategic plans. Brighton Museum and Art Gallery is mostly visited by adult people who belong to the age group of 45-54 followed by the groups of 25-34, 35-55 and 55-64 [TPBD16]. Furthermore, the organisation recognises that technology and its applications offer a wide range of opportunities to engage audiences and enhance visitor satisfaction by enriching the interpretative means for its exhibits [Roy16].

The following sections will provide more detail about the artefact itself and the development of the experiential framework.

4. The context of the exhibit

4.1. Collection and Pot oiseau

The Decorative Art collection of the Brighton Museum and Art Gallery has been designated of National Importance by the Art Council England. The collection includes artefacts that date from 1750 to present. Two of the museum's galleries are dedicated to Decorative Art by showcasing furniture, glass objects, ceramics, metalwork, textiles and other works of art [Royb].

Figure 3: *a) Pot oiseau; b) stamp of the Edition from the Madoura workshop on the bottom of the pot.*

Pot oiseau (bird pot) is part of collection and is exhibited in the 20th Century Art and Design gallery, which is the "flagship" gallery of the museum [Royc]. The pot was donated to the museum in 2012 by the art collectors and philanthropists Jean and Eric Cass through the Contemporary Art Society.

Pablo Picasso's playful attitude, his influences from traditional pottery and his creative spirit are all evident in the case of Pot oiseau (see fig.3-a). The artist takes advantage of the whole shape of the vessel to create his bird creature. Picasso employs the available space to paint his figures but maintains a sense of balance between colours and images. As the porous surface of pottery absorbs colour fast and does not allow alterations in strokes, the hand of the artist must have been fast and sure when decorating the original design. His technique would then be replicated by the craftsmen in Madoura to create several editions of this pot (see section 4.2 about Picasso's editions). As shown in fig.3-b this particular edition is number 134 of a series of 300 pots that were produced based on the original design by Picasso.

4.2. Picasso as a ceramicist

Picasso is mostly known as a painter and sculptor. However, his work in ceramics is what he dedicated himself to in the last decades of his life, when having an already matured artistic expression.

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Pablo Picasso (1881-1973) became fascinated with pottery after visiting the Ramié's Madoura workshop in Vallauris, a coastal area in Southern France. Picasso got impressed by the workshop and the potters' skills. He recognised the opportunity to engage into a new artistic exploration. He moved to Vallauris in 1948 and stayed there for seven years. Then he moved to Cannes but kept on collaborating with the workshop. Picasso produced more than 3500 ceramic designs over his lifetime [dW03].

Picasso, not a potter himself, quickly reconfigured traditional ceramic working methods. Hence, he either decorated, modelled and manipulated forms that the master potters produced for him or used the standard shapes that were produced at Madoura. The artist learned all the methods to paint and fire clay and even invented his own methods to decorate ceramics [AT67, Tac98, New07].

The fact that pottery naturally includes the process of replication was also acknowledged by Picasso, who wanted his ceramics to be accessible to everybody. With this stance in mind, he agreed to allow the workshop to market his ceramics. In order to produce replicas, the Madoura craftsmen were trained to use Picasso's techniques. Impressed by the quality of work, Picasso kept authorising Madoura to produce and sell editions of his original designs till the end of his life [New07].

The artistic style of Picasso's ceramics reflects his revolutionary work in cubism and often presents surrealist characteristics too. Place, history and tradition also play an important role. Hence, there are clear associations between Picasso's pottery and ancient Mediterranean subjects. Ancient gods, mythological creatures and animals with peculiar shapes appear on his works. These creatures never correspond exactly to classical prototypes and are rather interpreted uniquely by the artist's creativity [New07, dW03].

With ceramics, Picasso re-examined the relationship between forms and space and "broke" the boundaries between painting and sculpture. By experimenting with a variety of themes, materials, techniques and media, he demonstrated his remarkable creativity, expressive possibilities, artistic diversity and playfulness in the last twenty-five years of his life. In addition, his work invigorated the artistic work of potters in the 1950s [dW03, AT67, New07].

