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MUSEUMS AND NEW CHALLENGES: FROM DIGITAL CURATION TO WELL-BEING ENHANCEMENT. THE CASE STUDY OF THE ARCHAEOLOGICAL COLLECTION OF THE SIGISMONDO CASTROMEDIANO MUSEUM

1. Introduction

The digital revolution we have witnessed in recent years has facilitated the integration of technological tools in both the preservation and enhancement of Cultural Heritage. Furthermore, technology has introduced innovative solutions to improve the accessibility and experience of Cultural Heritage. Notably, the concept of digital curation within this domain remains in development, prompting ongoing discussions among museum curators regarding its precise definition and scope. According to the Digital Curation Centre (UK; https://www.dcc.ac.uk/), digital curation involves maintaining, preserving, and adding value to digital research data throughout its lifecyle. This definition inherently includes the processes of digital archiving and preservation while also extending to the broader practices essential for effective data creation and management. Moreover, digital curation involves the ability to enrich data, thereby generating new sources of information and knowledge. This definition was created for the purpose of being applied to different domains, encapsulating the life cycle of digital data and the process within which curation fits. In the cultural sphere, however, this definition appears to be much more multifaceted, as it is not only concerned with the need to curate the data and information from research, but also with the management, enhancement, and preservation of heritage by means of digital media and technologies.

In the work of Dziekan 2012, the author traces a new role for the curator, and on the new potential for the enjoyment of space after the digital revolution. It is precisely space that is the focus of many scholars' investigation, to build a relationship between the physical exhibition space and new spaces, such as Virtual Reality (VR) and the web. Extended Reality (XR) represents an important tool for 'expanding' the museum space, meeting new public, expanding the concept of visit itself, for example by enabling remote enjoyment.

This study is aimed at evaluating the use of VR as a tool to enable the enjoyment of a museum for a fragile audience, namely people hospitalized in a hospital ward. The application involves the creation of immersive and interactive virtual scenarios, with the possibility of performing certain activities, such as exploring a museum setting, based on museum therapy principles, and practicing stimulating playful-recreational activities, according to art therapy principles. The goal is to assess the impact that museum enjoyment in XR can

have in terms of promoting the psychological well-being of vulnerable people. Indeed, this approach seeks to reinforce theories that conceptualize the museum not merely as a space for public entertainment but as an institution with a meaningful social role within the community. Recent studies have shown how the enjoyment of museums can bring significant benefits to people's health, as the experience is able to act on the sense of identity, with a consequent impact on positive emotions and self-esteem. The United Kingdom is one of the spokesmen for combining culture and well-being and has promoted the establishment of the National Alliance for Museums Health and Well-being to encourage active citizenship and promote subjective well-being practices.

The experiment involved the Sigismondo Castromediano Museum in Lecce and took place at the Prof. Petrucciani Clinic (Lecce). During the campaign, the team used a Meta Quest 2 as VR headset, and two wearable devices for collecting and recording biosignals. This paper describes the methodology adopted with a focus on the storytelling strategy.

2. Extended Reality and Cultural Heritage

Extended Reality (XR) is an umbrella term that encompasses all immersive technologies, such as Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR). All immersive technologies expand the reality we experience by merging the virtual and real worlds or creating a fully immersive experience. In summary, XR refers to all the possibilities of combining real and virtual environments and human-machine interactions generated by computer technology and wearable devices, where X represents a variable that opens a new and broad spectrum of future opportunities (Chuah 2018).

The XR technologies intersects with the larger issue of physical accessibility to heritage sites, as it restores a sense of presence even where this is not feasible in reality. For example, visitors can explore protected natural or archaeological sites that could not otherwise be visited, learn about places that no longer exist, or even immerse themselves in a context that they could not personally visit, due to contingencies and limitations related to their personal sphere (Slater, Sanchez-Vives 2016). For instance, a visitor with motor disability does not have the opportunity to visit the second floor of Shakespeare's birthplace in Stratford-upon-Avon: the operators in charge of managing the site have installed a VR exhibit on the second floor that offers a virtual tour of the upper floor (Disability Rights Commission 2004).

To act on accessibility, a series of virtual or augmented experiences have also been created in the Apulian context: Masseria Torcito Experience is an application developed to put everyone in a position to enjoy a structurally non-accessible environment, that of an underground oil mill, in Salento. The fully navigable virtual model has been enriched with 3D content describing

the functionality of the ancient mill, thus meeting the curiosity of a wide and heterogeneous audience (De Paolis *et al.* 2021). Agnano RiVive is an Immersive Virtual Reality application developed for the Museum of Preclassic Civilizations of the Southern Murgia in Ostuni, where archaeological finds from the Archaeological and Naturalistic Park of Santa Maria di Agnano are preserved. The application gives the user the opportunity to explore the Upper Paleolithic settlement, located within the park, and interact with ancient objects (De Paolis *et al.* 2022b). An immersive VR application was also developed for the Castle of Corsano, a monumental ancient building, located in a small town on the Salento Adriatic coast, currently in a state of abandonment and inaccessible for more than 30 years (De Paolis *et al.* 2022a).

