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BEYOND STATIC COLORS: AN INTERACTIVE PARTICIPATORY DESIGN PERSPECTIVE ON COLOR-CENTRIC EXPERIENCES

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Abstract

By combining cognitive, sensorial, historical, and artistic aspects into one experience, digital interactive technologies have afforded new ways to perceive, preserve, curate, exhibit, and access cultural objects. However, there is a critical lack of frameworks and tools designed specifically for colored cultural artifacts–cultural items for which color is a key means of conveying the creative message. While colored artifacts are a priority for Conservation Science, due to their fragility and to the complexity of recreating original appearances, in this article we argue that the conservation of colored artifacts is not merely a matter of scientific studies, analysis and static preservation. Instead, we argue for holistic conservation including the valorization of the social dimensions of color, including for civic engagement. The work first investigates the types of data and knowledge that Conservation Science produces regarding colored collections which specifically consider the social dimension of color. We then research the relational ties between humans and colored cultural artifacts, proposing ways that caring attitudes can be triggered and maintained. We finally survey previous color-centric approaches to such artifacts with digital technologies in an interactive media participatory design perspective. We conclude with lessons learned and further directions, including novel research questions and ideas for future user experiences.

Keywords*: Cultural artifacts; Interactive design; Color heritage; Civic education; Digital hermeneutics*

Introduction

Colored artifacts have been critical tools for individual and communal development of humans for hundreds of thousands of years. By colored artifacts, we mean cultural objects and artworks for which colors are a primary source of transmission of the creative message (i.e., colors are semantically enriching). Some examples are Edvard Munch's paintings, in which color was employed with a crucial role, as "for Munch, color was not merely decoration. It was the arena in which the era's novel scientific and philosophical concepts could be revealed and exploited" [1]**.** In this way, as humans engage with colored artifacts, they engage with critical concepts, which they use as tools to navigate, explore and understand the world.

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However, when color fades, disappears, or is improperly represented, our perception and understanding is affected–potentially leading to false interpretations, or to a lower impact of an artwork's meaningfulness. For example, Christen Købke (1810-1848)'s painting *View of Lake Sortedam*, exhibited at SMK National Museum in Copenhagen as representative of Danish Golden Age art, and quoted as a contributor to the definition of Danish identity, was for long considered a rosy sunset, an evocation of a romantic evening mood. Recently, however, it has been discovered that the red color of the sky was actually due to color degradation of Prussian blue, leading to a need to revisit the previously consensus interpretation [2].

Sometimes, the effect of lost or misrepresented faded color has farther-reaching and more poisonous consequences. For example, in ancient classical civilization, the use of polychromy on sculptures was a crucial aspect of the artistry: "*it was only through the application of color that the artist achieved the desired vitality of his subject*" [3]. By connecting form and content, color increased the legibility of a figure, and bridged the gap between art and reality, taking the works from static sculptures to "living images", on the ambiguous line between the real and the imaginary [4] (Fig. 1A). The role of color is so important for these artifacts that its absence has led to the building of entire ideologies: it is the case of the white supremacist uses of purportedly white classical statues to support the idea of a white superior race. Spreading like wildfire through the internet, such political or racial ideologies have even led to aesthetic ideologies (e.g., "FASHWAVE", Fig. 1B).

Fig. 1. A) Kouros of Tenea's sensuality on its painted surface: lavishly arched eyebrows, elegantly stylized pubic hair, and ornamented nipples. Top left: original kouros from Tenea, Greek, ca 530 BC. Top right: 2015 reconstruction based on general evidence of polychromy on archaic kouros statues by Ulrike Koch-Brinkmann, Glypothek, Munich. Bottom left to right: relief created by weathering of painted pubic hair of Kouros of Hera, ca. 570 BC, Samos Archaeological Museum; disc earring in raking light of kouros from Didyma, ca. 530-520 BC., Antikensammlung, Berlin; visible-light photograph showing painted nipple and pattern on the areola of a Greek kouros, ca. 590-580BC, Metropolitan Museum of Art; **B)** White supremacist group *Identity Evropa*'s flyers, which popped up on college campuses in the United States throughout 2017 and 2018, featuring references to classical sculpture, Identity Evropa Twitter (top); "FASHWAVE"-style memes and images posted on white supremacy and fascist forums (bottom). Source: archive.4plebs.org