5. Development of the replica and digital media

5.1. Production of 3D printed pot

The methods that are usually deployed to digitise the shape and, to a certain extent, the appearance of a heritage artefact include photogrammetry, 3D scanners and depth-sensing devices. In this case, the shape of the pot was acquired by using the AICON3D SmartScan structure light scanner. The artefact was scanned inside a black gazebo that was set up in the Museum Lab. The gazebo ensures that light cannot enter the scanning area, optimizing scanning conditions and hence results.

The 3D model of the pot was then processed in the SmartScan processing software Optocat to fill holes produced as a result of the scanning process. This process produces a 3D model of the artefact with an accuracy of up to 0.01 mm (based on scanner's documentation). The resulting 3D model is shown in fig. 1-b and fig. 4.

In order to produce an accurate replica, the pot was printed on a 1:1 scale. The 3D model was cut into three pieces to fit on the deposition bed of the printer. Partitioning was done without deploying an automated solution, however 3D mesh decomposition can be done by exploring automated methods as well [LBRM12]. Subsequently, all pieces were printed in white PLA (Polylactic Acid) filament on a FDM (Fused Deposition Modeling) Fusion3 F400 3D printer. The pieces were afterwards pasted together, and post-processing steps took place in order to create a pot that would look and feel as close as possible to the original.

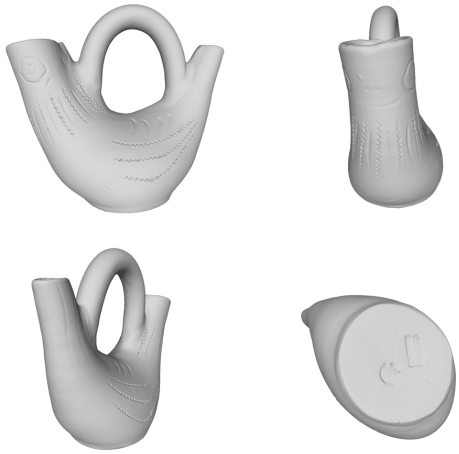

Figure 4: *Different views of the 3D model of the bird pot.*

Some of the key design requirements were:

Shape: The shape had to be kept as close as possible to the original, hence the three prints were carefully pasted together, and small amounts of plaster were added on the areas where the prints joined. Excessive plaster was sanded after drying.

Texture: In order to acquire a texture that would feel close to ceramics, the pot was covered with several layers of a mixture of PVA (Polyvinyl acetate) glue, marble powder, white acrylic colour and water. The whole pot was afterwards lightly sanded to acquire a more even texture. The pot was then given to an artist to work on its decorative aspect. The artist added depth to the areas of scored decoration using wood engraving tools and additional sanding.

Colour: The artist painted the replica to match the original pot and darkened some of the scored areas of the replica to create an illusion of depth. Then, parts of the handle were discoloured to replicate signs of handling that are evident on the original and applied acrylic colours to match the decoration of the original pot. In the end, the exterior of the pot was sprayed with matte varnish to recreate the unified finish of the original. The several stages of work to replicate the appearance of the pot are depicted in fig. 5.

Gloss: Several coats of Golden GAC-200 acrylic glaze were applied in the interior of the replica and around its rim to replicate the appearance of glaze as it looks on the inside of the original pot.

Weight: The weight of the printed replica was very light and very far from the weight of the original pot, which weighs 1418gr. Thus,

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Figure 5: *Various stages of post-processing and painting the bird pot replica. The original pot is used as a reference. Photos courtesy of artist Russell Webb.*

plaster in liquid form was gradually poured into the pot and left to dry. The final weight or the replica after this process was 1082gr.

The average times for the different phases of the production of the pot are as follows: 3D scanning-3h, digital processing-6h, 3D printing-16h, physical post-processing (sanding, pasting, primer application)-8h, painting-16h.