The virtualization of Cultural Heritage also responds to non-immersive fruition needs, while still facilitating both physical and cognitive accessibility processes: of particular interest is the Time Machine project, a multimedia system created by the University of Foggia to facilitate visits to the archaeological collection of the Sicily Foundation at Palazzo Branciforte in Palermo (De Felice 2012). Interaction between objects in the archaeological collection and museum visitors has been entrusted to a natural interface based on simple multitouch gestures such as touch, swipe, pinch, and so on.

Of all the technologies that make up e-health, VR is the one that creates the sense of presence, using immersive, interactive, and collaborative virtual environments. Certainly, the physical presence of the visitor in the museum, as in a place of cultural interest, is encouraged as much as possible, therefore, VR technology can be included in this context as a useful tool to restore a sense of presence where physical presence is not possible due to contingencies related to the individual. VR can also be seen as a tool for practicing playful and therapeutic activities such as art therapy and museum therapy. In this regards the study titled *Benefits of a 3-month cycle of weekly virtual museum tours in community dwelling older adults: Results of a randomized controlled trial* is particularly interesting, since it aims to examine a 3-month cycle of weekly virtual museum tours of the Montreal Museum of Fine Arts (MMFA) may have improved the sense of social inclusion, well-being and quality of life in older adults living in the Montreal community (Deveault 2022).

3. Objectives and methodology: the multi-layer storytelling model

This research aims to experiment VR as a tool for accessibility on the one hand and for promoting the psychological well-being of fragile people on the other. The application involves the creation of immersive and interactive virtual scenarios starting from the archaeological collection and context of the Sigismondo Castromediano Museum in Lecce, with the possibility of carrying out different activities such as exploring museum contexts (museum

therapy) and practicing cognitively-emotionally and behaviorally stimulating playful-recreational activities (art therapy).

After obtaining permission for the acquisition of photographic material from the Soprintendenza Archeologia Belle Arti e Paesaggio for the Provinces of Brindisi and Lecce, we moved on to digitizing the objects identified for storytelling, designing, and developing the VR application, and implementing an experimental protocol that produced some results on the impact on well-being of the use of this tool. The next paragraphs provide an overview of the different steps conducted to outline the methodology and results of the work.

The application aims to provide an alternative, engaging and stimulating tool aimed at improving the state of well-being of frail, hospitalized people using historical and cultural content that can act on well-being. To achieve this goal, the project points to pursue the following specific objectives: to emotionally engage and cognitively stimulate the user by reducing stress, inducing pleasant and relaxing emotional states, and enhancing cognitive functions such as memory, attention, and learning. Additionally, the project seeks to assess the user's well-being before and after the implementation of the protocol by monitoring physiological responses to the proposed activities through specialized sensors.

To detect the effects of the VR experience on users, non-invasive neurophysiological signal recording sensors have been applied during the activities. Through VR, the user is confronted with various artistic stimuli that can induce the feeling of being inside the virtual world.

For this reason, the crucial point of the experience design is the storytelling design. The concept of storytelling has taken on different definitions over the years, partly in relation to its application area. When storytelling comes to be applied to the museum world, and it evolves in parallel with the concept of the museum itself. Similarly, the term museum has taken on different meanings in recent years: from museum of collection to museum of relationship, communication, storytelling, community, and connection, with facets that are gradually different, but never incompatible, but complementary (Bonacini 2020). One of the youngest definitions, that of connection museum, points to storytelling as a tool facilitator of connection, and is shaped by the strong emotional, cognitive, and even technological component. Storytelling is the art of narration, a complex combination of knowledge, technique, and creativity. However, when storytelling is applied within a museum context, technique and creativity must be subordinated to knowledge, serving the museum's core message. Imagination, therefore, must follow well-defined parameters (Dal Maso 2018a, 2018b). Museum storytelling can thus be seen as a complex layering of connections between objects and stories. Starting with the digitization of the artifacts, the experience was modulated based on the stimulation of different senses.

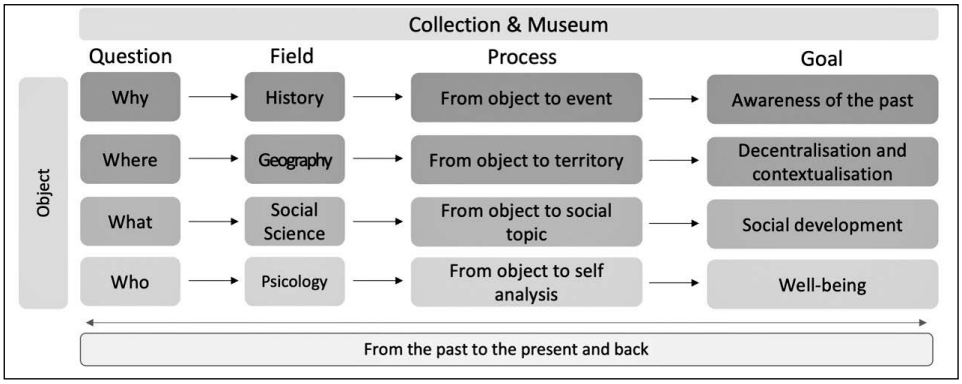

Fig. 1 – Multi-layer storytelling model.