While colored collections are already a priority for Conservation Science due to their fragility and the complexity of the research involved, especially for reconstruction of original appearance and prediction of future color evolution, the presented examples show how the conservation of color is not only a matter of preservation. The social dimension of color, its conservation and valorization are critical to counter incorrect, divisive and/or corrosive ideas. In

this way, colored artifacts should be a priority of Conservation Science *also* because of the importance of properly communicating them, for their use in civic education around concepts, and potentially using them as inspirations for future art.

In this way, colored artifacts' conservation knowledge can also be used and exploited for engaging citizens to interact, safeguard, curate and value them in the context of cultural re-appropriation policies. Regarding these topics two main EU projects have recently been financed, to develop citizen curation methods (EU Horizon SPICE: Social cohesion, Participation, Inclusion through Cultural Engagement https://spice-h2020.eu/) [5] and to create new ways to perceive, preserve, exhibit, understand and access colored Cultural Heritage collections (EU Horizon PERCEIVE: Perceptive Enhanced Realities of Colored collEctions through AI and Virtual Experiences). These projects take advantage of novel interactive media, user-centered design (UCD), and participatory design methods to cultural knowledge that are now possible due recent technological advancements. Specifically, interactive media integrates digital media (text, audio, image, video, animation – in 2D and 3D) into structured digital environments allowing people to interact with data [6, 7], while UCD describes the processes in which users influence how a design takes shape [8]. Since 1990, when Participatory Design emerged [9], participation is deemed as an essential part to direct the complete design of experiences, especially of cultural ones with strong social and civic dimensions. These approaches improve the tangibleness of cultural items and ideas by fusing cognitive, sensory, historical, and artistic qualities into one experience.

Given the importance for colored collections to be connected to their social/civic dimensions, the centrality of color in Conservation Science and the increased use of digital technologies for Cultural Heritage, we pose three research questions to guide this paper:

- Which types of data and knowledge, which keep the social dimension as central, does Conservation Science produce?
- What are the relational ties between humans and colored collections, and how can we trigger reflection, transformation, caring and action?
- How can digital technologies be used, in an interactive media participatory design perspective, to develop color-centric experiences?

The structure of the article, with the following main contributions, is as follows:

- **From Conservation to Valorization**: we investigate and summarize Conservation Science's knowledge contributions regarding colored collections which specifically either keep in mind or use the social and cultural dimension.
- **Caring for and about Color:** we research the ties between humans and color, humans and cultural artifacts, and humans and colored cultural artifacts, proposing ways that caring attitudes can be triggered and maintained.
- **Technologies and Color-Centric Interactive Participation:** we survey how color-centered knowledge has been approached by digital technologies in an interactive media participatory design perspective.
- **Final balance sheet:** we conclude with lessons learned and further directions, including novel research questions and ideas for novel user experiences.

From Conservation to Valorization

Conservation Science contributes to the reconstruction of cultural objects' original colors, supporting research about and the transmission of the objects' original messages. Color reconstruction can be based on analyses of remaining traces of pigments, but in many cases, this is not enough, and the analyses need to be integrated with other sources in order to obtain reliable results. Reconstruction, for instance, of ancient polychromy is particularly complex due to the small traces of surviving pigments and the scarce knowledge regarding original coloring techniques responsible for the appearance of the artworks. Conservation techniques (i.e., with

multiband imaging techniques and compositional analyses) can identify a specific pigment or chemical element applied to an area–to which it would be eventually possible to assign a certain RGB value–but what about the final rendering, the number of layers used by the artist, the shading, and so on? Comparative studies of similar, better conserved artworks and the study of production techniques can increase and integrate this knowledge (such as in Treu Head case study [10]), therefore increasing reconstruction and prediction accuracy. On the other hand, Conservation Science can also support the prediction of how colors may evolve over time, studying the deterioration processes of darkening, fading and yellowing often accompanied by flaking, crumbling and chalking of paint [11-14].