5.2. Development of video and application

A video to complement the original artefact and its replica was also produced to provide extra interpretative information and support the visiting experience (see fig. 6). The video was produced in Apple's video editing software iMovie 10.1.12 and then an application was developed using Android Operating System (OS) by deploying the Android Software Development Kit (SDK) in order to loop the video on a Samsung Galaxy Tab S3 (2017), 9.7" 32 GB tablet.

The video was delivered through an Android app which was developed using Java. The video player application enabled the user to play, pause and restart the video by using the Android Media API. The app prevented the user to exit the application.

Videos have proved to be valuable additions to exhibitions as they present an audiovisual narrative that is dynamic and interesting, while conveying information that can demonstrate processes and present complex stories about an artefact or theme. The video was short in order to have a stronger holding power with respect to visitors' attention [Ser10]. The final duration of the video, after a number of revisions in collaboration with the Decorative Art curator of museum, was two minutes and twelve seconds (2:12).

The video was developed around four sections with some textual information and visual material about: a. Picasso's move to Vallauris and South France; b. his work with pottery; c. the licensed editions and original imprints that the Madoura workshop produced as replicas; and d. pot oiseau. Fragments from the 1954 documentary "Incontrare Picasso" by Luciano Emmer, featuring Picasso forming a similar bird pot, were included in the video. Music was also added to enrich the experience. The piece that was selected was "Danza Espanola No. 1" from the opera "La vida breve", written by Manuel de Falla in the beginning of the 20th century. Picasso himself had collaborated with Manuel de Falla in 1917 for the ballet "The Three-Cornered Hat or Le tricorne". Manuel de Falla had written the music for the ballet, whereas Picasso worked on the set decoration and costumes of the opera [BS06].

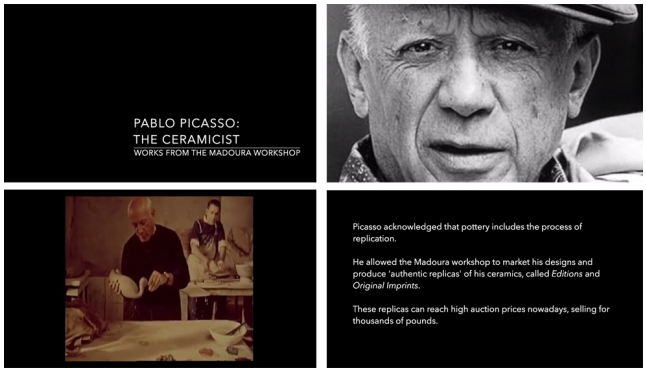

Figure 6: *Screenshots from the video. Textual information and images (image of Picasso from Wikimedia, under Creative Commons) along with video fragment from 1954 documentary Incontrare Picasso by Luciano Emmer.*

6. Evaluation

6.1. Evaluation design and participants

The evaluation of the proposed experiential framework took place at the Brighton Museum and Art Gallery in spring 2019. The evaluation aimed to investigate: a. how visitors respond to the physical characteristics of the replica; and b. the evidence about the outcome of such experience in terms of learning, enjoyment, appreciation, inspiration and so forth.

Both quantitative and qualitative data were collected. Data collection methods included semi-structured observations, questionnaires and semi-structured interviews. As the research topics draw on relativist constructivist theories, emphasis is given to the contextual aspects of the CH experience as well as the outcome of such experience [FD92, FMC98, FD13]. The outcome illustrates the role of replicas under a set of themes reflecting on CH interpretation through awareness/knowledge; engagement/interest; attitudes; behaviours; skills [Art14, DHU16]. The design of the evaluation had already been tested with another replica and target audience group and provided an interesting insight with regards to audience engagement with 3D replicas [SE19].