Sight is stimulated through immersion in a virtual environment in which the artifacts can be observed up close in high-resolution, hearing through a sound design based on musical or environmental evocation of the scenes represented on the ceramic artifacts, and touch, through both the possibility of touching 3D-printed reproductions of the figures of the ceramics and the use of an art therapy module in which the user performs a task of modeling a ceramic artifact. The narrative model used for the construction of this experience is referred to as multi-layer storytelling (Fig. 1). In detail, when presenting a museum collection, particularly to a non-specialist audience, the collecting history of the museum itself is often overlooked. That is, we frequently neglect to address the fundamental question: 'Why are these objects here?'

This is the first question suggested by the multi-layer storytelling model. Answering this question means providing the visitor with a deeper awareness of the significance of the studies and the ever-evolving processes that bring to the collection of ancient objects. In the case of the Castromediano Museum, for example, it is necessary to emphasize the importance of the research on the indigenous ancient peoples of the Salento area, since the foundation of the museum itself. Immediately, therefore, the importance of the second level of insight emerges, which poses the question 'Where do these objects come from?'. The collection plays a role as a glue with the territory, and thus the exhibits become real pointers that shift the visitor's attention from the museum to the archaeological sites from which they come. The third plane of analysis is to act on social issues from the objects in the collection, leading the visitor to reflect on the social dynamics of both the past and the present.

Looking at the Castromediano's collection, the main material attestations, as has been pointed out so far, are represented by ceramics: from the analysis of these important finds, we can narrate the changes in social dynamics

in the Messapian context. Finally, the fourth and final layer is one that acts with a view to initiating a more intimate, personal reflection on topics such as childhood, relationship with family, empathy, death, spirituality and so on. This fourth layer of the narrative starts from the desire to contribute about the impact that museums, and therefore their collections, can have on the psychological level of the visitor as individual, and as part of a community.

4. A brief history of Sigismondo Castromediano Museum

The Provincial Museum of Lecce history began in 1868 when the Province of Terra d'Otranto established a commission for the conservation of monuments of art and antiquities. This commission is chaired by Sigismondo Castromediano, duke of Cavallino, and aims to study the history of the territory. In 1968, the Provincial Museum of Lecce was officially founded by a resolution of the Provincial Council of Terra d'Otranto and was entrusted to the care of the same commission. Its main purpose is to collect art objects from the Terra d'Otranto, which includes the southeastern region of the peninsula, known largely as ancient Messapia. Initially, the collection grew through purchases from the antiquarian market and private donations, as there were no museums yet in Taranto and Bari. This led to a variety of objects that often did not correspond to their stated provenance. The first core of the collection was housed in Convento dei Celestini in Lecce, which was the seat of the city government and provincial administration, as well as the museum. Sigismondo Castromediano prepared technical reports to document the museum's activities up to 1875, including acquisitions, excavation campaigns and discoveries. Its museographic organization was innovative for the time, as it sought to communicate with a wider audience (Minerva 2020). However, the museum suffered a period of neglect after Castromediano's death in 1895.

The institution experienced a period of increased attention and reorganization under the direction of Pietro Romanelli and Mario Bernardini in 1920 and 1930. During this phase, the museum further increased its collection through the acquisition of new objects and excavation campaigns in the region. As part of the museum's reorganization, two volumes titled *Corpus Vasorum Antiquorum* were also published (Romanelli 1928). A pivotal moment was the acquisition by the Province of Lecce of the former Collegio Argento palace, with the goal of relocating the collection from Palazzo dei Celestini and setting up a more modern museum. In 1965, the renovation and exhibition design project were entrusted to one of the most prominent Italian museographers, Franco Minissi (1970). His new approach emphasized the museum's interaction with the public and included multipurpose spaces and cultural initiatives. After Bernardini, the direction of the Institute was succeeded by Giovanna Delli Ponti (1980-1994) and later by Antonio Cassiano

(1994-2012). These years mark a period during which the museum employed various sector professionals and invested in the acquisition of equipment for analysis and restoration. Over the years, the museum maintained Minissi's exhibition design and continued its activities until its closure. The museum reopened on June 22, 2019, under the direction of Luigi De Luca, with a new design for the spaces, restoring the original museographic layout by Minissi.

5. Building the digital storytelling: from digitization to the virtual scenes

The storytelling underlying all the work derives from the study and analysis of the Messapic collection and the museum's own collecting history, which is characterized by its important number of Messapic ceramic artifacts, both locally produced and of Greek provenance. In addition, storytelling considers the relationship between the artifacts and their place of origin, playing on the relationship between museum and archaeological site. Going into the details of the storytelling, to select the artifacts to be included within the museum therapy scenario, i.e., in the virtual museum, an analysis of the shapes and figurative themes of the ceramic artifacts present in the Castromediano Museum was carried out.