Critically, Conservation Science can produce data and knowledge regarding not only objects' original coloring, but also regarding the way that such colors would have originally appeared and been perceived. Color is a part of a phenomenon named "appearance", which involves perceptual attributes such as translucency, gloss and texture [15]. Imaging techniques, for example, can be used to study the relationship between the appearance of a material artwork and its virtual replica. Furthermore, color artifacts have been in many cases conceived to be placed in certain physical contexts (e.g., in specific monuments or to be appreciated in certain viewing conditions of lighting or social contexts, etc.), and for certain purposes (e.g., funerary or domestic art). Only a few studies consider these aspects, such as the work by Scagliarini on the role of mosaiced decorated pavements as guides to define the locations from which to appreciate wall paintings in Pompeii [16], but they definitely deserve an increased attention.

Moreover, Conservation Science increasingly sees the potential of Artificial Intelligence and Machine Learning based methods to extend the types of knowledge hereto mentioned, via the automatization of a variety of manual processes, and to obtain novel visual representations of color restoration and color reconstruction. This could aid Cultural Institutions which are interested in including color reconstruction in their exhibitions, but consider the entire process too complex, time consuming and expensive. Additionally, data-driven projects based on automatic methods can also help to improve and automate indexing of colored artifacts on shared databases, not only improving accessibility but also increasing the valorization of colored artifacts.

In this way, although not yet in place, shared methods (not only among scientists but also among designers, artists and ICT specialists), accessible databases, services and tools connected to, for example, European infrastructures of Heritage Science such as E-RIHS,[1] can make the results of Conservation Science more reusable for socially relevant practices and experiences.

Caring for and about Color

In this section, we will investigate and attempt to answer the second research question: *What are the relational ties between humans and colored collections, and how can we trigger caring and action?* In our view, in order to answer this question, it is necessary to first understand independently the roles color and cultural artifacts' play in individual and social human history and experience.

Humans and Color

Archaeological evidence shows that even modern humans' ancestors—including *Australopithecus*, *Homo erectus*, and *Homo neanderthalensis*—already used a variety of pigments [17-20], some for symbolic purposes. Why did humans, from the beginning, color an already colorful world? Paleoanthropologist Alison Brooks believes that, while there could be many reasons, at the core was a communication function [21]. In humans, caring about color is coded in our system, as the relationship we have with color is connected to the way we survive in this world. Overall, the human vision system's goal is to seize from the continually changing

[1] http://www.e-rihs.eu/

information reaching the brain the most fundamental data, and there are certain kinds of knowledge, such as the color of a surface, that can only be acquired through it [22].

Additionally, the experience of color is a subjective, relative, and unstable process. Josef Albers called color "the most relative medium in art", and Henry Matisse said that "seeing is already a creative operation, one that demands an effort" [23]. Although they were not speaking neurologically, these statements express a neurological truth about the experience of vision that has physiological underpinnings. First, from a physical standpoint, color is a feature of visual perception by an observer, not a property of electromagnetic radiation. Secondly, the context in which a perceived object is presented heavily affects the perception of color [22]. Additionally, color perception is an unstable and contestable phenomenon shaped by social and material factors [24]. Color perception, in this view, is not a private experience, but rather a shared and observable social experience.

It is not surprising then that color is a central feature of social life. The experience of color, while a subjective experience of electromagnetic energy, is deeply grounded in cultural meaning. For anthropologist Victor Turner (1920-1983), color use is socially patterned, and reflective of basic life-and-death processes and emotions [25]. Sociologist Rose-Greenland, in her approach to a sociological theory of color perception, sees color perception also as socially patterned and, additionally, as sanctioned, with material conservation being inherently political [24]. As Rose-Greenland notes, color can signal adherence—or resistance—to gender norms, political or sport alliances, and even gender, age, religion and marital status [9, 26, 27]. Color has long-lasting cultural meanings, such as for demonstrating allegiance to ideologies and social values, such as the values of peace and of war. Colors even affect mood, which explains the careful attention that institutions pay to principles of color harmony in public spaces [28].