In total, thirty-two (32) random adult visitors participated in the research. Observations happened first without disrupting the visiting experience. Then, the participants were approached and asked

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Figure 7: *Setup for the replica and video application in front of the display with the "authentic replica" of the bird pot.*

to provide informed consent in order to allow the use of the observation notes. Observation notes included information about the social context of the visit, the social interactions that the replica might have triggered and the physical context of the experience in terms of physical handling, attention to media and issues related to usability. Participants were also asked to provide their feedback about the experience through a short questionnaire which examined the overall impression of the experience of the replica and asked visitors to rate the replica and complementing media on a five-point satisfaction scale. An interview then followed to investigate the qualitative outcome of the experience in terms of awareness/knowledge; engagement/interest; attitudes; behaviours; skills.

6.2. Pilot study and lessons learned

Before proceeding with the bulk collection of data, a pilot study was conducted. Hence, the setup for presenting the replica and complementary digital media along with the position of the observation and interview area were tested.

Two people, volunteering at the museum, participated in the pilot study. The 3D printed replica was placed on a table in front of the display with the original artefact. A tablet with the video playing on loop was also placed on a stand and a label with the phrase "Please touch" complemented the whole setup (see fig. 7). The participants were invited to the area were the exhibit was and interacted with the replica. Observation notes were kept while participants were exploring the exhibit and interpretative media. When the exploration had finished and after giving informed consent, participants were provided with a questionnaire to fill in about the properties of the replica, the quality of the complementary media and other questions related to the contextual parameters of the experience. Each session ended with a short interview that was audio recorded.

The pilot study has proved very useful as it revealed issues that should be taken into consideration for future data collection sessions. Some of the topics that came up, resulted from observing the participants and asking them about the experience and others were discussed directly with the curator of Decorative Art right after the initial trials.

Some of the details were related to:

- the appearance of the textual information (font size) on the video and on the label
- the volume of the music from the video that was kept at a medium level to prevent visitor distraction
- an intervention on the code of the video application to prevent the tablet from going into sleep mode
- the position of the replica in a direction that imitated the position of the original to emphasise somehow its connection with it
- the observation and interviews spot, which was located at a distance that allowed observing visitors without being too intrusive.

Lastly, an issue that was discussed on the pilot day but became obvious during the first day of bulk data collection was that visitors were reluctant to touch the replica. Even though we had placed the label with the phrase "Please touch" on the table, it was surprising to notice that visitors would occasionally touch the table, the tablet, and the label itself instead of trying to touch the replica. For this reason, the phrase on the label was changed to become more explicit by motivating visitors to "Please touch the pot".

6.3. Findings

The following paragraphs reflect the evaluation findings from thirty-two (32) adult participants who interacted with the 3D printed replica of the bird pot at the Brighton Museum and Art Gallery. For the data analysis, a thematic structure is deployed focusing on the personal, social and physical context of the experience as well as the outcome of such experience.

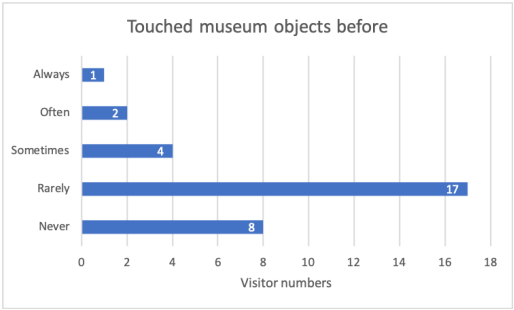

Figure 8: *Previous experience in touching objects.*

Personal context. Eighteen (18) participants were women and fourteen (14) were men. In many instances it was noticed that women were more wiling to take part in the research or men were happy to give their place to women. Hence, there was an effort to balance sample. Most of the participants were of white ethnic background (27 amongst the 32 participants). The group of visitors over the age of sixty (60+) is overepresented in the research as eighteen (18) participants belonged to it. Eight (8) more participants were in the age group of 50-59, three in the group of 40-49, four in the group 25-39 and four in the younger group of 18-24 years old.