Quantitatively, Dionysian subjects are commonly attested at archaeological sites in the region, a proportion that is similarly reflected in the museum's collection. Vases with Dionysian scenes have been found at numerous sites within necropolises and sanctuaries, but less frequently in inhabited contexts. As pointed out by Mannino 2006, Attic vases with deities, heroes and personifications found in Messapia number about twenty and recur predominantly in craters. On vessels framed the early Classical age, a single figure or a pair often recurs, as in the case of the Pelike of Eriphyle and Polynices. The spread of some myths rather than others may depend on the political propaganda activities promoted by Athens in the years of Cimon and Pericles. However, it is unclear whether in the Messapic areas where these vases were found, buyers recognized the political messages of Athenian politics. One hypothesis is that in Messapia, the selection of Attic vases was the preserve of a small number of families. Of notable interest is the goblet krater depicting Bellerophon in the act of striking Chimera, a rather rare myth on Attic pottery found in Western settings (Mannino 2006). In the Messapian grave goods, there is a measured use of Attic ceramics, and a strict selection of vascular forms. The latter go to be important indicators to attest male and female depositions, since, for example, the krater form is the main indicator of Messapian male burials (Mannino 2006). Some Attic ceramics, especially *lekythoi*, are found in female depositions, recognized through the presence of the trozzella, the typical Messapian vessel used to carry water (Semeraro 1990).

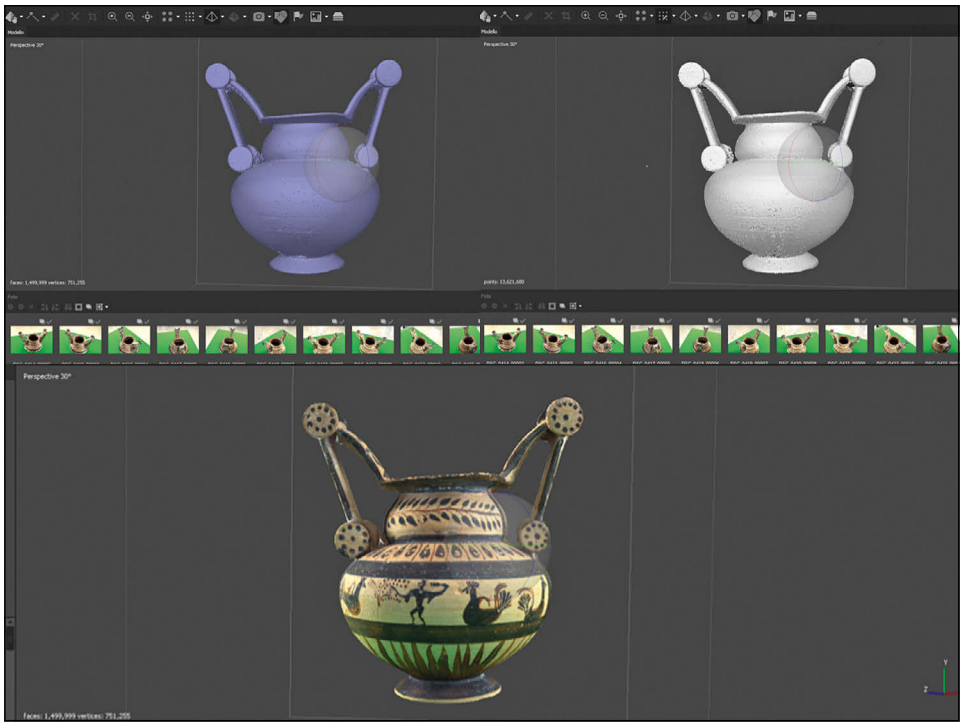

Fig. 2 – Photogrammetry process in Agisoft Metashape.

The collection plays a role as a glue with the territory and therefore the finds become real pointers that from the Museum shift the visitor's attention to the archaeological sites from which they come. Specifically, it is possible to refer to the concept of the cultural landscape of the three cities (D'Andria 2015): a system composed of the cities of the Valle della Cupa, namely *Rudiae*, Cavallino and *Lupiae*, i.e., ancient Lecce, from which a good part of the artifacts preserved in the museum come. Of primary importance is the operation of study and reorganization of the collection within the catalog edited by D'Andria (1990), for the Exhibition *Archeologia dei Messapi*, organized thanks to the collaboration between the Soprintendenza Archeologica della Puglia, the University of Salento, and the Provincial Administration of Lecce.

As for the art therapy scene, it is set in the ancient Messapian settlement of Cavallino, Apulia, one of the most flourishing settlements of the Archaic period. Around 470 B.C., however, it was abandoned due to a traumatic event, suggested by the demolition of fortifications, the destruction of houses by fire and the filling of moats and cisterns. However, it is likely that scattered

Fig. 3 – Objects of the virtual collection after photogrammetry processing (from 1 to 8 according to Tab. 1).