The cultural currency of color allows for a conceptualization of color as material. Rose-Greenland finds three reasons for doing so. First, based on Klett's [29] idea, she sees that to trade on immaterial sensations (such as private sensorial experiences), we need to materialize them first into an externalized object. Second, she believes that materializing color perception draws attention to the importance of temporality, specifically the instability (and hence contestability) of color. And finally, materialization allows for the use of analytical parameters that comprise cultural objects [24]. As an example, Rose-Greenland notes how in Yolngu culture, specific combinations of colors and their pigments are used to spiritually honor objects and bodies, and that it is this very materiality of pigment colors that links them to the natural world [30].

Humans and Cultural Artifacts

As such, color perception, if conceived beyond the visual perception and instead as a social experience, is a tool that allows humans to enter into the world and into themselves. This is parallel to the role of cultural artifacts in connection to humans. Cultural Heritage (CH) is about objects, traditions, and people—and how the relationships between them are active, fluid, and socially bound.

To develop successful valorization and civic education projects surrounding cultural artifacts, it is necessary to understand such relationships. The humanities—with interpretation of cultural objects as one of its core functions—have much to offer in this endeavor. What humanists can bring to the development of civic education projects, technologies or programming around highly visual objects is, first and foremost, a championing of aesthetic literacy. The highly visual culture that we currently live in points towards a critical place for aesthetic and visual education, including successful contextualization and education about visual objects' histories. But visual literacy encompasses more than accuracy. Critical to a project of visual literacy for civic development is an affirmation of art and interpretation as among humanity's signature activities. Championing visual literacy means championing the value of teaching about art and interpretation [31].

Virtually in every pursuit of knowledge, the contextual approach—that is, bounding things within their appropriate context—has been deemed as an imperative step to understand objects

and their functions. This approach to interpretation has been deemed as so imperative that it has been claimed that "an object out of context is not readable" [32]. Contextualizing objects, such as cultural artifacts, allows for a deeper understanding of their lives and functions in social contexts. In material culture studies, material objects have been conceptualized as having social lives, containing selves and being fluid. Hoskins [33] argues that just as persons with biographies and life cycles, things can be said to have social lives and histories. Specifically, things contain and preserve memories and embody personal and social experiences. As such, objects provide a powerful medium for materializing and objectifying the self, a perspective which emphasizes the manner in which things have a fluid significance [33].

As such, situating knowledge in the pluralistic manner described by Donna Haraway [34] becomes crucial: this paradigm reckons irreducible differences and the radical multiplicity of local knowledge, with the aim to pursue a practice of objectivity that works with contestation, deconstruction, passionate construction, webbed connections, and hope for transformation of systems of knowledge and ways of seeing. In this way, contextualizing objects necessitates seeing them as carriers of social lives and knowledge(s), which are bound to the locations upon which they are created and interpreted.

Humans and Colored Cultural Artifacts: Strengthening Weak Ties

What we observe today is a general weakness of caring attitudes towards our colored patrimony. Conservation Science is considered more a provider of "scientific facts" than a socially valuable activity that would deserve attention and financial support by decision makers. The lack of policies protecting and valuing colored cultural heritage demonstrates the little understanding of the social dimension behind colored artworks, their interpretation and communication.

Studies on innate biological human caring attitudes shed light on the reason why the care about colored collections is fragile. Care theory has recognized the relationship between a caregiver and care receiver: the caregiver and receiver enter into a mutually satisfying relationship and if this relation is not satisfied, is not mutual, the caring fails [35]. In the case of human-to-human relationships, as in the case of a parent (the caregiver) and a child (the receiver), this is evident because the ties are strong (i.e., when the child cries, the parent immediately reacts). When a stressful event happens, the reaction is immediate, emotional and neurobiological.

On the contrary, with human-to-object relations, such as in the case of artifacts, this does not happen even when an event takes place, since the ties in this case tend to be weak. The problem, therefore, can be solved by strengthening this relationship, overcoming the distance between the visitor and the artwork, increasing understanding and transforming the experience into something more personal. There are a number of factors that can influence caring and can be adopted: attachment, personification, uniqueness and peculiarities, sense of wonder, compassion, perception of fragility, and sense of justice. *N. Nodding* [35] and *C. Andre and M. Velasquez* [36] describe the inherent need to do what is "right" for the individual by using the ethics of care: empathy. Above all, studies on empathy demonstrate how it is not a genetic trait that operates as an instinct or reflex action toward other people, but a trait that can change through life with a number of strategies [37, 38].