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Fifteen (15) visitors came from the local area (distance of less than 10 miles away from the museum) and others from afar (maximum distance was around 6000 miles). The vast majority of participants (31 people) had visited a museum before but their visiting pattern differentiated. Hence, seventeen (17) of them would have visited a museum up to ten (10) times a year, whereas eight (8) would have visited a museum more than ten (10) times a year and even up to ninety (90) times a year. Some visitors did not share information about distance of residence. Amongst the fifteen participants who had not visited Brighton Museum and Art Gallery before, eight (8) lived at a distance of more than 200 miles away from the museum. Only one lived locally at a distance of 2 miles away from the museum.

Table 1: *Tendencies in participants' expectations.*

Visitor No	Expectations (tendencies)
8	Explore a specific collection (e.g. Egyptology, local archaeology, paintings) and learn about local history
7	Be inspired to make art / work on creative activities
6	Explore collections / general visit
3	Learn and be inspired
3	Nothing in particular (no expectation)
1	Do voluntary work
1	Meet someone
1	Expected to touch artefacts
1	Not expected to be able to touch anything
1	Expected to be asked about the experience

As far as it concerns previous experience, twelve (12) participants claimed that they had some connection to CH through their professional or voluntary work. Twenty (20) participants had used technology in museums before and twelve (12) had not. However, most of the second ones belonged to ages above fifty and might have not felt confident to use technology in a CH setting. As for touching museum objects before, the results are not surprising as most people had never of rarely touched museum objects before as fig. 8 reveals. Amongst the three that were always or often touching museum objects, one had previous experience as a museum volunteer and one as an artist.

People's expectations were also recorded in order to find out what people were looking forward to do during their visit. Table 1 describes expectation tendencies. In terms of people's interests when visiting the museum, most participants said that they did not have a specific interest; some were interested in all collections or interested in specific collections; and one participant mentioned that was interested in the history of the Royal Pavilion in Brighton.

The **social context** of the experience is related to the composition of visit, the social environment and the interactions within a group or between groups. Indeed most of the participants came to the museum with someone else (21 out of the 32 participants). When the area was crowded it was not always easy for people to pay attention to the exhibit and interpretative content.

As for interactions between the members of a group, these were mostly of verbal character. The majority of visitors discussed about 3D printing and 3D technologies, the resemblance of the replica

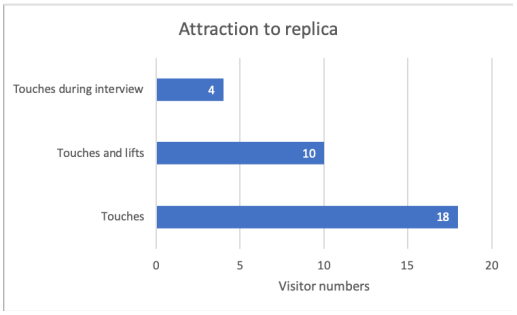

Figure 9: *Types of attraction/interaction with the replica.*

pot to the "original", and compared the replica to it. Some also discussed about Picasso, his work and the way that he was shaping pots, as demonstrated in the video. A great number of interactions was dedicated to the possibility to touch. Some visitors were turning with surprise to their friends or family when they read the label with the phrase "Please touch the pot" and pointed to it. Some of their quotes were: *"Look!", "Look! It says please touch!", "This is perfect! Can I touch?", "It says please touch!"*. All these quotes along with visitor's comments during the interview corroborate that people are reluctant to touch and when they are given the opportunity to do so, they become skeptical, surprised or even scared (one participant mentioned that he was expecting the alarm to be triggered by touching the replica).

Lastly, some more physical interactions included people bringing their friends and siblings to the area where the replica was placed to show it to them; pretending to pour liquid out of the replica pot; and even posting photos of the original on social media after inspecting the replica.