	Objects of the virtual collection	Related content of storytelling
1	Trozzella, Rudiae. First half of 5th cent. b.c. Sigismondo Castromediano Museum, Lecce.	The Mythe of Hercules' labours.
2	Attic Pelike, Rudiae. 460 b.c. ca. Sigismondo Castromediano Museum, Lecce.	The Mythe of Eriphyle and Polynices.
3	Attic goblet krater. Lecce, Bank of Italy. Late 5th cent. b.c. Sigismondo Castromediano Museum, Lecce.	The Mythe of Bellerophon against Chimera.
4	Black-figure columnar krater. Cavallino, loc. Piancastello. 480-470 b.c. Sigismondo Castromediano Museum, Lecce.	The Mythe of Odysseus and Achilles.
5	Attic columnar krater, Rudiae. 480-470 b.c. Sigismondo Castromediano Museum, Lecce.	Music in ancient world.
6	Crater with dancing maenad, Rudiae. Second half of the 4th cent. b.c. Sigismondo Castromediano Museum, Lecce.	Rituals in ancient world.
7	Astragaloi from Cavallino, fondo Sentina. 4th cent. b.c. Sigismondo Castromediano Museum, Lecce.	Play and leisure in ancient daily life.
8	Tintinnabula in the form of piglet. Cavallino, Fondo Sentina. 4th cent. b.c. Sigismondo Castromediano Museum, Lecce.	The childhood in ancient past.

Tab. 1 – List of the museum objects digitized for the virtual collection.

housing complexes and farms were still present between the Classical and Hellenistic ages, as burials are attested between the late 5th and 3rd centuries B.C. The Attic vases from this site can almost all be framed around the second quarter of the 5th century B.C. For the application, the Cavallino site serves as a narrative device for the reconstruction of an outdoor scenario that

Fig. 4 – Immersive 3D environment of the museum.

contextualizes some artifacts within the find site, thus telling the social story from the objects. The setting chosen for this scenario is specifically Cavallino, where the remains of an ancient pottery kiln were discovered. Objects that populate the virtual museum are eight (Tab. 1) and they have been digitized by means of photogrammetry technique, of a shooting campaign and with a post elaboration of the images in Agisoft Metashape (Figs. 2, 3).

The virtual scenarios have been modelled in Blender and the VR application has been developed in Unity. The integration of Blender and Unity offers a robust pipeline for developing VR applications. Blender, an open-source 3D modeling software, provides extensive tools for creating detailed virtual environments. Unity, a leading game development platform, excels in rendering these environments in real-time, allowing for immersive VR experiences. In the museum scene, the user moves through an indoor scenario and can navigate and enjoy selected artifacts from the collection. The space features warm and welcoming tones, soft and localized lighting on points of interest. The aesthetic is based on a simplification of the actual museum, eliminating distracting elements but maintaining the philological coherence of the place (Fig. 4).

The collection, consisting of eight objects from different archaeological sites in Salento, is arranged around the room, with each item placed on a cube and highlighted by a directed light. Narration is centered around the figurative themes of ancient ceramics, particularly the myths and convivial

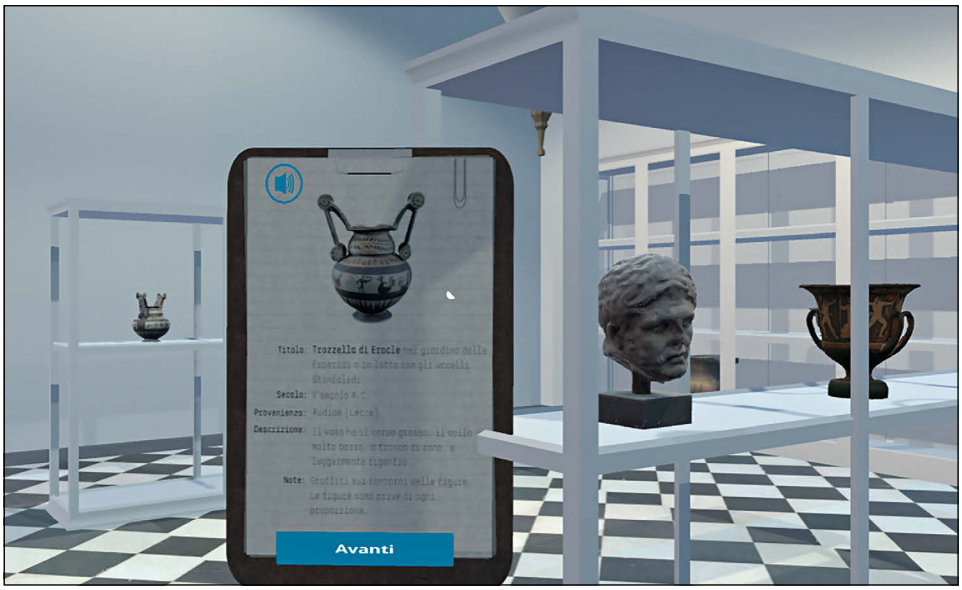

Fig. 5 – Immersive 3D environment of the *Antiquarium*.

scenes depicted on them. The user can interact via controllers with buttons to play or pause audio tracks, which feature a blend of ambient sounds, musical melodies, and a narrative voice over. These audio tracks provide an emotional audio guide, offering a storytelling experience about the artifacts. The narrative voice narrates the myths depicted, each of which is linked to a specific aspect of human psychology. In this experience, the user is tasked with an active role; once the tour in the exhibition room concludes, the user can move on to a second room, called the *Antiquarium*, which architecturally echoes a room from the museum's first location, that of the Palazzo dei Celestini in Lecce (Fig. 5). Inside this room the artifacts are arranged on shelves and inside cabinets, along with other artifacts, not belonging to the collection. The purpose of the task is to search for artifacts by recognizing them based on the sound, consistent with what experienced in the previous room.