Works in the Cultural Heritage domain have identified a specific type of empathy, named "historical empathy", and explained it as a process of cognitive and affective engagement with historical figures [39] that can be stimulated using a "facilitated dialogue" approach, encouraging individuals to share their views and experiences, their personal beliefs, challenging them to examine factual information presented while, at the same time, considering the perspectives of others [40]. This is the approach of the SPICE project, where citizens are involved in the development and sharing of their own interpretations in an "interpretation-reflection loop" [41]. As Soto states, "*implementing caring practices will promote engagement*" [42], so considering the different presented factors and adopting various approaches starting from citizens can lead to

the vaporization of colored artifacts. As such, the potential of interactive participatory design for colored collections becomes evident.

Technologies and Color-Centric Interactive Participation

Recent technological advances have afforded new participatory and interactive approaches to knowledge, and as such increased the tangibility of cultural objects and ideas. Some of these approaches have allowed for the combination of cognitive, sensorial, historical, and artistic aspects into one experience. As such, the advent of new technologies has paved new avenues for tackling education about cultural artifacts, their interpretations, and their implications. This is especially true of colored cultural artifacts. In this section, we will investigate and attempt to answer the third and last research question: *How can digital technologies be used in an interactive media participatory design perspective?* As such, we will first succinctly discuss participatory and interaction design, and how these are increasingly connected to the use of digital technologies. We will then survey ways in which digital technologies have previously been used around colored artifacts in order to engage citizens, and their diverse eXtended Reality (XR) strategies, including projection mapping of color reconstruction, natural interaction with color reconstruction, alternative texturization and personalization, and multisensoriality and immersiveness.

The attempt to more fully integrate the use of technology with the materiality of a heritage display is part of a wider line of debate on making the museums and their artifacts more engaging for visitors, overcoming the separation between technology and heritage holdings. Increasing interest in the physicality of the experience with cultural objects is also shown by many works in museum studies [43-45] as well as the rise of public installations focused on multiple levels of engagement [46, 47]. *D. Petrelli et al* [48] believe that "the digital and the material can become components for the design of a holistic visitor experience that crosses the digital-material boundary. The challenge is in weaving the digital and the material to create seamless immersive and novel visitors' experiences". There are numerous recent examples of new museological approaches that take a decidedly multi-disciplinary approach with human and ludic factors in computing, such as adding content layers on exhibitions through technology, enhancing audience immersion through digital techniques, developing virtual museums and serious games [49], personalizing hybrid museum experiences through digital gifting [50], controlling interactive exhibitions through the use of tangible smart replicas or tangible data souvenirs, and more. Below we will discuss some exemplary case studies for these approaches.

Color Reconstruction and Projection

In August, 2014, two thousand years after Augustus's death, color was projected onto the original marble friezes at the Ara Pacis Museum, in Rome. The *Colours of the Ara Pacis*, [51] organized by the City of Rome, consisted of light projections on both the western front of the Ara Pacis altar, with panels of Aeneas and the Lupercal, and on the eastern front, with those of Tellus, the goddess Roma and the great vegetal frieze. The project aimed to bring back to life the original colors of the monument, through a sophisticated lighting system (Fig. 2, top). This project was based on projection mapping and was not interactive.

Color Reconstruction and Interaction

A second project by the same group, *L'Ara Com'era* [52], instead had a storytelling and interactive component. A multimedia story, the experience merged history and technology in an immersive and multisensory visit to the monument, with characters, divinities and animals coming alive in color and 3D to illustrate the origins of Rome and the family of Augustus.

Traditional green screen shots with the involvement of real actors were inserted in a 360° environment, and an innovative Augmented Reality experience was developed. Using head-mounted AR visors (Samsung GearVR) and the camera of the devices inserted in them, virtual elements and real elements merged directly into the visual field of visitors. The AR application

recognized the three-dimensionality of the bas-reliefs and sculptures, carrying out real-time tracking, so that virtual contents appeared to the visitor as "anchored" to real objects, contributing to the effectiveness, immersion and sense of magic of the whole experience (Figure 2, bottom).