The evaluation of the **physical context** of the experience is dedicated to the performance of the replica itself, the location, atmosphere and the interpretative means that are deployed. All participants were able to find the replica easily, as it was placed in front of the display with the "original", in an area adjacent to the central corridor of the main gallery of the museum. Not everybody stopped to pay attention to the setup and exhibit. Hence, the research presents data from visitors who paid at least some attention to the artefact in the display and/or interpretative information. Visitors were attracted by the setup, but not everybody touched the replica. Eighteen (18) participants touched the replica with their fingers without trying to lift it or change its position. Ten (10) participants demonstrated a bolder behaviour and lifted the replica, whereas four (4) touched only during the interview (see fig. 9). Such findings might suggest that people are still very careful when using a sense (i.e. touch) that they are not used to employ when visiting a museum. Therefore, even when they touch, they limit their physical movements to very "modest" levels.

The means/media that visitors paid attention to are presented in fig. 10. Most visitors paid attention to the "original" artefact as well as the interpretative means. Fourteen participants (14) paid attention to all media/means at a time. Only four (4) participants did not pay attention to the original artefact at all. Therefore, we might argue that the presence of the replica in the majority of cases did

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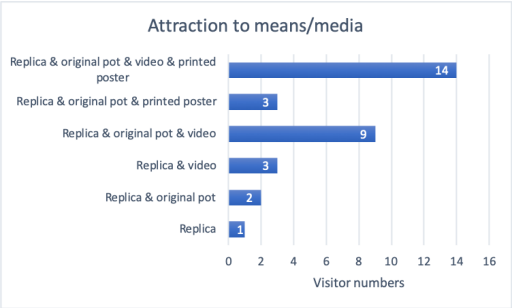

Figure 10: *Visitor attraction to media/interpretative means.*

not distract people's attention from the original artefact in the display. Something that many CH professionals might fear with the introduction of new media into exhibitions and settings.

In addition, the approximate time spent in front of the exhibit and set up with the replica was recorded to be between 2 and 3 minutes for the majority of visitors (22 out of the 32 participants). Time can vary depending on visitors' interests, background or the social aspect of the visit (just to name a few parameters). However, this duration is considerably higher than what other research suggests [Car17] about visitors' attraction to exhibits. Also, spending this amount of time seems significant considering that most visitors do not spend more than 20 minutes in an exhibition [Ser97].

Regarding the attraction to the video about Picasso's work with ceramics: most people watched part of it (15 participants); fewer watched it all (8 participants); some did not watch at all (6 participants); two (2) participants watched it more than one times; and one (1) watched it during the interview. When questioned about the quality of the video the majority of users (24 out of the 32) were "very satisfied" or "satisfied" with it.

When evaluating the replica, people were asked to rate its sensorial properties on a five-point satisfaction rating scale. This was done in order to complement the evaluation of the experience with measurable results as for the features of the replica and does not intend to compromise the importance of contextual parameters when investigating social phenomena. The results of this evaluation are presented in fig. 11.

The results demonstrate that most people were "very satisfied" or "satisfied" with the properties of the replica. Therefore, the aim to create a replica that would be as close as possible to the original, while taking into consideration contextual parameters (e.g. durable material, nonhazardous, easily replaceable, low cost etc) might have proved correct. In some cases, visitors found it difficult to rate some properties such as brightness, reflectance or gloss, thus they were "neither satisfied nor unsatisfied" with them. Same happened with weight, maybe because visitors could not compare that property to the "original" artefact. One participant, however, mentioned that the replica was "surprisingly heavy". Temperature could also be perceived as difficult to rate. As for the durability, one person mentioned that would like the replica to be made of a more durable material. One person, who was "very unsatisfied" or "unsatisfied" with most of the features of the replica, had a close