The 3D spatial audio enhances the experience by making the search dynamic and engaging, giving the user the sense of approaching or moving away from an artifact based on the direction of the sound. Additionally, the user is provided with a virtual catalog that supports object discovery, summarizing the information shared during the tour in the previous room. The user is cast in the role of a museum curator who must select objects to complete the exhibition catalog.

Fig. 6 – Immersive 3D environment of the ancient laboratory, view from outside.

Fig. 7 – Immersive 3D envirorment of the ancient laboratory, view from inside.

The art therapy scene is set in the ancient Messapian town of Cavallino (Lecce). It is a reconstruction of an outdoor scenario that contextualizes some artifacts within the site of discovery (Figs. 6, 7). Particularly important is the possibility to move around the virtual environment and interact with the objects. Following the narrative of the previous scene, the user is now taken to an ancient pottery production center, where he or she gets to see how the artifacts on display in the museum were crafted. To enhance the feeling of

Fig. 8 – 3D touchable printed reproduction of the pottery decoration.

presence, an aesthetic is used that replicates a natural environment, within which the potter's workshop is placed. It is a place that combines aspects of both nature and human-made environments, which encourages the user's curiosity, immersion, and abstraction in the therapy.

Within this setting, the user is called upon to perform a task that combines learning and relaxation needs: a VR-based art therapy technique that involves modeling ceramics using ancient traditional methods, in line with the 'learning by doing' paradigm. The vase being modeled is the *trozzella*, a typical artifact of the Messapian material culture, attested in several archaeological sites in Salento, including Cavallino, between the 6th and 3rd centuries BC. The purpose of the task is to virtually model and decorate this artifact, with instructions that come from experimental archaeology. The art therapy task is designed to be carried out through three modes: passive mode, i.e., observation only, with controllers, through a guided sequence of operation, or using specific gestures of the user's hands. These possibilities are provided to the user so that he or she does not feel inappropriate to the task at hand: the game becomes scalable and suitable for different targets, especially in terms of age and cognitive and motor abilities. In some cases, a 3D-printed version of the painted decorative motifs was provided to assist visually impaired individuals in perceiving the figures through touch, while the application's audio described the pottery (Fig. 8).

6. Test

Following the development of the VR application, a test campaign was conducted, composed by two experiments. The aim of this phase was to measure and discuss the impact of VR museum fruition, by exposing the

user to different stimuli through varying degrees of immersiveness. In the experiments conducted, the experience gradually becomes more immersive, generating data that can be compared with each other. To summarize, the first experiment was conducted on two groups of participants: a first group conducted the visit and enjoyment of the artifacts in VR and a second group conducted the visit of the same scenario on a monitor. Two metrics were used for evaluation: a psychometric self-report test, developed by UCL to measure the degree of well-being induced by a museum experience, named 'UCL museum wellbeing measures toolkit', and the mobile app HRV Camera ECG BLE, for measuring heart rate before and after the session. This trial focuses on simply observing the digital artifacts represented within the virtual archaeological museum. The sample consists of a total of 40 individuals, 18 female and 22 males, with an average age of 27 years.

To analyze the data collected in the first experiment, both descriptive and inferential statistical techniques were employed. Initially, descriptive statistics, including means and standard deviations, were computed to summarize the responses obtained from the UCL Museum Wellbeing Measures Toolkit and heart rate variability (HRV) recordings. The percentage variation of well-being scores was calculated as the difference between post- and pre-experience scores, normalized by the pre-experience score and multiplied by 100. Similarly, the percentage variation in heart rate was computed for both the VR-based and monitor-based experiences.

For inferential analysis, a Kruskal-Wallis nonparametric test was performed to compare the variations in heart rate and the 12 well-being items between the two experimental conditions. The results revealed statistically significant differences ($p < 0.05$) in the heart rate variations and in the 'Unhappy' item, indicating that the virtual reality experience was particularly effective in reducing negative emotional states. Additionally, a two-sided Kendall test was conducted to examine correlations between heart rate variations and well-being scores. For the VR condition, significant negative correlations were observed between heart rate and the 'Nervous' and 'Upset' items, suggesting that a reduction in physiological arousal was associated with decreased anxiety levels. In contrast, no significant correlations were found in the monitor-based scenario.

The heart rate distribution for the VR condition also exhibited a leftward shift, confirming a trend of decreased heart rate post-experience. These findings support the hypothesis that virtual museum experiences in VR can modulate both subjective well-being and physiological responses, with a more pronounced effect on users initially experiencing negative moods (Gatto *et al.* 2022).