Fig. 2. The *Colours of the Ara Pacis* experience, with color projected on the Ara Pacis altar (top); *L'Ara Com'era* experience, where visitors used visors in an immersive experience of the Ara Pacis altar (bottom), Source: arapacis.it

Other exemplar projects using digital technologies and exploiting natural interaction in combination with color reconstruction were developed in the Keys to Rome[2] exposition context. One of them, emphasizing the visual dimension, was “The Revealing Flashlight” [53, 54], an application of AR and natural Interaction, allowing visitors to see more details and possible reconstructions by pointing their fingers at an object (Fig. 3). The application allowed a new interaction and visualization technique in spatial AR, helping to reveal detail of cultural artifacts including their reconstructed colors. It locally and interactively augmented a physical artifact by projecting an expressive 3D visualization that highlights its features, based on an analysis of its previously acquired geometry at multiple scales. The Revealing Flashlight worked with NISAR technology, through the Leap motion sensor, which, when the user placed the finger in the air above the sensor, recognized the finger and the movement, transferring the data to a computer, which was connected to a projector in front of the original piece. A video demonstration of how the technology was used is available online.[3] This made advanced 3D analysis accessible to the public with an everyday gesture, by naturally combining the inspection of the real object and the virtual object in a co-located interaction and visualization space. As such, this technology is an example of using Augmented Reality based on natural interaction employed in a real location, directly on top of a cultural object to show its original color.

[2] http://keys2rome.eu/eng/expo.html
[3] https://www.youtube.com/watch?v=RIsxoe_nHA0

Fig. 3. The Revealing Flashlight application and interaction mode, which allowed visualization of original colors on marble slates when users pointed their index fingers at the slate. Picture courtesy of v-must.net

A second technology developed in the context of the Keys2Rome exposition was AR-tifact [54], an application of Augmented Reality in which an iPad worked as a "magic" window through which the visitors could see a fragment or cultural artifact and its reconstructive details, including reconstructed colors. AR-tifact used the instant AR framework developed by Fraunhofer IGD, and in order to follow the general interoperability requirement for browsers, the basic system was extended and adapted to comply with multiple browsers and HTML5 requirements. The AR-tifact system could run on nearly every smartphone, increasing the potential of the technology. The main advantage lied in the use of web technologies, which are easy to handle, thereby simplifying the implementation and integration process.

The Metropolitan Museum of Art (The Met) in New York City has developed some high-profile interactive experiences surrounding colored reconstructions of ancient art and architecture. *Color The Temple: Using Projected Light to Restore Color* (2015) developed a tool that uses projected light to digitally restore color on The Temple of Dendur[4] (Fig. 4, top). The project not only projected color, but it also projected animated versions of the stories depicted on the Temple. Animations were also used to highlight glyphs, make them larger, and explain how seemingly flat figures in Egyptian art actually represent 3D scenes. The Met also developed perhaps the most recent interactive experience surrounding color reconstructions in a museological context. The Chroma AR (2022) experience was developed as part of the *Chroma: Ancient Sculpture in Color* exhibition, featuring reconstructions of ancient sculptures and introducing a new polychromous reconstruction of The Met's Archaic-period Sphinx finial. Chroma AR allows visitors to explore the Sphinx in augmented reality through a smartphone (see Figure 4, bottom). Users can virtually recreate the sphinx in full color, in their own space, comparing the vivid reconstruction and as it looks today. The project features both interpretive and playful components that reflect collaborative work among scientists, imaging specialists, conservators, technologists, art historians, and others.[5]

Alternative Texturizations and Personalization

Another project has aimed at using texturization of cultural artifacts but in the context of an emotional, potentially challenging and meaningful experience to users. ColorColab [55] is a proposed interactive art installation surrounding color and multiple ancient sculptures or their copies. The experience would allow users to choose one or various polychrome visualizations of the sculptures through the use of an online tool or an augmented reality (AR) interface (Fig. 5). A repertoire of premade palettes would be available in the lab for users to explore and play with. Some palettes are based on scholarly research on ancient pigments. A second category of premade palettes available is based on iconic paintings, art history masterpieces, or artist commissioned