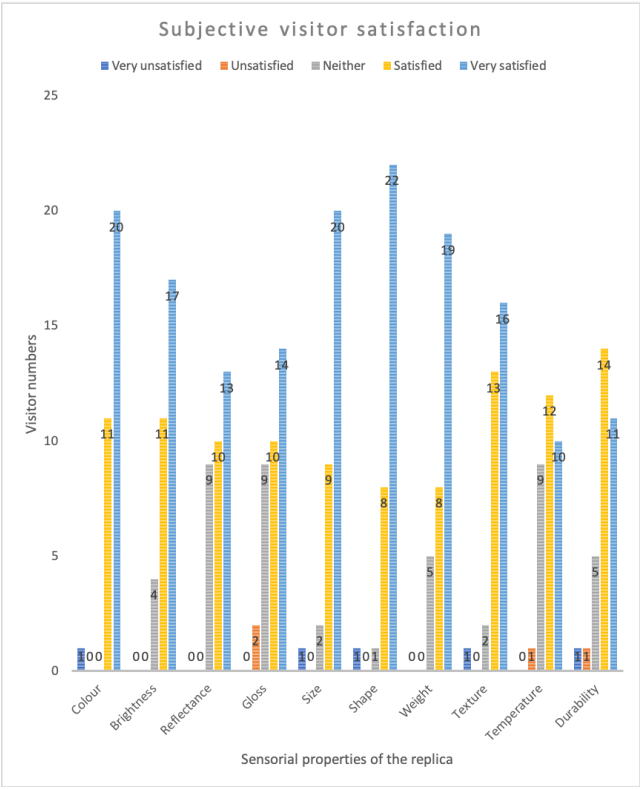

Figure 11: *Subjective visitor satisfaction from the sensorial properties of the replica.*

connection to CH and was very skeptical about the use of technology in general to replicate objects.

Participants also made further comments about the replica and whether it could be improved. One participant would want a protective varnish to be applied on the replica (he did not know that a matte varnish had already been applied); another visitor would want the surface to be more glossy; two people noticed minor differences in the incised decoration between the replica and the "original" bird pot. As for the media, one visitor mentioned that she would want the images on the video to change at a slower pace, while another said that he would want a bigger screen to be placed at the eye level. Generally, there weren't any patterns that could relate people's rating of sensorial properties with previous professional experience in CH, although most of those who proposed improvements had previous CH experience or were involved in artistic activities.

The **outcome-perception of the experience** consists of the analysis of the qualitative data under the five (see section 6.1) proposed themes. Visitors' comments reflecting **awareness and knowledge** as effects of the experience range from learning new facts about Picasso and his work in ceramics, to expanding information that they already knew. In many instances, people were able to recall information that was included in the video or the printed poster or even mentioned details using previous knowledge about the subject matter. Most visitors argued that the replica and complementary video

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helped them to make sense of Picasso's work and build an understanding of the process of making the bird pot. This had happened because -as they said- they were able to have a closer look, hold and explore the replica in front of the display. Few visitors said that the replica was just interesting and had not helped them to discover more information about the artefact or the artist, as they already had vast knowledge of the subject.

People's feedback with respect to **engagement and interest** is related to enjoyment, surprise, emotions and other inspiring aspects of the experience. Surprise was one of many people's first impressions as they were invited to hold the replica. People explicitly mentioned that they enjoyed using more than one senses to explore the pot. Many visitors commented that such experience made them feel closer to Picasso and the "original" artefact, while some were awed and amazed by being able to almost hold a "Picasso". The combination of media was something that most of them mentioned as engaging. Some paid specifically attention to the music of the video or the fragment showing Picasso working on a similar pot. However, the majority admitted that the replica was the most powerful point of attraction, as it is rather unusual to see an object freely available to touch in front of a museum's display. Two visitors said that the experience brought memories related to friends doing pottery or other art exhibitions in different museums. One visitor also mentioned that he was inspired about artwork and that other artists could imitate that too.