The second experiment involved a heterogeneous sample consisting of 33 patients of the medical clinic (Casa di Cura Prof. Petrucciani, Lecce),

who performed the VR protocol under the guidance of the therapist, with the support of the development team. All patients, during the experiment, performed at least one experience between that of art therapy and that of museum therapy, and answered psychometric questionnaires both before and after the session. Within the experimental group, seven patients performed the protocol with the biometric sensors. Specifically, before and after the session, the following standard questionnaires were administered: Hospital Anxiety and Depression Scale (H.A.D.S.) and Perceived Stress Scale (P.S.S.). The process consists of two phases, the actual experimental protocol, and the analysis phase. The first phase consists of three steps:

– Pre-therapy H.A.D.S. and P.S.S. questionnaire.
– Experience in VR, consisting of session 1 (adaptation to VR), and session 2 (the practice), in which the patients were alternately assigned the art therapy scenario and the museum therapy scenario. During this step, with reference to the 7 patients who performed the complete protocol, the signals from the Electrodermal Activity (EDA), Blood Volume Pulse (BVP), Electroencephalography (EEG) sensors were also recorded.
– Post-therapy H.A.D.S. and P.S.S. questionnaire.

In addition to the Meta Quest 2 headset, two devices were used to measure the biosignals: EMPATICA E4 and Emotiv EPOC X. For the experiment, all data recorded by the sensors were acquired for the measurement and assessment of skin conductance, heart rate, and brain electrical signal, all of which are associated in the literature with protocols for the induction of stress reduction. After the acquisition, collected data and their correlation were analyzed through statistical methods.

The differences between post- and pre-experience scores were computed, and percentage variations were calculated to quantify the changes induced by the VR-based protocol. The results indicated a significant decrease in all three variables, with stress levels showing a more homogeneous and well-defined reduction pattern. Conversely, anxiety and depression also exhibited negative percentage variations, albeit with a more gradual and heterogeneous trend.

Regarding the analysis of biosignals, the EDA data were processed using Matlab Ledalab 3.4.9, applying the Continuous Decomposition Analysis (CDA) method. This approach decomposes the GSR signal into tonic and phasic components through standard deconvolution. A median filter was applied to isolate the phasic component, and a threshold of 0.01 μS was set for onset detection. The number of peaks in the Skin Conductance Response (SCR) was then computed, serving as a crucial metric for evaluating arousal and emotional state variations. The results showed a progressive reduction in the number of SCR peaks compared to the baseline, indicating a decrease in sympathetic nervous system activation and, consequently,

a reduction in arousal during the virtual museum experience. For heart rate analysis, standard deviations of heart rate frequency were calculated, revealing a trend toward a partial decrease in heart rate following the VR session. Data processing was conducted using specific libraries in R, a free software environment for statistical computing and graphics. However, for electroencephalographic (EEG) analysis, data acquisition was inconsistent across subjects, preventing a robust statistical evaluation. As a result, while preliminary observations suggest potential EEG variations, further studies with a larger and more controlled dataset are needed to draw statistically significant conclusions.

The analyses conducted on the psychometric data showed a decrease in the levels of stress, depression and anxiety. This hypothesis also seems to be supported by the signals arriving from the sensors used. The results highlighted a correlation between the increase in the well-being of patients and the experience in the virtual museum. This engagement goes beyond observation, involving the user's hearing and manual skills using a multilayered and emotional storytelling approach. Additionally, virtual activities specifically designed to stimulate cognitive functions were incorporated.

7. Conclusions and future work

This work examines the challenges of digital curating and digital transformation in museums, adopting an approach focused on contemporary museology. It aims to explore the contribution of these hybrid methodologies and evaluate their effectiveness in terms of communication, engagement, accessibility, and visitor experience, with particular emphasis on their impact on well-being. The methodology made use of digital technologies with the aim of providing a proposal for digital fruition through XR technology, enriched by sensors for the acquisition of biosignals and their subsequent analysis. Aspects related to the technical development of the application and interoperability with the sensors, as well as the analysis of data derived from them, will be explored in a subsequent and specific in-depth study. In this contribution, attention has been focused on the importance of storytelling as a tool for designing content in line with the specific needs of the intended audiences, particularly a fragile public, such as people admitted to a hospital ward may be. From a first analysis of the data, it has emerged how immersive enjoyment of cultural contexts and content, using VR technology, can help fragile audiences in their daily lives, intervening positively in decreasing stress levels and cognitive stimulation. However, this study shows the strong potential of technologies as a means of conducting innovative experimentation in the field, particularly VR as a tool to achieve a good sense of presence, and the great ability of museum

and art content to elicit certain emotional states as well as provide effective cognitive stimulation.

Further research is needed to fully understand the impact of museums on well-being, considering different experiences, audiences, and degrees of immersiveness, and thus the contribution of fruition technologies, designing the whole experience and evaluating its impact no longer just from a user experience perspective, but from a perception perspective, in neuro-psychological terms. Only in this way can the studies be comparable, and the methodology become more robust, resulting in scientifically reliable protocols and baselines.

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REFERENCES

Bonacini E. 2020, *I musei e le forme dello storytelling digitale*, Roma, Aracne Editrice.

Chuah Hui-Wen S. 2018, *Why and Who Will Adopt Extended Reality Technology? Literature Review, Synthesis, and Future Research Agenda* (http://dx.doi.org/10.2139/ssrn.3300469).