[4] https://www.metmuseum.org/blogs/digital-underground/2015/color-the-temple
[5] https://www.metmuseum.org/exhibitions/listings/2022/chroma/chroma-ar

work. A third type of available palettes is based on the top fabric patterns of the year and the most used colors and trends of the modern fashion world. Finally, a database of user-uploaded palettes is available for any other use to get inspiration from. Importantly, it would also be possible for the user to dynamically design their own palette, including from the colors of their own skin, body, clothes, and surroundings. ColorColab's educational purpose in the context of museums is connected with the notion of awakening, which aims to arouse curiosity, to lead to questioning and developing the capacity to think.

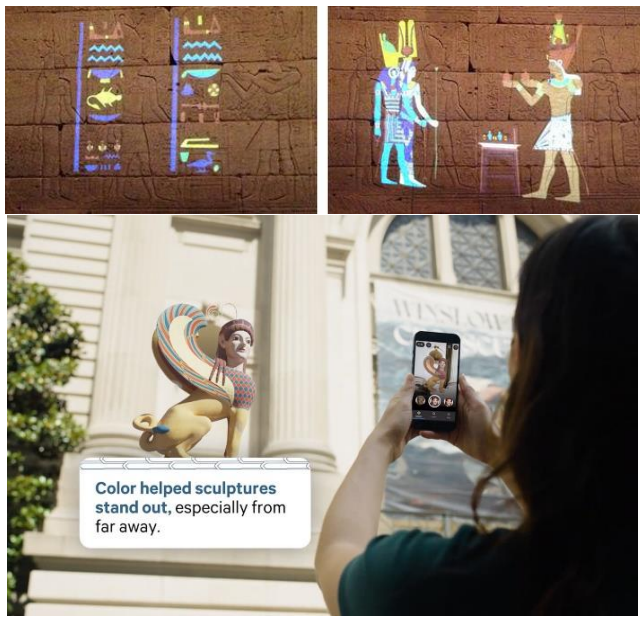

Fig. 4. The Met's interactive experiences surrounding color reconstruction. *Color The Temple* (2015) animated glyphs and scenes from the depicted stories (top); Chroma AR (2022) allowed smartphone users to interact with a digital color reconstruction of a sphinx (bottom), Copyright: The Metropolitan Museum of Art

Fig. 5. The design of the ColorColab experience, allowing users to explore colorization of multiple sculptures with a variety of palettes that the user may choose from or create. The experience is meant for museums which host sculptures, as users could explore their own colorizations on the real statues via AR (left); Multiple texturizations for the same statue of Hebe (right). The alternative texturizations are one-click based, and allow the user to change each region (hair, nails, clothes, skin, eyes) independently

Immersive Multisensory Experiences

Immersive, multisensory media experiences are one of the most recent trends in innovative engagement with cultural artifacts. Mixing new media art worlds and museology, and engaging users in thinking about and interacting with art, these experiences are designed both for digitalized and for born-digital colored art [56]. Some of the best-known examples include Grande Experiences "Van Gogh Alive"[6], Van Gogh Museum "Meet Vincent"[7], the Lumiere venues from Culturespaces showing Klimt, Van Gogh, Dalí, Gaudí and others.[8] In these experiences, color is absolutely centric, with works presented digitally in hyper-fine detail, allowing users time to study color and technique in new scales.

Another valuable example of these multisensory, immersive experiences being designed around color and employed for modern art pieces is MUNCH Museum's "Poison: An Edvard Munch Experience", which leads users into "a painted world of unreliable stories and shifting perspectives" [57]. The experience is centered around Edvard Munch's (1907) *The Green Room* series of images, showing a room with green wallpaper in which people meet in various situations (Fig. 6). Through the use of floor-to-ceiling video projections, AI-powered morphing visuals, movement tracking, light experiments, and spatial sound, the immersive experience invites users to inhabit the Green Room as "a strange creature, unstable and unsettling" in order to learn something new about Munch – and about themselves. Specifically, as the visitor moves in the room, a (video) mirror image appears next to them on the wall, gradually transforming into a painted silhouette, following the visitor into the adjoining space, where the walls are covered from floor to ceiling by projections [58]. The experience is powerfully interactive and immersive, as the technologies create hypnotic imagery that literally responds to each step that the user makes.