The **attitudinal** aspect of the experience might relate to someone's values, self-esteem, beliefs and attitudes towards people or things. Some participants mentioned that such experiences with the provision of 3D replicas allow them to better appreciate and value artefacts, while taking away the "fear of engagement with objects". Most visitors also commented that 3D printed objects would motivate them to go to museums more often (22 out of the 32 participants). Others said that they would go to museums anyway but acknowledged the usefulness of replicas or mentioned that they would do their visit more interesting. Many participants mentioned that 3D replicas would be particularly useful for children, visually impaired visitors and people with learning disabilities. Another visitor proposed the use of replicas as standard educational tools for artists in museums. Lastly, few users mentioned ethical considerations with respect to replicas. Those people generally liked the idea of replicas, but would not want everything to be replicated in a museum, as it makes objects less "special". They also mentioned that CH organisations should be honest when exhibiting a replica and always put that information upfront for visitors to see.

The experience of exploring the exhibit with the support of the replica, the video and the printed information constituted an activity, where people used tactile, observational and often communication **skills**. People's answers regarding knowledge, awareness and engagement witness that those skills were successfully deployed by visitors in many instances (e.g. when recalling information or memories as a result of exploring the replica). Moreover, when visitors were asked, whether they would talk to other about this experience (intellectual and communication skills question), most of them responded positively (27 out of the 32 participants).

The **behavioural** aspect of the experience is closely connected to actions, possible changes in people's lives and progress that might be the outcome of the experience (e.g. further skill acquisition and learning). People commented on the positive contribution of replicas to get closer to artefacts and access CH information by using more than vision. Some have suggested that digitally fabricated replicas could become a standard practice in museums to assist CH interpretation for adults, children, and people with impairment. Three participants also mentioned possible changes in CH management practices, such as the idea of exhibiting replicas in order to protect the originals, the potential to generate income for CH organisations by selling replicas and the possibility to present replicas when CH institutions cannot access or afford original artwork. Finally, some people mentioned that they would take further action by discovering more about replicas and 3D printing.

7. Discussion and conclusions

This paper presented the development and the evaluation of CH experiences, where digitally fabricated replicas are used. The research conceptualises such experiences as a negotiation between the personal, social and physical context, while investigating their outcome in terms of: awareness/knowledge; engagement/interest; attitudes; skills; and behaviours. A case study which was designed and evaluated following the research framework was described. Hence, a 3D printed replica of the Pot oiseau along with digital media was presented to the visitors of the Brighton Museum and Art Gallery and data were collected about the experience.

The analysis of the results demonstrates the great potential that 3D replicas have within experiential frameworks as they enhance: learning of facts about the original artwork; appreciation of the artistic work; awareness of the creative process; triggering of people's interest; recall of memories and emotional connections to the artwork and beyond; deployment of skills and in some instances social interaction. Replicas can also motivate people to visit museums more often and contribute towards the democratisation of CH by offering access to information that was not possible to approach before. Replicas can also assist audiences, such as children and people with impairments to better experience CH. They also have the power to support management processes in the CH sector. However, the results also reveal that people are very reluctant to employ touch as part of their "sensorial apparatus" when visiting a museum. Therefore, CH institutions should re-educate visitors to touch by making clear to them that they can actually touch replicas; and by carefully designing an as much as possible inviting environment for the replica to rest and be handled.

Finally, most visitors did not seem to mind that the replica was not an "authentic" object and appreciated the fact that they could touch it. A certain skepticism about "authenticity" was expressed by few visitors only and was mostly related to the loss of craftsmanship or "artistic work" and "soul" of the artefact. Nevertheless, these people did not deny the usefulness of replicas and mentioned that they would want CH organisations to be honest and state it clearly when exhibiting one.

Future work for the research involves further analysis and presentation of data about other experiential scenarios and replicas. By doing this, we aim to propose a set of principles to assist CH professionals when making decisions about the incorporation of digitally

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fabricated replicas to support artefact interpretation in CH settings and beyond.

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