Dal Maso C. 2018a, *Introduzione. Storytelling: perché*, in C. Dal Maso (ed.), *Racconti da museo. Storytelling d'autore per il museo 4.0*, Bari, Edipuglia, 11-24.

Dal Maso C. 2018b, *Non solo narrativa*, in Dal Maso 2018a, 69-84.

D'Andria F. 1990, *Archeologia dei Messapi*, Catalogo della mostra, Bari, Edipuglia.

D'Andria F. 2015, *Tre regine nella terra di mezzo*, «Archeo», 363, 38-52.

De Felice G. 2012, *Una macchina del tempo per l'archeologia. Metodologie e tecnologie per la ricerca e la fruizione virtuale del sito di Faragola*, Bari, Edipuglia.

De Paolis L.T., Chiarello S., D'Errico G., Gatto C., Nuzzo B.L., Sumerano G. 2021, *Mobile Extended Reality for the enhancement of an underground oil mill: A preliminary discussion*, in L.T. De Paolis, P. Arpaia, P. Bourdot (eds.), *Augmented Reality, Virtual Reality, and Computer Graphics. AVR 2021. Lecture Notes in Computer Science*, Cham, Springer (https://doi.org/10.1007/978-3-030-87595-4_24).

De Paolis L.T., Chiarello S., Gatto C., Liaci S., De Luca V. 2022a, *Virtual Reality for the enhancement of cultural tangible and intangible heritage: The case study of the Castle of Corsano*, «Digital Applications in Archaeology and Cultural Heritage», 27, e00238 (https://doi.org/10.1016/j.daach.2022.e00238).

De Paolis L.T., Faggiano F., Gatto C., Barba M.C., De Luca V. 2022b, *Immersive Virtual Reality for the fruition of ancient contexts: The case of the archaeological and Naturalistic Park of Santa Maria d'Agnano in Ostuni*, «Digital Applications in Archaeology and Cultural Heritage», 27, e00243 (https://doi.org/10.1016/j.daach.2022.e00243).

Deveault M. 2022, *La plateforme éducart du Musée des beaux-arts de Montréal: recherche développement sur la mise en place d'un projet numérique, thématique, multidisciplinaire et collaboratif*, «Digital Studies/Le champ numérique», 12 (https://doi.org/10.16995/dscn.8102).

Disability Rights Commission 2004, *A Practical Guide for the Retail Sector: Part III of the 1995 DDA: What Shop or Store Owners Need to Know*, Stratford-upon-Avon, DRC.

Dziekan V. 2012, *Virtuality and the Art of Exhibition*, Chicago, Intellect Ltd.

Gatto C., Calabrese L., Chiarella S., De Luca V., D'Errico G., Nuzzo B.N., Raffone A., De Paolis L.T. 2022, *Wellbeing assessment of a museum experience in Virtual Reality through UCL measurement tool kit and heart rate measurement: A pilot study*, in *IEEE International Conference on Metrology for Extended Reality, Artificial Intelligence and Neural Engineering (IEEE MetroXRAINE 2022) (Roma 2022)*, 483-488 (https://doi: 10.1109/MetroXRAINE54828.2022.9967568).

Mannino K. 2006, *Vasi attici nei contesti della Messapia (480-350 a.C.)*, Bari, Edipuglia.

Minerva B. 2019, *Il Museo Sigismondo Castromediano tra passato e presente*, in R. Casciaro (ed.), *Musei in Puglia. Tradizione e futuro*, Lecce, Congedo Editore.

Minissi F. 1970, *La nuova sede del Museo provinciale di Lecce*, Galatina, Editrice Salentina.

Romanelli P. 1928, *Corpus Vasorum Antiquorum, Museo Provinciale Sigismondo Castromediano di Lecce*, fasc. I-II, Milano-Roma, Casa editrice d'arte Bestetti e Tumminelli.

Semeraro G. 1990, *Note sulla distribuzione delle ceramiche di importazione greca nel Salento in età arcaica. Aspetti metodologici*, «Archeologia e Calcolatori», 1, 111-163 (https://www.archcalc.cnr.it/journal/articles/9).

Slater M., Sanchez-Vives M.V. 2016, *Enhancing our lives with immersive Virtual Reality*, «Frontiers in Robotics and AI», 3 (https://doi.org/10.3389/frobt.2016.00074).

ABSTRACT

This study is aimed at evaluating the combination of storytelling and eXtended Reality to enable the enjoyment of a museum collection for a fragile audience, namely people hospitalized in a hospital ward. The application involves the creation of immersive and interactive virtual scenarios, with the possibility of performing several activities, such as exploring a museum setting, according to Museum therapy principles, and practicing stimulating playful-recreational activities, according to Art therapy principles. The goal is to assess the impact of the fruition of the 3D archeological collection, in terms of promoting the psychological well-being of vulnerable people. The experimentation involved the Sigismondo Castromediano Museum in Lecce and took place at the Prof. Petrucciani Clinic (Lecce). During the experimental campaign, the team used a Virtual Reality headset, and two wearable devices for collecting and recording biosignals. This paper provides a description of the methodology adopted with a focus on the storytelling strategy.