Fig. 6. A snapshot of MUNCH Museum's "Green Poison: An Edvard Munch Experience", which is a multisensory installation in which color, specifically green, takes center stage. Sources: tv2 and Munchmuseet.

Data-Driven Analyses

Perhaps the clearest effect of the technological revolution of the last decades on the understanding and preservation of cultural artifacts has been the spread of their digital replicas. The use of information technology to capture or represent the data studied by conservation scientists, archaeologists, art historians and architects falls now under a new branch of knowledge, Virtual Heritage [59, 60]. Digitization of CH artifacts is motivated by various goals including public dissemination, exchange between experts and institutions, and as novel tools for search [61]. This growing number of digital replicas can be exploited jointly with conservation data and knowledge in order to do large-scale analyses of statistical nature, including with the aid of Artificial Intelligence tools. For example, digital replicas (e.g., images of paintings) can be selected and grouped according to different criteria (e.g., artist attribution, time period, related

[6] https://grande-experiences.com/van-gogh-alive/
[7] https://meetvincent.com/
[8] https://www.atelier-lumieres.com/en

emotions, evocation of certain abstract concepts)—and dominant color visual analyses can be performed over such selection. *D.S. Martinez Pandiani and V. Presutti* [56] performed color palette analyses for a selection of paintings tagged with two concepts ("consumerism" and "horror"), providing insight into the color distributions of colored artifacts purportedly evoking these concepts.

Conclusions

Color and cultural artifacts are critical tools for humans to navigate the world. In this article, we focused on colored artifacts (i.e., artifacts for which color is central to their semantics) as crucial tools for humans to learn about themselves, others and the world. Despite the fact that colored collections are prioritized by Conservation Science due to their fragility and the complexity of reconstructing their original appearance, the examples presented in this paper demonstrate how the conservation of color is not just a matter of preservation. To combat inaccurate, polarizing, and/or damaging beliefs, the social dimension of color, its conservation, and its valorization are crucial.

In fact, Conservation Science and Heritage Science have a big role in creating knowledge for participation and reconnection with the social dimension of the artifacts. Specifically, they can produce useful knowledge on original colors (where conserved); on similar examples as potential comparisons; on artistic techniques used in certain historical periods; on color *appearance* through imaging techniques; and, importantly, on the artifacts' original physical and social contexts and purposes.

Unfortunately, the relational ties, on top of which participatory designs could be built, are weak and need strategies to be strengthened, based on the reinforcement of cognition and emotion. Appropriate metaphors are needed to help explain in simple messages to citizens the importance of caring for and conserving colored artifacts, overcoming the distance between the visitor and the artwork, increasing the understanding and transforming the experience into something more personal or closer to people's experiences.

The attempt to more fully integrate the use of technology with the materiality of cultural heritage display is part of a wider line of debate on overcoming the separation between technology and heritage holdings. As such, we have surveyed how the data and knowledge produced in the context of conservation of colored collections has been and can be used from an interactive media participatory design approach by taking advantage of digital technologies. Based on our research, some of the approaches that have been used for color-centric experiences include projection mapping and natural interaction of color reconstruction, alternative texturization and personalization, multisensoriality and immersiveness. We have also pointed out that data driven techniques based on AI could lead to novel knowledge, as well as improve and increase the use of these results in exhibitions and in interactive media.

Further ideas for future directions for color-centric interactive media design include re-appropriation strategies through civic participation and personal engagement; strengthening the sense of belonging and caring attitudes through empathy; materialization of colors into externalized objects; color interactive experience beyond the visual appearance through bodily experiences; colored artwork installations for aesthetic and visual education promoting exchange in a pluralistic manner with the aim to pursue a practice of objectivity; use of digital and scientific data for new research questions and new user experiences that could make understanding damages, how to intervene, to reconstruct and to virtually reconstruct, increasing awareness on the fragility of colored artifacts, and, at the same time, increasing understanding on their beauty and cultural richness.

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